91st Congress }
1st Session }

JOINT COMMITTEE PRINT

INDUSTRIALIZED HOUSING

MATERIALS COMPILED AND PREPARED FOR THE

SUBCOMMITTEE ON URBAN AFFAIRS

OF THE

JOINT ECONOMIC COMMITTEE
CONGRESS OF THE UNITED STATES

APRIL 1969

Printed for the use of the Joint Economic Committee

U.S. GOVERNMENT PRINTING OFFICE

25-808 WASHINGTON : 1969

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.00

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LETTERS OF TRANSMITTAL

APRIL 16, 1969.

TO THE MEMBERS OF THE JOINT ECONOMIC COMMITTEE:

Transmitted herewith for the use of the members of the Joint Economic Committee and other Members of Congress is a staff document prepared for the Subcommittee on Urban Affairs, entitled "Industrialized Housing."

The views expressed in this document are those of the respective authors and do not necessarily represent the views of the subcommittee or individual members thereof or of the committee staff.

WRIGHT PATMAN,
Chairman, Joint Economic Committee.

APRIL 9, 1969.

Hon. WRIGHT PATMAN,
Chairman, Joint Economic Committee,
Congress of the United States, Washington, D.C.

DEAR MR. CHAIRMAN: Transmitted herewith for the use of the Joint Economic Committee and other members of the Congress is a compendium entitled "Industrialized Housing." This collection includes articles and materials by specialists who have studied the application of industrialized housing techniques in the Soviet Union, Europe and America.

The subcommittee is grateful to those experts and to their organizations who gave generously of their time and talent in the preparation of the volume.

The study was prepared under the general supervision of James W. Knowles, Director of Research for the Joint Economic Committee, with the responsibility for planning, coordinating, and editing being done by Richard F. Kaufman of the committee staff.

The views expressed in the compendium are those of the authors and do not necessarily represent the views of the Subcommittee on Urban Affairs or individual members thereof.

Sincerely,

RICHARD BOLLING,
Chairman, Subcommittee on Urban Affairs.

APRIL 2, 1969.

Hon. RICHARD BOLLING,
Chairman, Subcommittee on Urban Affairs, Joint Economic Committee, Congress of the United States, Washington, D.C.

DEAR MR. CHAIRMAN: Transmitted herewith is a compendium entitled "Industrialized Housing." This collection includes articles and materials by specialists who have studied the application of industrialized housing techniques in the Soviet Union, Europe and America.

The compendium was designed to bring to the attention of Congress efforts in other nations to use mass production techniques in the residential housing industry. A survey of the available literature and reports indicates that there has been remarkable success with a variety of industrialized housing techniques.

Most experts agree that the constraints on industrialized housing in the United States are non-technical. That is, the technological problems of applying the principles of industrial production to the housing industry have been largely solved. But important political and economic problems remain.

The United States continues to be faced with a critical shortage of decent housing for low-income families. Whether we are willing to explore the possibilities of meeting this shortage, and other long-range needs, through industrialized housing is an important public policy question.

The committee is grateful to those experts and to their organizations who have given generously of their time and energy. Richard F. Kaufman, of the staff of the Joint Economic Committee, undertook responsibility for coordinating and editing this compendium, under the supervision of James W. Knowles, our Director of Research, in accordance with plans developed under your direct supervision. Miss Andrea Hoffman assisted in preparing the manuscript for publication.

The views expressed in these papers are those of individual contributors and do not necessarily represent the positions of the Joint Economic Committee, individual members, or the committee staff.

Sincerely yours,

JOHN R. STARK,
Executive Director.

INDUSTRIALIZED HOUSING

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LOW COST HOUSING IN THE SOVIET UNION

by

A. Allan Bates*

A. Introduction

The Soviet Union is the first, and thus far, the only nation which has solved the problem of providing acceptable low cost housing for its masses of citizens.

Within a few years—perhaps a decade—it will probably be generally acknowledged internationally that the best housed inhabitants of any large country in the world are those of the U.S.S.R. The political impact of this situation will be profound. The United States will suffer devastating comparisons.

The impact of these statements is so great that if they can be supported they must be given urgent and effective attention by the public leaders who shape American national policy.

In the U.S.S.R. *all housing* built in the last twenty years has been deliberately designed as low cost housing. In the U.S.A. *no housing* built during that period or now designed for future construction can be characterized as "low cost housing." It is most important, however, to understand that the nature and location of the post-war Soviet housing projects are but one element in the far-reaching plan for the development of the urban civilization of the future. One who sees only the concrete and brick dwellings sees little and comprehends nothing thereby.

The typical American suburban single family dwelling standing detached on its own plot of ground is a beautiful culmination of western domestic history. It is actually the last stage of the peasant cottage of past centuries, now carried beyond recognition of its origins. But the peasant-based rural civilizations of the past are rapidly becoming transformed into the industrialized urban civilizations of the future and in the process the individual detached home is giving way to the city apartment. The American traditional private dwelling is not generally regarded by the rest of the world as practical or even entirely desirable. To most of mankind it is simply a prohibitively expensive luxury on which only Americans or the rich of a few other countries would think of spending so much money. Therefore we offer no leadership in the world process of urbanization and our example will not be followed in the matter of housing.

Soviet political theory, on the other hand, has been consciously directed toward the development of an industrialized (that is, urban-

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ized) society. The building of cities has been the central and largest industrial activity of the entire economy. This activity has had both short-range objectives and long-range objectives. The short-range objective which thus far has been dominant has been to build cities quickly and on a scale never attempted before in human history. The long-range objective has been to build the most attractive and livable cities possible for a future urbanized society. The short-range objective has, in general, been astoundingly well achieved in spite of devastating wars, unprecedented revolution, continual foreign interference, lack of experience and the necessity of carrying out unexampled pioneering in the fields of human mass motivation and organization. That the short-range objective has been sometimes achieved clumsily and occasionally even with tragic by-products was inevitable.

The long-range objective, the attractive city, is beginning to come into stronger evidence in the U.S.S.R. It has always been recognized that what made any city great were first and foremost its communal facilities. The Athenian Acropolis, the Roman Forum, the "grands boulevards" and the river-side promenades of Paris, the parks of London and the lake front of Chicago are examples of urban beauty by which the lives of the citizens have been deeply enriched.

The Soviet urban ideal is to exalt communal life to a new level of human experience. Conversely they believe it practical and in keeping with their concepts of future urban living to limit family housing in a manner compatible with health and comfort but not to include lavish facilities for home sports, entertaining or private prestige. This balance of communal versus private facilities promises in principle and as a matter of economics, to be the pattern which all urbanized nations will follow. The Soviet housing policies and operations therefore constitute an approach to the universal housing problem which seems to be of international applicability.

B. Technology

The *technology* of building in the U.S.S.R. must be divided into two parts:

The Technology of the Product

This is not unique. Buildings of basically similar design can be seen in many countries of Western Europe. Architects and Engineers of the U.S.S.R. visited repeatedly in France, Sweden, Denmark, England and other countries over a period of years beginning about 1947. They absorbed various elements of design and borrowed them freely with collaboration from Western European engineers. Russian changes and developments in design are largely made for the purpose of facilitating mass production.

The Technology of Production Methods

In their visits to Western Europe the Russians studied the various factories in which prefabricated buildings were produced. They even bought several factories, shipped them to the U.S.S.R. and operated them there. During these operations they experimented continuously on ways and means of improving the production procedures.

Of these two aspects of building technology it is the latter, the production technology only, which presents important unique aspects in the U.S.S.R. There and only there is it a true mass production operation. In the countries of Western Europe prefabricated buildings essentially the same as those which characterize the Russian cities, are produced by industrialized methods which, however, have never been developed on an effective mass production scale. The economics, therefore, of prefabricated building production in Western Europe and in Russia are in no way comparable even though the resulting technical products may be quite similar.

I have made estimates of the costs of housing production as it is done in the U.S.S.R. (See appendix A.) I have not depended on figures published or given to me by Russians. My estimates are founded upon my own extensive observations at many European and Soviet factories and building sites over a period of years (1955–1968) during which industrialized building technology has advanced rapidly. The costs which I have estimated refer only to apartments recently built (1965–1967) and constructed under favorable circumstances. My estimates are not based upon ruble-dollar exchange rates but rather on man-hour labor inputs at various levels of skill and on materials and equipment requirements per unit of product. In comparison with Soviet cost figures which have been published and those given me personally by reliable Soviet engineers my own calculated costs are actually somewhat high. The differences however are not of significant magnitude. Costs in the U.S.S.R., as elsewhere, vary from region to region as well as from year to year.

The low costs of Soviet residential building arise primarily from intelligent use of the same two practices, standardization and mass production, which keep the costs of so many American products low. These can and may lead to monotony but do not necessarily do so. An infinite variety of structures can be built of standardized bricks.

A third important practice notable in Soviet building is the reduction of all designs to the utmost functional simplicity compatible with modern civilized standards of living. As might be expected, these emphasize and take advantage of the communal aspects of urban life.

The relationship of technology to cost is important, but should not be over-emphasized. As will be pointed out later, the low cost of Russian housing results from many factors in addition to technology. These factors are all so interrelated that they must be discussed collectively in order to produce intelligible conclusions. Further discussion of costs appears later in this paper.

A large number of American groups and delegations have visited the Soviet Union in recent years to inspect Soviet housing in expectation that they will thereby learn some technological tricks which can be utilized in the United States to lower the cost of American residential construction. More such American delegations are planned for the future with the same objectives in mind. Most of these visits are largely a waste of time, insofar as their stated purposes are concerned. Soviet residential building methods cannot be used in the United States for reasons which have nothing to do with the technology involved. Soviet residential building is carried out for reasons and purposes which are practically nonexistent in the United States. To compare the average Russian apartment recently built with any home or apartment in the

United States is as meaningless as a comparison between an average American suburban house and a grand villa on the French Riviera.

C. Low-Cost Housing, a Definition

Discussions of "low-cost housing" which are currently so widespread in the United States actually have nothing to do with anything that could realistically be called low-cost housing. It will be invariably found on careful examination that these discussions actually relate to *subsidized* housing for occupancy by low-income groups. A workable definition of "low-cost housing" can easily be derived and would be useful for discussion purposes.

There are, in the United States, slightly fewer than 60 million "*household units.*" These are defined by the Bureau of the Census as groups of persons who maintain separate home facilities. Household units vary widely in their composition. The most common is a man and wife with one or more children. Other kinds of units are: a man and wife without children, a man or a woman with children or other relatives, a group of single persons living together, an elderly person maintaining a home alone, etc. etc. Of the 60 million household units in the United States, approximately 20 million have an income of less than $5800 per year and the average income of this group is probably about $4400. It is these people for whom the cost of adequate housing in the United States has become painfully burdensome or even disastrous.

Among the 20 million household units which comprise this least affluent segment of American citizens, by no means all are either badly housed or particularly desirous of improving their housing conditions. There are, for example, many elderly people who would have no wish to go through the ardors of a move in view of their prospectively few years to live. On the other hand, there are many young men and women in the earliest stages of their careers who are quite content to live in inexpensive, one-room or efficiency apartments. In addition to those of the 20 million least affluent who have no urge to improve their housing, there are several million units for whom relatively little can be done. These will include such as single families or small groups living in the isolated backwoods hollows of Appalachia. As a first approximation, it may be reasonably estimated that about half of the 20 million units form an urgent market for genuinely acceptable low-cost housing. A group of this magnitude comprising some 9 or 10 million household units and which would include upward of 50 million persons would seem to comprise a market so large as to be immensely attractive to the building industry in the United States. Unfortunately, this is not true.

Actually these millions who are in greatest need of housing in America comprise no market whatsoever for the building industries as they are now organized in the United States or as there is any prospect of their being organized for years to come.

It is a rule of thumb that a family can spend 20 percent of its income on housing. This rule actually has no relevance to our 10 million least affluent and worst-housed families. These 10 million can be assumed to have an approximate average income of about four thousand dollars per year. For household groups with such an income, an abnormally high proportion of living costs is taken up by food, transportation, clothing, medical requirements and incidentals. Probably, at most, these units can *afford* 10 per cent or less of their income for housing, that is, four hundred dollars or less per year. There is no decent housing in the United States which approaches this cost.

Presuming that the average low income family of our concern should have at least 700 square feet of living space available to them in their home, such space could be conceivably carried financially at a cost of around four hundred dollars a year if it could be made available at a total initial cost of not over five to six dollars per square foot. This then, I will take as my definition of lowcost housing; that is, homes which provide all necessary amenities and space for minimal healthy living at a total of not over five to six dollars per square foot. Obviously, inflation will continuously affect this figure but, not, in general, favorably.

D. Current and Prospective Housing in the Soviet Union

The housing programs of the Soviet Union must be examined in historical perspective and in the light of the prevailing circumstances and purposes of that nation. The Soviet Union, during the second World War, suffered more property destruction than has any other nation in all the wars of history. It also suffered the loss of immensely more manpower than did any other nation in World War II. The U.S.S.R. emerged then from this war with both a need for housing and a deficiency of manpower of unprecedented proportions. It was quickly and correctly determined that the necessary reconstruction could not be carried out by traditional means. Therefore, the decision was made to industrialize all building operations. There was no experience in the Soviet Union for such an industrialization. Neither the necessary skilled workmen or the relevant managerial element existed. Necessary transport of materials was practically at a standstill. The populace was widely scattered because of the destruction of thousands of cities, towns, and villages. In retrospect, the impediments to any notable Soviet accomplishment in housing in the years after the second World War were such that no responsible person could possibly have predicted what has, in fact, happened. Actually, within 15 years after the close of the War there were more housing units being constructed in the Soviet Union than in the United States or any other nation of the world.

The American visitor touring the cities of the Soviet Union today will almost invariably view the housing which currently exists in the U.S.S.R. with American comparisons in mind. The comparison on this basis inevitably leads the visitor to the conclusion that even post-war Soviet housing is sadly inferior. To a certain extent, this conclusion is valid. Nevertheless, it is completely superficial and dangerously misleading. Most of the present urban housing in the U.S.S.R. has been built in the last twenty years and was constructed under extremely difficult circumstances, partly alluded to above. To one who has visited the Soviet Union repeatedly during the last ten years and who has observed extensively, intimately and expertly the building work going on there, the improvements in quality during that time are striking. The residential structures of the first post-war decade, erected as they were under incredibly dire pressures, were of low quality, subject to rapid deterioration, without benefit of maintenance and located with no consideration for esthetic appeal. This housing is in large part still occupied and visible today. By American visitors, it is frequently taken to represent post-war Russian housing.

In the period from about 1958 to the present, the quality of Soviet housing has improved steadily. The residential structures now being erected would be acceptable *as low cost housing* anywhere in the world, including the United States. Quality is still by no means at the high levels customary in typical high-cost American housing. The average American visitor of 1968 on viewing even a quite new Russian apartment would find it open to much criticism *from the American point of view*. But it is precisely this point of view which is not applicable and which leads to invalid conclusions.

It has long been a tenet of socialist theorists and leaders, including Marx, that a socialist society should and would be a predominantly industrialized society. But industrialized societies must be largely urbanized. Since the Soviet Union, before the Russian Revolution, was overwhelmingly agricultural in character, it could be said that the central problem of the post-revolutionary regime was totally to transform the basic nature of the Soviet Union. Essentially, this meant that not only the thousands of destroyed cities and towns had to be rebuilt but also that hundreds of new towns and cities had to be constructed. These ends have been accomplished to an impressive extent and are still being pursued on a scale and at a rate unprecedented in history.

The fundamental theory of Soviet city building is that people live in communities, not in houses. The basic building unit, therefore, is not the house or apartment but the community. The theory has not thus far been entirely followed. Indeed, when one examines the Soviet towns and cities, it is evident that in actual practice the theory, until now, has been more disregarded than applied. Nevertheless, if a visitor is aware of the theory and observes carefully the evolution of Soviet housing as evidenced in the construction of the last decade, he will be convinced that notable progress is being made in putting it to use. On further reflection the American visitor may also probably come to the conclusion that the lack of any such guiding principle in American housing construction has been disastrous for our cities.

Conforming to the principle that people live in communities, not in houses, the Russian urban design has been evolving toward the development of "microdistricts" or, as we might say, neighborhoods. The microdistrict is conceived to be a relatively self-contained community within the city. It may comprise some four to eight thousand people and within its close limits will be found all the stores, schools, community dining, medical, recreational, administrative and service facilities needed for the daily use of the occupants. Since in such a planned microdistrict everything ordinarily needed for family life is within five or ten minutes walk of every inhabitant, most of the daily transportation requirements which plague modern cities are eliminated.

A number of such microdistricts, suitably grouped, form a city within which are the large communal facilities needed by urbanized populations. Public transportation to these larger city facilities can be relatively effective at low cost and without producing the enormously wasteful, nerve-wracking and debilitating American rush-hour traffic. A few microdistricts have taken form spontaneously in American cities and a few more have been planned. In a limited sense, Greenwich Village in New York City is one of the older spontaneous neighborhood microdistricts. It is to be noted that where such microdistricts have taken shape they are usually regarded highly and living space in them becomes expensive—an evidence of the demand for good neighborhood living.

The slums and ghettos of contemporary cities in the U.S.A. and Europe are among the vilest manifestations of the unplanned disorder of our urban communities. The American tourist in the Soviet Union, seeing the massive prefabricated apartments of Moscow, built in the immediate post-war years and therefore of unattractive quality, is moved to ask, "Are these not just the Russian slums and ghettos of the future?". Such slum-ghetto development is highly unlikely. A slum or a ghetto is not just a collection of substandard housing. It is much more profoundly a state of mind arising from the cultural and economic isolation of the slum dwellers. But in the U.S.S.R. it is virtually impossible for an individual *not* to participate in the economy. Except for very young or for elderly retired persons unemployment is essentially non-existent in a socialist state-planned economy. Thus neither the economic nor the cultural isolation which are typical of the slum-ghetto can develop in the Soviet city. There are still areas of old pre-Revolutionary substandard housing existent in some of the Soviet cities but they do not constitute slum-ghettos. And they are rapidly being demolished and replaced by modern housing. Slums are not profitable under the Russian form of economy.

When emphasis is on design of the community rather than on design of the individual house, then intelligent functional design of housing becomes possible. A conscientious efficiency expert can only be appalled at the inefficiency with which space is used in the typical American private dwelling. Under the community-design approach the private residence facility is recognized as a necessary but quite limited component in a neighborhood life system. The "systems analysis" method so widely advocated in America today as the means of solving complex problems is of little use in solving our urban housing problem because the house—not the community—is erroneously regarded as the "housing problem."

The housing currently produced in the Soviet Union looks, and is, highly space-restrictive by U.S.A. standards. Less than ten square meters (about 110 square feet) of living space is allotted per person. This is meager by middle and upper income American standards. It is a generous allotment, however, in comparison to most Western European and American *slum* living space. Furthermore, the present ten square meters per person is recognized by the Russian designers as being less than adequate. Only the overwhelming postwar demand for home space has imposed the tight restrictions. Most housing now being planned and some already under construction allots twelve and a half meters of living space per person as the national standard. Even this 25% increase is to be maintained for only a short few years after which space allowances will move up to 15 and then to 18 square meters per person. These provisions are lavish by world standards though not by American upper-middle-class usage. It should be noted, incidentally, that the Soviet definition of "living space" does not include kitchens, bathrooms, halls, stairways, etc. These are provided as free accompaniments to "living space."

The interior finishing and built-in furnishings of the present Soviet apartments are highly functional. Heating, lighting, ventilation, and sound insulation are adequately provided for purposes of health and comfort. Baths and kitchens are small and the fixtures in them are simple but functionally sufficient. Hot and cold running water, steam radiators, linoleum or hardwood parquet floors and kitchen stoves, electrically or gas heated, etc., are all standard. But again, it must be repeated that in the Soviet theory of urban life, human existence is most rewarding when communal activities are optimized. Thus low-cost community dining rooms are built into all modern apartments. Individual home kitchens can thus be modest in size and equipment. The private house or apartment is a place where one goes to sleep and to carry out such private activities as reading, writing, arts and crafts, meditation or conversation, etc. which require quiet and concentration.

E. Costs

The cost of housing in the U.S.S.R. cannot be compared with that of housing in the U.S.A. because, as was pointed out earlier, different purposes are served by housing in these two nations. Nevertheless, it is not uninteresting to estimate what housing as built in Russia would cost in the U.S.A. if it were possible to build in America as the Soviets build in the U.S.S.R. The Russian technology is fundamentally low in cost if it is carried out on a large mass scale. Otherwise it is very expensive. The materials used, the capital equipment required, the labor force needed are all inherently inexpensive in character when utilized on a large scale. Productivity under good management can be astoundingly high.

Demand for the housing produced must be planned several years in advance and the demand must be fixed in each local area at levels far higher than any now contemplated in the U.S.A. The size of the national demand is of secondary interest since the housing produced can be economically transported over only small distances, preferably less than fifty miles. The demand must be for at least several thousand family units a year over a period of five or more years All of these units must be constructed from combinations of a few basic standardized components and they must be clustered among relatively few construction projects. The actual final buildings, however, can vary widely in appearance and accommodation.

Land in the Soviet Union is valued at widely different levels for different purposes. Some central city land is valued very highly and thus is used only for limited appropriate purposes. Land, however, has no price or cost in the U.S.S.R. since none of it is privately owned. Thus speculative manipulation of land prices is avoided and land costs play no part in housing costs. This is of vital importance to low-cost housing. It should be frankly stated and recognized that land speculation makes true low-cost housing in significant quantity nearly impossible in the United States.

The *financing* of housing in the U.S.S.R. reflects the socialist system of economic enterprise and varies somewhat according to the jurisdiction under which a housing project is constructed, that is, whether the national government, a Republic, a municipality, an industry or a private cooperative group undertakes the building responsibility. In the most important instances, construction by national government, Republic or municipality, an annual budget for home building is set up and is financed by general taxes, most of which are collected from the turnover of industrial and wealth producing enterprises. The system is somewhat analogous to that by which public schools, highways and national defense are paid for in the U.S.A. Costs of home financing do not appear in the costs of home building under this system. Since every citizen in the U.S.S.R. participates through indirect taxation in the building of all the homes and since all the homes are occupied on a basis of approximate equality by all of the citizens, there is no element of subsidy involved. Rents are kept so extremely low for everybody that rental payments play an almost insignificant part in home costs and home financing. The costs for architectural services, for research and development, for administration, etc., are all spread over so immense a volume of housing that they become vanishingly small relative to any one dwelling.

What then would be the cost of constructing housing in the U.S.A. if the current technology applied in the U.S.S.R. were in wide use here? The answer, I am confident, is that American industry could produce housing of required quality for 5 to 6 dollars per square foot—or less. Even though both the question and the answer are academic they cannot be ignored. Neither the Russian building technology nor any other of similarly industrialized nature can be used in the U.S.A., as long as our ways of establishing home-building markets, of manipulating land costs and of arranging financing are as they are. Nor are these the only impediments to industrialized housing in America; the working methods of our architects and contractors, our labor customs, our building materials manufacturer's conservativism and our complex localized building code practices all throw up barriers against progress toward industrially mass-produced low-cost housing—the only true low cost housing possible.

Opposition to industrialized housing in the U.S.A. is largely based on fallacy and misunderstanding. The American building industries are not now producing any significant quantity of low cost housing as defined in the earlier paragraphs in this discussion. Therefore any industrial operation which could produce such housing would not be seriously competing with present building industries. These industries would still have undisturbed their markets among middle and upper income families which are the only markets they can serve now.

The effective market for low cost housing in the U.S.A. comprises some ten million household units which are largely located in about a dozen metropolitan areas. The smaller of these areas could each easily provide a demand for at least 5,000 low cost family units a year for a period of not less than ten years. The larger areas would each provide a similar market for at least 20,000 to 40,000 units. Markets of these magnitudes are sufficient to support successful ventures in totally industrialized housing. Even so, production of low cost housing at these rates would fall far short of supplying the desperately urgent demand.

The only alternative to genuine low cost housing is subsidized housing. From every social, moral and political viewpoint it must be evident that, in principle, good low cost housing of acceptable quality is superior to subsidized housing. Nevertheless, it seems apparent that the U.S.A. is inescapably committed to the inferior practice. Yet even on that basis no serious national program has yet been planned which can notably improve the housing conditions of our low income citizens during the next decade.

Meanwhile during that period the citizens of the U.S.S.R. will probably have become the best housed people of any large nation in the world. Derogatory comparisons of the quality of postwar Russian housing with average American housing are irrelevant. Applying the technological principles used in building in the U.S.S.R., quality can be as high as may be required at any time for any purpose. Both the technology and the level of quality are continuously improving in predetermined stages fixed by the Soviet building research and development program which is the largest in the world. This program has produced tens of thousands of experimental dwellings during the last ten years. No such tremendous program of research and development in housing has even been conceived in the U.S.A. Nor is such a program possible under present or foreseeable circumstances.

The magnitude of the experimental Soviet housing activity bears a relationship to the astounding volume of housing production in the U.S.S.R. For the last several years the number of household dwelling units produced annually in the U.S.S.R. has been nearly twice the number produced in the U.S.A. This number (in the U.S.S.R.) is scheduled to increase continuously during the coming decade reaching a production of about three million units annually in the later years of the period. On this basis by the late 1970's well over 25 million additional new dwelling units, housing over 80 million people will have been made available for the citizens of the Soviet Union. And along with these tens of millions of home units there will be provided all of the other communal facilities, services and amenities which conduce to a culturally rich community life for Soviet men, women and children.

There is no reason to doubt that the Soviet cities and towns of the future as thus envisioned and promised will come to exist on schedule. The history of Soviet building progress over the last ten years, as I have repeatedly and personally studied it by first hand observation, has been one of immensely bold and intelligent pioneering. Mistakes and failures have been numerous and sometimes of catastrophic proportions. But they have never been hidden or denied. Instead, they have been publicly acknowledged and eventually corrected by research or other means. But with all of its shortcomings the Soviet building program has been an almost incredible success achieved on a scale and at a speed vastly greater than any other in human history.

There is no prospect that we in the U.S.A. will be able to embark upon a similarly meaningful building program for our cities in less than five to ten years. And the subsidies for any such meaningful program will have to be staggeringly greater than we have ever thought of before. But the longer we delay the more formidable the subsidies will become and the more dangerously unpredictable will be the human condition in America's cities.

APPENDIX A

General Considerations

The costs of apartment building in the Soviet Union can not be given in dollars by any simple ruble-dollar exchange rate. However, if it were possible to construct low cost housing in the U.S.A. according to the practices and principles which prevail in the U.S.S.R. the costs in the U.S.A. of doing so, can be estimated approximately from a knowledge of the kinds and amounts of the materials, labor and investments which are involved. The estimates which follow are of that nature and are drawn from repeated observations and inspections which I have made in the Soviet Union during the period 1960–1967.

Several methods for producing mass low cost housing have been under development in the U.S.S.R. for nearly 20 years. That which has proved most successful thus far is the "large panel" system which, since 1960, has been displacing other procedures. In this approach each wall, floor and ceiling of a room is designed to be factory-produced as a single prefabricated unit, a "panel." Openings such as doors and windows are easily provided by inserts in the panel castings. An entire apartment building containing hundreds of family units of from two to six rooms each may comprise only four or five basic panel types. The building will require no framework or skeleton even though it may be up to sixteen (or more) stories in height. Speed of erection is astounding.

Labor requirements are notably simplified by highly repetitive job use of skills most of which are relatively simple and quickly learned. In the example described hereafter, the terms plumber, electrician, welder and carpenter are used but it should be understood that the tasks required of such labor in the large panel system do not demand the highest skills which these names imply. Following a Soviet practice I have indicated eight categories of skill in order to provide some idea of comparative ranges of labor. Pay rates are suggested only in terms of averages which would be roughly in accord with American rates. Similarly, costs of materials, fixtures and equipment are indicated at levels which reflect the very large quantities and the simplified, standardized designs and specifications which are encountered in Soviet practice. The dollar values throughout are probably, on the whole, rather generous given the basic presumptions of 1) very large scale production, 2) standardization of products and processes, 3) continuity of all operations twelve months of each year over a series of years.

In order to convey a concept of the subject I will discuss a basic four-room apartment together with the means by which it may be produced. It is to be understood that the indicated productivity is that which can be achieved under favorable circumstances such as are now encountered fairly widely in the U.S.S.R. This means principally a well established and experienced organization operating in an adequately large and continuing national and local market.

The case discussed is not a record of any particular project in the U.S.S.R. It is to be understood as a simplified composite portrayal of operations and practices now in use in various Soviet communities. Actually there is no single, precisely prescribed or universally applied production procedure for manufacturing large panel housing. The method itself is in continuous evolution. The management of each

Soviet "building combine" has total responsibility for all operations necessary to convert raw material into finished housing. A given combine manager may, for example, choose to do all interior decorating either in the factory or on the building site. Or he may choose to do most of the electrical wiring at the factory and little at the building site—or vice versa.

Since residential and commercial building in the U.S.S.R. are largely one and the same thing both physically and financially, the definition and analysis of housing costs require the exercise of informed judgment and knowledge of Soviet urban policy. In point of fact this intimate commingling of housing with stores, restaurants, theatres, offices, schools, etc. is basic to Soviet social planning. It simplifies housing and home life and eliminates much of the urban traffic problem. It is central to the long-range program for identifying the private citizen with the community.

Some Details

The "four-room" apartment may comprise four equal areas of about 10′ x 14′ each enclosed by walls with suitable openings (doors and windows, etc.). One of the four areas is a "service center" including kitchen facilities plus bath and toilet cabinets which may be prefabricated standard units. The entire apartment is composed of only three basic types of precast panels, (1) long wall, (2) short wall, and (3) floor-ceiling. From fourteen to sixteen panels are required according to design. The panels are produced in two or more coordinated factories and assembled on the building site by well drilled labor teams all of which (factories and labor) are components of one responsible organization.

On the basis of man-hours of labor at various skill levels and of mass produced, standardized materials and fixtures costs will be approximately as in the given summaries. The figures are my estimates based upon first hand study of many building enterprises and upon numerous discussions with Soviet managers as well as examination of account records and reports. All figures are rounded off for quick convenience.

NOTE.—The particular apartment considered is postulated to be one of ten thousand built by one building combine as a single project in one annual cycle. The project may include from fifty to two hundred buildings distributed over one or more sites.

I. BUILDING SITE COSTS

A. Labor

To depict the type and amount of labor required I have indicated two typical crews as I have observed them in action. These are:

(1) *Structural crew*
which assembles the panels to form the building;

(2) *Finishing crew*
which installs fixtures, decorates, etc.

In operation two Finishing Crews follow up one Structural Crew all under supervision of a single Site Superintendent who may be responsible for construction of several apartment buildings simultaneously.

Following a Soviet practice I have divided laborers into several broad skill ratings, #8 being the highest, #1 the lowest. The average hourly pay rates which I have suggested would be roughly in line with American practice. However since there are few job skills in U.S.

construction operations which closely resemble those depicted here, the skill ratings must be arbitrary and rates can only be approximates.

All crew personnel marked with an asterisk (*) are, in effect, apprentices. Each "building combine" is responsible for maintaining its own labor training activities. Hence in the factory and at the building site, apprentices are relatively plentiful and receive "in work training".

1. Structural crew:

	Skill rating[1]
1 panel assembler (crew chief)	6
*2 panel setters	3
1 welder	5
*1 welder's helper	3
1 mason	5
*1 mason helper	2
1 crane operator	5
*2 crane slingmen	2
*2 ground laborers	1
½ site superintendent	8

12½ total crew

Will erect 25–35 panels per day (including bath cabinets) = equivalent of 2 apartments per day.

Average wage, $4 hour (8 hours) = $32 per man-day × 12.5 = $400 per crew-day.

$\frac{400}{2}$ = $200 per apartment, total erection cost.

[1] Average rating, 3.5.

NOTE.—A structural crew works as a compact closely scheduled team. Its operations may be subject to some weather interference.

2. Finishing crew:

	Skill rating[1]
1 carpenter (crew chief)	6
*2 carpenter helpers	3
2 plumbers	5
*1 plumber helper	2
2 electricians	5
1 painter (usually women in U.S.S.R.)	4
*2 painter helpers	2
¼ site superindent	8

11¼ total crew

Will finish equivalent of 1 apartment per day.

Average wage: $4.50 per hour (8 hours) = $36 per man-day × 11.25 = $400 per crew day.

$400, total finishing labor cost per apartment.

[1] Average rating, 4.

NOTE.—The finishing crew is usually scattered through a series of adjacent apartments at any given time. Their work is almost entirely protected from weather interference.

B. Materials and Fixtures (per apartment)

1. Flooring (prefabricated wood parquet or "plastic")		$150
2. Electrical (fixtures, switchgear, etc.)		150
3. Plumbing:		
Bath, toilet, lavatory	$200	
Kitchen sink	50	
Kitchen stove	50	
4. Cabinets and shelves		100
5. Paints		50
6. Doors, window guard rails, etc		150
Total materials and fixtures		900

C. Delivery

All panels, materials and fixtures to site	150

D. Miscellaneous (per apartment)

1. Site preparation and foundations	100
*2. Heating plant and distribution facilities (central for 10,000 apartments, 1st cost $2,500,000)	250
*3. Water and sewer (project mains and connections)	200
Total	550

*I have chosen to show these facilities as adjunct to the individual apartment because their terminals are in the form of fairly expensive and necessary installations internal to the apartment.

II. Factory Costs

Factories to produce 10,000 apartments per year (equals 150,000 panels).

A. Building, equipment, accessories

1st cost	$8,000,000

Annual costs:

1. Amortization (10 years)	$800,000
2. Maintenance and equipment replacement	300,000
3. Operating (heat, power, light, water)	400,000
4. Interest (10 percent), average per year	400,000
Total per 10,000 apartments (= $190 per apartment)	1,900,000

B. Labor

750 persons (skill rating 3.0 average).
40 hours per week at $3.50 per hour.
Total $105,000 per week labor cost at factories.

$$\frac{10,000}{52} = 195 \text{ apartments produced per week.}$$

=$540 factory labor cost per apartment.

NOTE.—In numerous factories inspected the productivity varied in the broad range of from about 1 man-day to 2 man-days per panel. Good practice apparently averages around 1.2 to 1.5 man-days according to design of panels produced. The above figures show about 1.5 man-days per panel, equal to 22 man-days per apartment. Factory labor skills required are, in general, not very high. Numerous apprentices are employed on productive training jobs.

C. *Materials* (all materials bulk delivery at plant)

1. Concrete (plant mixed): 30 cubic yard per apartment at $10 per cubic yard, total concrete cost	$300
2. Steel reinforcement: 400 pounds per apartment at 20 cents per pound, total steel cost	80
3. Glass, insulation, wood trim, steel inserts, etc	150
Total factory materials cost	530

III. OVERHEAD [$100.00]

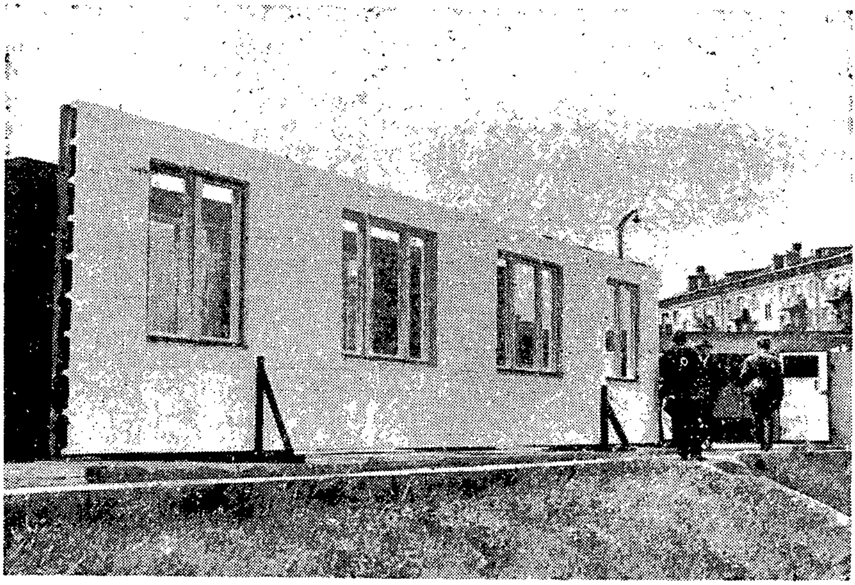
Including: Administration
Research and development
Architectural and engineering

Summary total costs (per apartment)

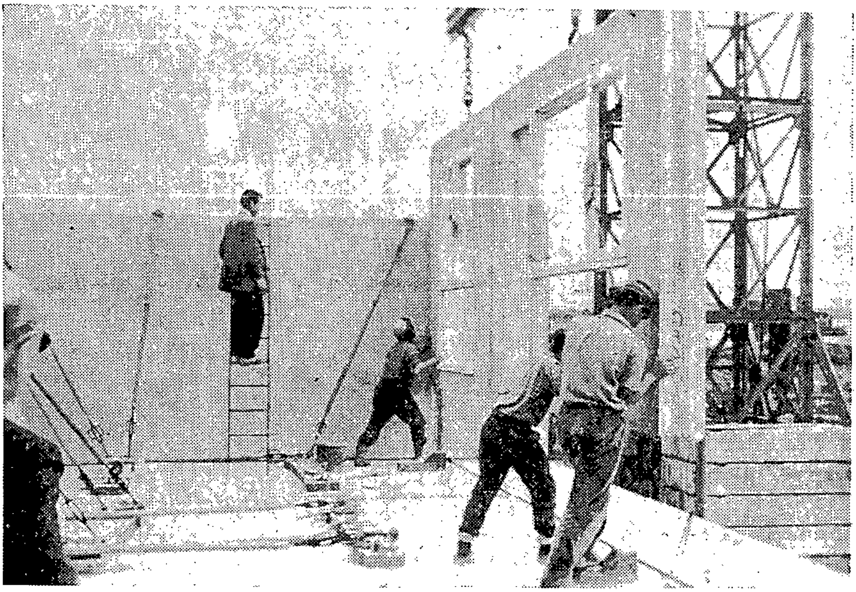
I. *Building Site*		
A. Labor:		
1. Structural	$200	
2. Finishing	400	
B. Materials and fixtures	900	
C. Delivery	150	
D. Miscellaneous	550	
		$2,200
II. *Factory*		
A. Buildings and equipment	190	
B. Labor	540	
C. Materials	530	
		1,260
III. *Overhead*		100
Total cost per apartment		3,560

In relation to the quality of the housing provided by the Soviet building system this final cost of $3,560 for the apartment described is *far* below costs anywhere else in the world. It is evident that many of the above detail costs could vary by a considerable percentage without raising total cost sufficiently to bring it near to Western levels. Actually such variations are encountered from region to region in the U.S.S.R.

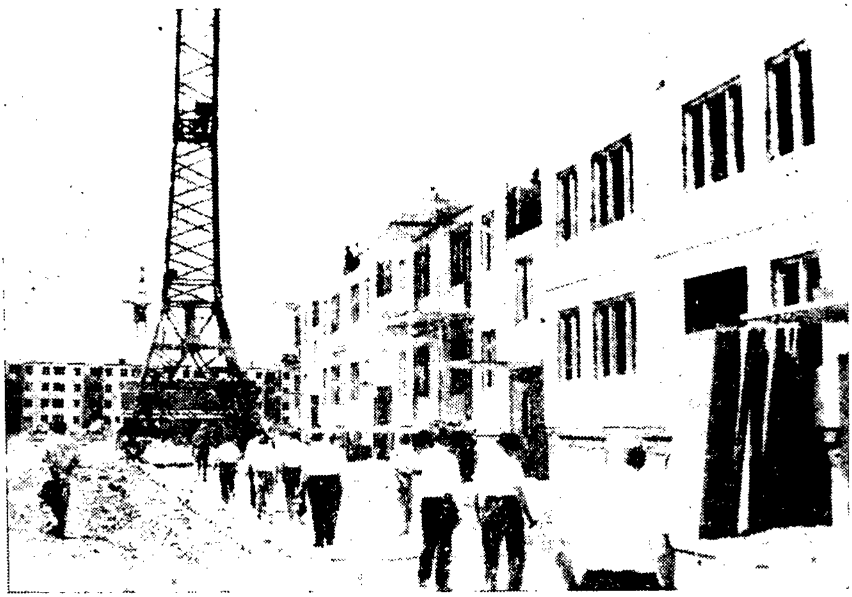
APPENDIX B



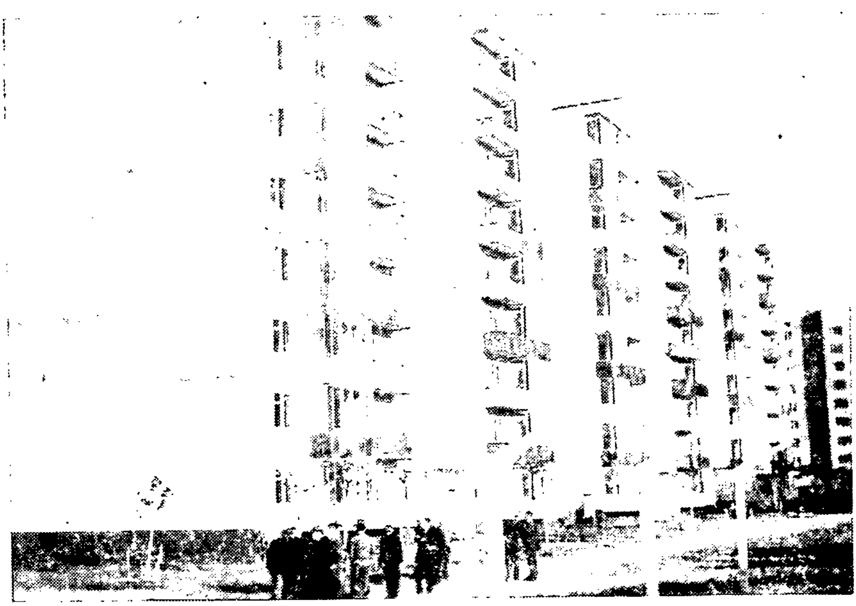
1. Large panel construction. The single factory-made panel with built-in windows constitutes the entire front wall of a flat in an apartment building.



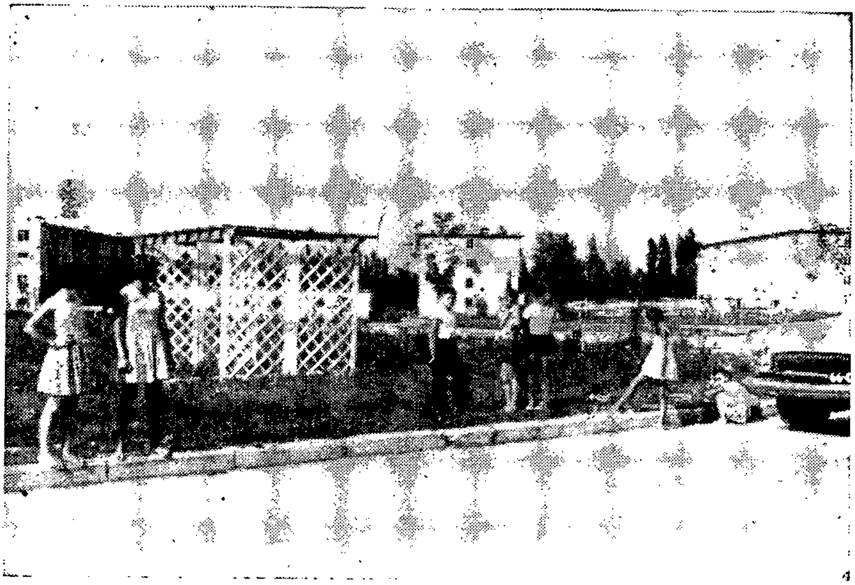
2. Installation of a complete panel during construction of an apartment. All floors, interior walls and ceilings are comprised of large panels.



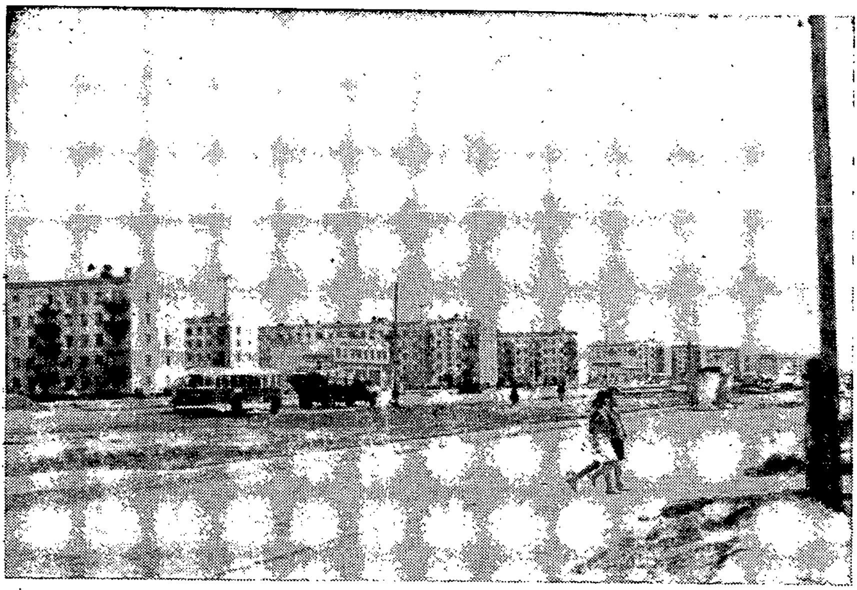
3. Installation of large panels on low-rise apartments on construction site.



4. High-rise apartment buildings constructed entirely of large panels.

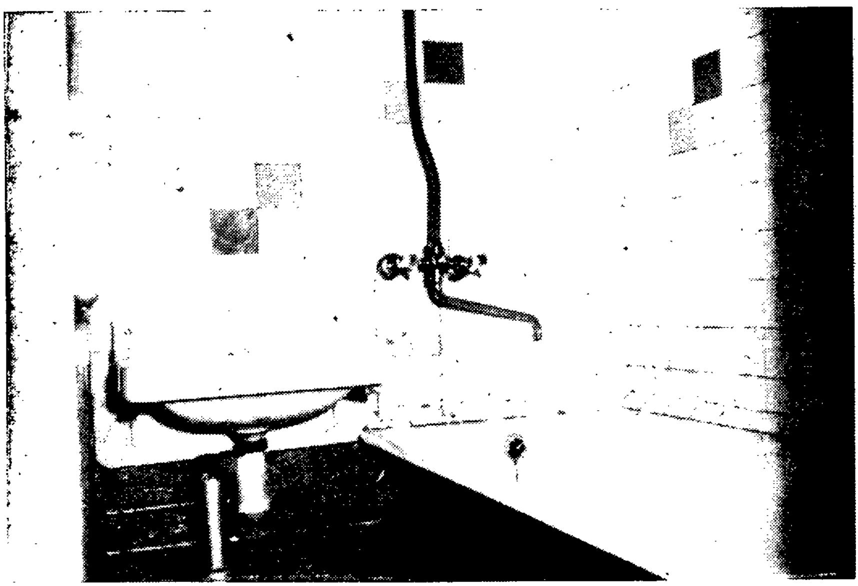


5. Low-rise apartment project of prefabricated panels. Note large proportion of green space for parks, playgrounds, etc., which is typical of Soviet residential projects.

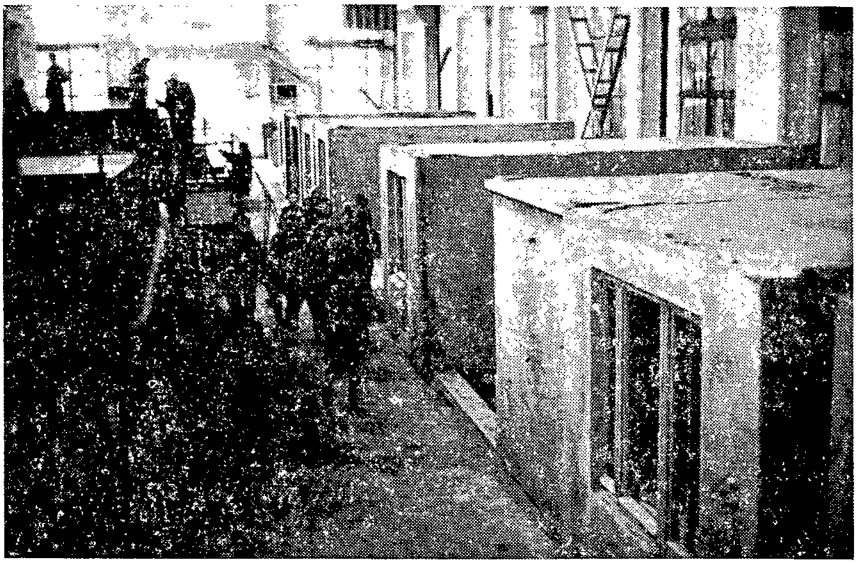


6. Late construction phase of "new town" development. Note wide streets and wide spacing of buildings. Landscaping to follow later.

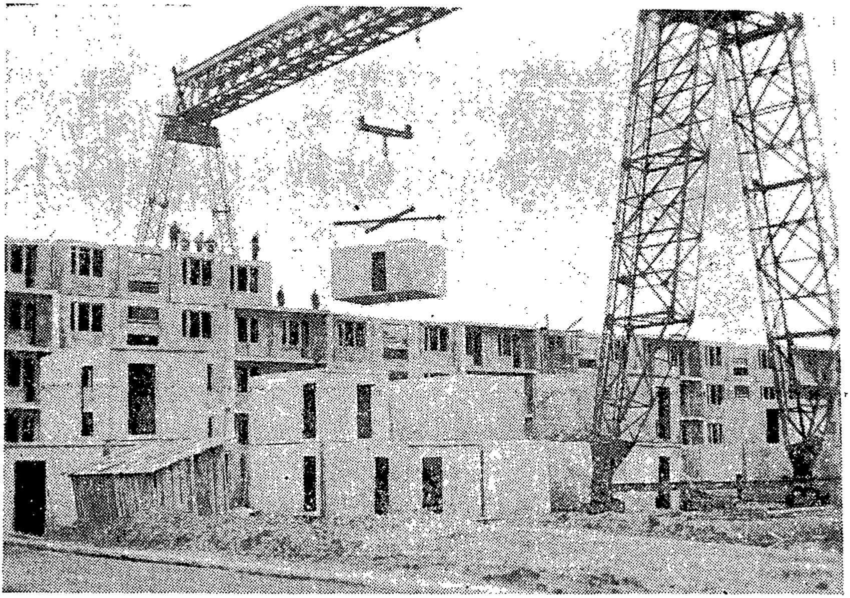
7. Details of interior finishing in new Soviet apartment. Papered and painted walls, hardwood parquet floor (partly covered by felt mat), hot water radiator, prefab glassed-in balcony.



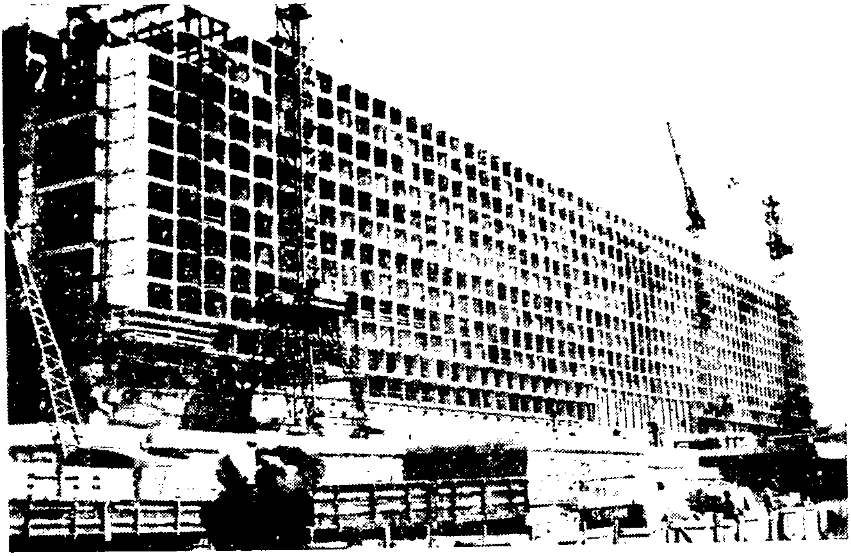
8. Details of bathroom. Cast-iron enamel tub and porcelain wash basin served by single swing faucet providing hot and cold water to both fixtures. Porcelain tile walls, painted concrete floor, exposed plumbing.



9. Prefabrication of complete rooms. At left, casting and curing molds. At right, new precast rooms just removed from molds and placed on tracks for delivery to trucks. Windows and door frames installed at the factory.



10. Construction site of new apartment being built by stacking prefabricated entire rooms.



11. New hotel in Moscow totally prefabricated by a method also used in apartment buildings, etc. Less than one-fourth of the hotel is shown in the picture.

URBANIZATION AND NEW HOUSING CONSTRUCTION IN THE U.S.S.R.

by

LEON M. HERMAN *

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INTRODUCTION

The process of urbanization has been advancing at a rapid pace in the Soviet Union during the past four decades. When the Soviet Government took its own first census—in 1926—the results showed that 82 percent of the population still lived in rural areas. A perceptible movement of people from the villages toward the cities had been underway in Russia for some time, namely since the process of industrialization began during the 1880's. However, the full effect of this movement was not reflected in the population structure before the end of the fourth decade of the present century. By the time of the 1939 census, one third of Russia's population had become city dwellers.

Since then, the percentage of the urban inhabitants has been rising steadily. The first census taken after World War II, in 1959, indicated that people living in rural settlements still constituted a slight majority. Two years later, the percentage relationship between the two components of the population stood at an even 50–50. By the beginning of 1968, the Soviet Union reported that the figure for urban inhabitants rose to 55 percent of the population as a whole.

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I. Dimensions of the Inherited Housing Problem

The construction of new housing ranked rather low as an investment activity in the official Soviet scheme of things during the 25 years of the Stalin regime. To quote the present Communist Party chief of the U.S.S.R., Leonid Brezhnev, speaking to a conference of builders on May 11, 1964: "It is no secret to anyone that in the years of Stalin's personality cult housing construction was much neglected and the housing problem became quite acute." [1] In general, most recent Soviet leaders have agreed, in their public statements, that the dimensions of the housing problem inherited from the Stalin period were staggering. The state-owned urban housing fund, which had increased by 185 percent between 1913 and 1950, was so severely strained during the fifties as to compel the municipal authorities to reduce the allocation to 5 square meters* of living space per person. By way of comparison, the officially designated minimum "norm" for urban housing in the U.S.S.R., established as far back as 1927, had been set at 9 square meters per person (100 square feet). As a result, most urban apartments in the large, rapidly growing cities have long functioned in the form of communal housing, requiring the occupants to share the available living space, along with the kitchen and bathroom facilities.

After the beginning of comprehensive economic planning in the U.S.S.R. in 1928, with its primary emphasis on industrial growth, investment in housing construction declined sharply as a proportion of the total capital outlay on the national economy. The downgrading of this sector was reflected in a drop from a share of 22.2 percent allocated during 1918–28 to 11.7 percent of all new investment for the period of the first five-year plan. The relative share of housing in total domestic capital investment remained at approximately this level throughout the Stalin regime; both before and after World War II. For example, during the fourth five-year plan (1946–50), covering the period of postwar reconstruction, the investment in housing amounted to 12.6 percent of total economic investment.[2]

HOUSING SPACE AND URBAN POPULATION IN THE U.S.S.R.

[Data as of the end of year]

	1926	1955	Index of growth
Urban housing space (in million square meters)	216.0	640.0	300
Urban population (in millions)	26.3	88.2	335

Sources: Narodnoe Khoziaistvo SSSR v 1956 Godu. p. 177; Narodnoe Khoziaistvo SSSR v 1965 G. p. 7.

As a result, the housing stock in the cities declined relative to the number of inhabitants. Viewed on a per capita basis, available living space [3] was calculated at 4.67 square meters in 1950 (4.78 in 1955), as compared with 5.85 in 1926.[4]

*One M^2 equals 10.75 square feet.

[1] *Pravda*, May 12, 1964.

[2] T. Sosnovy, in Joint Economic Committee. U.S. Congress. *Dimensions of Soviet Economic Power*, Washington, 1962 p. 329.

[3] The living space of an apartment, according to Soviet usage, includes the bedrooms and living rooms only, while total ("useful") floor space measures the whole of the interior of the apartment, including kitchen, bathroom, and corridors. As a rough proportion, living space takes up some 65–70 percent of the total ("useful") space of an apartment.

[4] *Dimensions*, etc., p. 331.

II. The Beginning of the Current Building Program

During the early 1950's, the Soviet Government was still spending only about 2 billion rubles, or 30 rubles ($33) per urban inhabitant, yearly on the construction of new housing. With the rise of N. S. Khrushchev to leadership in the U.S.S.R., the situation underwent a conspicuous change. Four years after his accession to power, the new First Secretary of CPSU (Communist Party of the Soviet Union) launched a major campaign for the improvement of housing conditions in the urban centers of the nation. In a decree, issued on July 31, 1957, the leaders of the Communist Party and the Government committed themselves to a program of greatly expanded residential construction. The objective of the program, according to the decree, was to "liquidate the current housing shortage during the next 10–12 years."

Most immediately, the decree ordered an increase of 100 percent in the volume of new housing to be built during the current five-year plan period (1956–60), as compared with the amount completed during the preceding five-year span. On the basis of such an acceleration in the rate of new residential construction, the national authorities expressed the hope that the practice of assigning families to single room occupancy could be abandoned in the years ahead in favor of allocating separate apartments to families entitled to obtain new housing.

TABLE I.—TOTAL VOLUME OF NEW HOUSING BUILT IN THE SOVIET UNION SINCE WORLD WAR II [1]

[In million square meters]

	1946–50	1951–55	1956–60	1961–65	1966	1967
Volume of new housing	200.9	240.5	474.1	490.6	102.1	103.1

[1] Includes housing financed by the State, cooperatives, private urban residents, and collective farms personnel.
Source: SSSR v. Tsifrakh, v. 1967 Godu. Moscow, 1968, p. 136.

The decree, furthermore, outlined some of the measures contemplated by the Government to bring about a systematic conversion of existing construction methods to the new, industrial technique of building apartment houses. These measures, explicitly, called for a far-reaching transformation of the construction industry, including the character of its supply base as well as the methods used in the manufacture of building materials. Among the benefits expected to be gained from a conversion to industrial construction methods were both a marked reduction in building costs and a saving in time required to erect new dwelling facilities.[5]

Since 1957, the major urban centers of the Soviet Union have witnessed the rapid rise of large complexes (called "massives") of new apartment houses built on cleared stretches of unoccupied land, for the most part in the outlying areas of the city. These new urban housing complexes are built on a mass scale, with provision made for the parallel construction of schoolhouses, preschool facilities, stores and other accommodations essential for the service of the residents. These support facilities are housed either in separate, specialized buildings or directly on the first floor of the apartment houses.

[5] *Zhilishchnoe Stroitelstvo* #11, 1967, p. 12.

The new building program began to show impressive results in the five-year period ending in 1960. During the latter quinquennium, state-financed housing alone (the principal sector) increased by about 100 percent over the preceding five-year plan period: the actual rise was from 113 to 224 million square meters. Individual owners of one-family dwelling units living in urban settlements also increased their stock of new housing, but by somewhat smaller margins.

III. The Making of a New Industry

At the beginning of the present campaign for increased residential building, Soviet authorities reported that there were more than 100,000 individual construction projects underway in the various regions of the country. These projects were under the jurisdiction of a multitude of ministries and agencies. Building activity was admittedly fragmented, with individual construction sites working in isolation from one another. The available inventory of construction equipment was widely scattered and all too often not fully used; construction schedules were enforced rather loosely. Inevitably, too, overhead staffs were excessive, and the costs of construction inordinately high.

A. Beginning of Modernization Process

During the late fifties the Soviet Government initiated a drastic reorganization of the building industry, chiefly by way of ordering the widespread adoption of the industrial method of construction. This drive began with a series of separate measures providing for the establishment of new productive capacities for the production of prefabricated components parts, which was followed in due time by a land-mark decree, published in 1959, calling for a shift toward the use of "the progressive" method of construction by means of precast large panel component elements as the "main approach" to coping with the expanded official program for building urban housing units. This initiative was followed by a parallel effort on the part of the central construction planning agencies to begin the preparation of (*a*) several standard architectural designs for modern factories capable of mass producing precast concrete component parts; and (*b*) a series of standard designs for apartment houses to be built by the large panel method. In support of this new ambitious program, furthermore, specialized equipment for the pre-fabrication of sectional concrete building components also began to be designed and produced by the machine-building plants of the country.

The productive capacity of this new industry expanded at a rapid pace. In 1959, the U.S.S.R. already had a total of 1,851 plants engaged in the production of sectional precast concrete elements. Moreover, two-thirds of these plants were production units of a modest size, capable of turning out annually an average of about 10,000 cubic meters of finished product. By 1965, the production base of the industry increased to 2,305 plants, including a sizable proportion of large scale enterprises. As shown in the table below, plants producing between 10 and 70 thousand cubic meters of sectional components still accounted for over 60 percent of total output in 1965:

TABLE IV.—PRODUCTION OF SECTIONAL PRECAST CONCRETE COMPONENTS BY ENTERPRISE OF VARYING CAPACITY

Annual volume of output (in thousand cubic meters)[1]	1959		1965	
	Number of enterprises	Share of total output (percent)	Number of enterprises	Share of total output (percent)
To 10	1,215	19.1	1,201	11.9
From 10.1 to 20	289	17.1	482	17.0
From 20.1 to 40	218	26.1	354	23.4
From 40.1 to 70	85	16.6	186	20.2
From 70.1 to 100	24	6.9	41	11.2
From 100.1 to 200	18	12.2	33	11.7
Over 200	2	2.0	8	4.6
Total	1,851	100.0	2,305	100.0

[1] Excluding small polygons and production at building sites.

Source: A. S. Boldyrev (editor) Promyshlennost' stroitel'nykh materialov. Moscow, 1967, p. 81.

Thus by the middle of the sixties the Soviet Union had at its disposal well over 2,000 modern, mechanized plants for the production of precast concrete components. Furthermore, new capacity continues to be added at a lively pace, averaging some 40 new plants a year, capable of producing over 5 million cubic meters of precast concrete components. For the industry as a whole, total annual capacity reached a figure of 63 million cubic meters of concrete components in 1966.

The fixed capital of this new industry is officially placed at a value of 3,580 million rubles.[6] New investment is coming in annually at a rate of some 257 million rubles. As far as employment is concerned, the industry is reported to have a labor force of 700,000 persons, including 65,000 employees in the engineering and technician category. Total annual production currently amounts to 3,590 million rubles.[7]

In terms of its daily output of finished product, the precast concrete industry of the USSR turns out an average of 200,000 cubic meters of building components, ready for shipment to the construction sites of the country.

Economists of the industry in the Soviet Union have calculated that the use of precast concrete components is currently saving the state 900 million rubles ($1 billion) a year, which is equal to 4 percent of the value of all the new buildings. This amount reportedly includes the annual savings of 10 million tons of steel, 35 million cubic meters of lumber, 9 million units of brick, 30 million square meters of dry wall, along with other types of standard building materials.

These economies in question are sometimes illustrated in the Soviet technical press as follows: it takes an average of 13 months to erect a 5-story brick building of a standard size, while the same size structure can be built of concrete panels in 9 months. As shown by one of these calculations, the amount of labor saved by the use of the prefabricated residential building method came to 23 million man-days in 1965.[8]

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[6] At the official rate of exchange, one ruble is valued at $1.11; converted at its purchasing power equivalent in the construction industry in particular, one ruble is generally valued at $2.

[7] *Stroitel'naia Gazeta.* July 15, 1966, p. 2.

[8] *Ibid.*

In order to accelerate, in particular, the large-panel building method, the Soviet Union has erected within the past dozen years some 275 specialized factories with an aggregate capacity of 17 million square meters of finished housing space.[9] Most of these plants are located in Moscow, Leningrad, and the capital cities of the republics of the union.

PRODUCTION OF CEMENT AND PRECAST CONCRETE COMPOUNDS

	1955	1960	1965
Cement (in million metric tons)	22.5	45.5	72.4
Precast concrete components (in million cubic meters)	5.3	32.4	63.1
Including wall panels (in 1,000 cubic meters)		954	6,325

Source: "Zhilishchnoe Stroitelstvo," No. 11, 1967. P. 16.

Within the past few years, there has come into being in the U.S.S.R. a new type of enterprise, known as the house-building combine (DSK). There are now 80 of these units in operation, capable of annual output of 7.5 million square meters of living space. The typical "combine," which originated in Leningrad, encompasses under its jurisdiction the prefabricating plants as well as the building sites. This means that the "combine" produces the component parts, groups them in sets, delivers the required materials to the place of construction and assembles them into buildings and facilities. Under this method, more of the detail and finished work can be completed, by using mechanized processes, on the factory premises prior to their shipment to the construction sites.

The house-building "combine," as a rule, does not maintain warehouses at the building site and, therefore, must do its assembly work, as it were, "from the wheels." This helps to reduce the amount of loading and unloading work at the site. Instead, truck services are generally required to constitute an integral part of the operation, and are used continuously to support the activities of the builders. As shown by the experience with this method in Leningrad, this form of "building from the wheels" makes it possible to reduce labor consumption by 40 percent, while building time in general is reduced by 30 percent.[10]

Among other things, this new method of home-building seems to have blurred the line of demarcation between two separate branches of economic activity, namely the building materials industry and the construction industry. A sizeable proportion of the work formerly done by builders is now carried out in the factories built to prepare complete walls, ceilings, and floors, ready for delivery to the building site to be set in place with the aid of hoisting machines.

TABLE III.—*Production of precast concrete components: 1950–66*

[In million cubic meters]

1955	5.0	1964	50.0
1958	18.0	1965	56.1
1960	30.2	1966	63.8
1961	35.9	1967	70.1
1962	41.9	1970 (plan)	80.0
1963	45.7		

Source: Statistical yearbooks of the U.S.S.R.

[9] Boldyrev (Editor) *Promyshlennost*, etc., p. 83.
[10] Boldyrev, *Promyshlennost*, etc., p. 83.

B. RECENT IMPROVEMENTS IN DESIGN

During its early phase, the large panel method of house building drew a good deal of criticism from the Soviet citizen as well as the foreign observer, mainly on the grounds of the quality and design of the finished apartment. The residents complained about both the inadequate size and the equipment of the kitchen, the primitive plumbing unit, the undersized foyer and diminutive rooms. The latter features, as currently explained by spokesmen for the Soviet industry, are not necessarily characteristic of the large panel method of construction. Rather, they simply represent the standard apartment design of an earlier period, which is now obsolete, although it was used for new dwellings built a decade ago by whatever method or material.

"At present," according to one high official of *Gosstroy* (State Building Committee), "a new improved series of standard design has been approved to replace the old one, which to a significant degree excludes these shortcomings." [11] Soviet specialists appear to be confident that "in the long run" the opportunities for improving the quality of construction in general, and finishing work of the interior in particular, are better in the case of the concrete panel method than in conventional brick construction. By way of support for this proposition, they point to the fact that large panel construction has successfully passed out of the experimentation phase to become the accepted method of providing new housing space for the growing population of the Soviet cities. The figures used to illustrate the trend in that direction are as follows:

[In million square meters]

	1959	1960	1961	1962	1963	1964	1965	1966
New urban housing space, total	53.5	55.8	56.6	59.8	61.9	58.9	63.2	65.2
Including large panel buildings	0.78	1.97	5.2	9.1	12.5	14.7	18.7	20.5
Percent of large panel in total new housing	1.5	3.5	9.2	15.2	20.2	25	30	31.5

In their continued search for better ways, Soviet architects have encountered no technical difficulties in changing their designs from the standard five-story building to structures rising as many as 9, 12 and 16 stories high. In some instances, they report, it was possible to erect these taller, more comfortable buildings, which include elevators and garbage chutes, with a capital investment on both housing and communal facilities equal to that required to build the traditional 5-story projects.[12] They do indicate, however, that for the time being, the bottleneck in erecting this type of structure is the inadequate current level of deliveries to the construction industry of large tower cranes with a lift capacity of 7–10 tons.

IV. Public Investment in New Urban Housing

A. HOUSING AS A CLAIMANT UPON PUBLIC FUNDS

The capital outlay of the Soviet Government on new residential construction in the cities has been rising, although somewhat uncertainly,

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[11] *Zhilishchnoe Stroitelstvo*, No. 11, 1967, p. 16.
[12] Ibid.

since the mid-fifties. Between 1956 and 1960, for example, the annual outlay rose from 2.9 to 5.5 billion rubles. Viewed as a percent of total capital investment by the state, this was a notable advance, namely, from 15.4 to 18.0 percent.

Thereafter, the absolute figure for state expenditures on urban housing continued to move upward, as shown by the recorded rise from 5.4 in 1961 to 7.1 billion rubles in 1966. But the momentum of the rise was not very impressive, inasmuch as the share of housing in the total economic outlay by the state in fact declined during this 5-year period from 17.0 percent to the 1966 figure of 15.5 percent.[13]

For the current five-year plan (1966–1970) the Soviet Government has promised to do better. Average yearly outlays are planned to run at a rate of 15 billion rubles, and the annual share of housing in total new investment in the economy is projected to reach 25 percent.[14]

In general, it appears that the position of public housing, as a claimant for appropriations, has grown more firm in recent years. Nevertheless, it still continues to fluctuate with the rise and fall of the pulling power of the other major claimants for capital funds, namely industrial investment, military expenditures, high priority scientific research, and agriculture.

MAJOR STATE CAPITAL EXPENDITURES OF THE U.S.S.R.

	In billion rubles			
	1960	1965	1966	1967
Industrial investment	12.6	17.6	18.5	[1] 19.4
Agricultural investment	2.5	5.3	5.7	6.2
Defense expenditures	9.3	12.8	13.4	14.5
Housing construction	5.5	6.3	7.1	[1] 7.9
Scientific research [2]	3.3	5.7	6.8	7.2
Total	33.2	47.7	51.5	55.2

	In percent			
	1960	1965	1966	1967
Industrial investment	37.9	36.9	35.9	35.1
Agricultural investment	7.5	11.1	11.1	11.2
Defense expenditures	28.0	26.8	26.0	26.3
Housing construction	16.6	13.2	13.8	14.3
Scientific research	9.9	11.9	13.2	13.0
Total	100.0	100.0	100.0	100.0

[1] Estimated figures.
[2] Including some expenditures made directly by enterprises.

Source: Statistical yearbooks of the U.S.S.R.

When the current five-year plan period comes to an end, in 1970, the urban housing fund, public plus private, should show a gain of 480 million square meters. On a yearly average, this would come to 96 million square meters of new housing, as against 76 million per annum added during 1961–65.

[13] *Strana Sovetov za 50 Let*. Moscow 1967. p. 203.
[14] Radio Moscow. Domestic Service, Interview with I. A. Gãnichev. Presumably, this refers to urban housing as a whole, including privately financed. To make this figure comparable, it should be noted that it corresponds to the recorded share of 20.9 percent for 1961 and 17.2 percent for 1966.

To date, expressed in terms of completed urban apartments, the additions made during the years 1966 and 1967 amounted to 1,850,000 and 1,900,000 units, respectively.

B. THE COST OF CONSTRUCTION

As a result of the widespread use of industrial methods, the industry has succeeded in bringing down the cost of housing construction. As reported in the technical press, the amount of labor used at the building site in large panel residential construction comes on the average, to 35–40 percent less than in the case of building brick units of the same size. Building time "in most cases" is reportedly reduced by between one-third and one-half. All in all, according to official data for the period 1959–65, the cost per one square meter of living space by the large panel method was generally lower than brick construction by 12–15 percent.[15]

INVENTORY OF MACHINERY IN BUILDING INDUSTRY OF THE U.S.S.R.

[In 1000 units; end-of-year-figures]

	1950	1960	1965	1966	1967
Excavators	5.9	36.8	69.2	75.4	81.0
Scrapers	3.0	12.2	20.1	21.5	22.7
Bulldozers	3.0	40.5	68.5	74.0	79.1
Mobile cranes	5.6	55.0	83.3	90.0	96.6

Source: "SSSR v Tsifrakh v 1967 Godu," p. 110.

From data available for the republic of Ukraine we learn, for one thing, that the cost of construction in that republic has tended to be lower than in a number of other constituent republics. For another, it is reported that for the year 1966, for the Ukraine as a whole, the average cost per square meter came to 134 rubles. In accounting for this relatively low rate, the authorities explain that the republic has been building chiefly 5-story dwellings (72 percent of all housing), which are most economical. Another reason cited was the heavy reliance on large-panel construction, in which the Ukraine achieved as average cost of 123 rubles per square meter of housing space, "the lowest in the country." [16]

Expressed in dollars, at the ruble-dollar ratio generally used for this industry (one ruble has the purchasing power equivalent of two dollars), the above cost, for the large-panel method in particular, is somewhere near $22 per square foot of housing.

One phenomenon that tends to raise the cost of building in the Soviet Union is the continued heavy incidence of manual labor in the construction industry. While many operations are highly mechanized, about 60 percent of all wage-earners in construction work without the aid of machinery. Manual labor tends to predominate especially in loading and unloading of building materials, in finishing work, and in laying bricks.[17]

[15] *Zhilishchnoe Stroitelstvo*, No. 11, 1967. p. 12.
[16] *Ekonomika Sovetskoi Ukrainy*. December 1967, pp. 25–26.
[17] I. A. Slepov, *Tekhnicheskii Progress i Organizatsia Stroitelnogo Proizvodstva*. (Technical Progress and the Organization of the Construction Industry), Moscow, 1965, p. 13.

Upward creeping building costs are reported to be confronting the authorities from another direction. It seems that while notable results in efficiency have been attained in recent years by the increased mechanization of home building, some of the economies achieved are offset by the rising cost of machinery. "Within the last few years," according to one recent report, "the cost of machinery delivered by industry to the construction enterprises has increased many times." One example cited in this account deals with an excavator having a bucket capacity of 2 cubic meters. As originally designed and produced, this machine was priced at 36,850 rubles. Under actual working conditions the design of the excavator proved faulty. This called for a change in design, and a new model began to come off the assembly line (E–2005), having the same bucket capacity but bearing a price tag of 58,087 rubles.[18]

On the whole, the process of mechanization has been proceeding rather unevenly in the industry. As one example, technological progress seems to have altogether by-passed the production of bricks. This despite the fact that, as noted recently by *Pravda*, "Soviet builders will be using brick for a long time to come." Yet, this sector of production remains neglected. Manual labor remains prevalent; working conditions are difficult, wages are low, and labor turnover is high. There is no valid reason, according to *Pravda*, for the failure thus far to mechanize this sector: "Experience abroad has shown that it is possible to set up small but fully mechanized and automated brick plants in all parts of our country without a large capital outlay." If this were done, the author argues, it would not be necessary to haul heavy loads of precast concrete over great distances; the pressure on available cement and metal would be reduced; and the added burden on the country's transport facilities would be eliminated.[19] By all accounts, furthermore, the building industry, like many others, is regularly short-changed on its urgent requests for railroad cars and trucks from the central ministries in charge of allocating these scarce facilities.

V. Types of Housing Ownership

A. STATE-OWNED HOUSING

The bulk of the housing in the cities of the Soviet Union is owned by the state. Agencies of the state, furthermore, continue to account for most of the new urban dwelling units being built today, although private individuals and, more recently, employee cooperatives are also permitted to build and own residential structures. As a matter of administrative practice, the actual management of state-owned housing is entrusted to local agencies, chiefly local municipal authorities, but also, in special cases, to industrial enterprises and other governmental establishments.

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[18] *Ekonomicheskaia Gazeta*, No. 23, June 1966, p. 38.

[19] *Pravda*. November 12, 1968. See also article by I. Ganichev in *Trud* January 19, 1968. The author is a high-level construction specialist who asserts that most building machinery now being produced in the U.S.S.R. is of relatively low capacity because the production ministries in question "have an obsolete notion of what constitutes modern construction equipment."

TABLE 11.—URBAN HOUSING CONSTRUCTION IN THE U.S.S.R.

[In million square meters [1] of total useful space]

	1951–55	1956–60	1961–65	1966	1967
Built by the state	113.0	224.0	300.4	65.9	76.6
Built by individuals	65.1	113.8	94.0	15.9	16.8
Total	178.1	337.8	394.4	81.8	93.4
Private housing as percent of total	36.5	33.7	23.8	19.4	18.0

[1] 1 square meter equals 10.75 square feet.

Source: "Strana Sovetov Za 50 Let," Moscow, 1957, p. 245; "SSSR v Tsifrakh v 1957 Godu," Moscow, 1958, p. 136.

By reason of its scarcity, housing has always been considered in the Soviet Union as an important fringe benefit for industrial and other employees of the state. Today, as much as ever, good housing continues to be regarded as a prime factor in helping enterprises to attract and maintain a stable labor force. Hence, important industries, but also research organizations and administrative agencies engaged in high priority projects, are often allocated relatively more ample building funds in order to help them to provide a better housing standard for their personnel.

The amount of capital to be invested in housing by the state in a given year, as would be expected, is large enough an outlay to be under the jurisdiction of the central authorities of the USSR. As a matter of administrative practice, the planning of state investment in housing and related communal facilities has been maintained since 1959 as an independent area of activity, separate from construction of industrial installations. Yet, the center, i.e. Moscow, becomes involved in all activities concerned with the investment of capital as well as the allocation of building materials, wherever it originates. Thus, for example, the State Planning Commission (Gosplan) regularly includes in its own annual plan the new capital to be invested in construction by enterprises out of their own special "social welfare" funds. At the same time, much to the discomfiture of plant managers, the Ministry of Construction of the USSR alone has the right to authorize the allocation of building materials to all construction sites, including those financed directly by enterprises out of their own funds set aside for employee benefits.[20]

During the early decades of the Soviet period the share of the state in the available stock of urban housing began to rise rapidly. By 1940, state housing accounted for 63.4 percent of all the residential space available in the cities, as compared with 47.2 percent in 1928. In part, it may be noted, this increase was accelerated by the housing reform of 1937, which transferred to the state sector most, but not all, of the cooperatively owned apartment houses built during the first two decades of the Soviet regime.

Since then, this share has remained fairly stable. In 1967, for example, the state [including cooperatives] owned 67.2 percent of the entire urban housing stock, with the remaining 32.8 percent belonging to individual private owners.

[20] *Ekonomicheskaia Gazeta,* No. 14, 1968, p. 2.

B. PRIVATE HOUSING

Private individuals in the Soviet Union are permitted to build single-family dwelling units at their own expense, subject to the supervision of the municipal authorities who are responsible for the approval of the design, and the designation of the site. The form of construction is also subject to certain restrictions. A privately built home, for example, must not exceed two stories in height; must contain no more than 5 rooms and 60 square meters of space.[21] During the pre-war years, privately owned housing contributed, on the average, some 3 million square meters of dwelling space per year, while state agencies added annually about 11 million meters of useful housing space.

On principle, Soviet authorities tend to consider the construction of homes by private persons more appropriate to medium and small towns than to the larger cities. The usual explanation in this case is that "we must not allow our cities to be transformed into overgrown villages."

For a number of years after the end of World War II, the Soviet Government exhibited a tolerant attitude toward the practice of individual home construction. Housing space was extremely scarce in most parts of the country, so that additions made to the housing stock in general, whatever the source, were publicly welcomed by the Soviet officialdom. For a time, during the fifties, the authorities in fact sought to encourage private building by extending credits to the prospective home builders through the State Construction Bank, a practice that continues to the present, although on a somewhat reduced scale. Such credits, covering no more than 50 percent of the building costs involved, are generally advanced for a period of 7 years. The actual disbursement by the Bank is made in several stages, in accordance with the progress of construction.

More recently, however, private construction lost favor with the central authorities for a variety of reasons. The leadership appears to have objected chiefly to the fact that it created a wide variety of opportunities for multiple building activities by enterprising individuals, for resale, speculation, and unearned income. Accordingly, the high target for private housing written into the seven-year plan (1959–65) failed to be fulfilled: only 149 million square meters of floor space were added by the private sector during this period, which was 57.2 percent of the original goal of 260 million square meters.[22]

The formal call for restraint upon private home building came in a decree published by the Soviet Government on August 6, 1962 under the heading "On Individual and Cooperative Housing Construction." In this decree, the authorities asserted that the time had come "to discontinue the allocation of land plots for individual housing construction . . . and the issuing of credits to individual builders" in the major cities of the country, specifically in the capital cities of the constituent republics.[23] As far as other urban settlements are concerned, the central authorities left the issue open, passing responsibility in this respect to the governments of the individual republics who were to rule on such questions as where and to what extent private building is to be permitted or banned. In those towns where individual home

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[21] *Sputnik Profgruporga* (Guide of Trade Union Group Organizer). Moscow 1960.
[22] Joint Economic Committee, *New Directions in the Soviet Economy,* 1966, p. 541.
[23] *Pravda,* August 7, 1962.

building is to be permitted, the decree advised the republican authorities to retain the established procedures for granting credits and for allocating the necessary building material.

The effect of this decree was not slow in coming. Privately built housing, which reached a peak of 27.2 million square meters in 1959, declined to 20.9 in 1962, falling thereafter to 16.2 million square meters in 1964.

Although restrictive measures against individually built housing have been eased somewhat since the retirement of N. S. Khrushchev in October 1964, this form of construction has not regained its former vigor. In 1966, for example, it accounted for 20.6 percent of all new housing built in the cities, as against 33.7 percent in 1959.[24] In terms of dwelling space, the figures for privately built homes in 1966 and 1967 were, respectively, 15.9 and 15.6 million square meters. According to present accounts, the principal technical difficulties encountered by private builders are said to be a persistent shortage of building materials as well as the fact that land offered to private builders often happens to be located on remote and otherwise inconvenient sites.

C. COOPERATIVE HOUSING

Personal income has risen sufficiently in the Soviet Union in recent years to create a demand among some elements of the population for better housing. These higher paid employees are evidently able and willing to pay a higher monthly rent than most citizens are now paying for the housing they rent from the State. This rising trend in income has brought considerable pressure to bear upon the Soviet Government to help organize housing construction on a cooperative basis, using for that purpose the private savings of the membership rather than state funds. The appropriate government decree to this effect finally came on June 1, 1962 under the heading of "On Individual and Cooperative Housing Construction." The decree in question provided, among other things, that members of a housing cooperative must agree to place their organization under the supervision of existing housing administration authorities, such as that of the municipal authorities, industrial enterprises, or other governmental establishments.

From the viewpoint of the Soviet Government, the cooperative mode of house-building has two notable advantages. In the first place, it helps to reduce total demand for state-subsidized housing by a considerable margin. Secondly, it serves to sop up substantial amounts of purchasing power in the hands of the high-income groups of its population. In fact, it becomes one of the tangible ways in which the country's well-paid citizens can convert their higher ruble earnings into a conspicuous form of consumption.

In general, the technical procedures of the house-building cooperatives are expected to be worked out in close coordination with the standard designs, cost estimates, and time schedules of the regular housing construction agencies of the state.

The process of establishing a cooperative begins with the deposit by the membership of funds amounting to at least 40 percent of the estimated cost of construction. This payment is to be made to the

[24] *Ekonomicheskaia Gazeta*, No. 39, 1967, p. 29.

State Construction Bank as a basis for obtaining the necessary credit for the balance of the expenditures. The credit, usually covering 60 percent of the estimated cost of construction, is to be extended for a period of 10 to 15 years, repayable with an interest charge of 1 to 2 percent in equal annual installments. Land for cooperative apartment building must be allocated in regions equipped with roads, water mains, sewers, and electric power lines.[25] Thereafter, the building plan of the cooperative is included in the general plan of the contract work to be undertaken by the regular state construction units.

House building cooperatives began to add to the total urban stock of new housing on a modest scale in 1963, providing in that year 1.8 million square meters of floor space. This figure rose to 4.8 in 1964 and 7.0 million square meters in 1966, as shown below:[26]

[In million square meters]

	1963	1964	1965	1966	1967 (plan)
Total (useful) space	1.8	4.8	6.5	7.0	7.9
Living space	1.3	3.4	4.5	4.9	5.4

Thus, cooperatively owned housing accounted for 13.5 percent of all new urban apartments built in 1967, as compared with 3 percent in 1963.[27]

Typically, according to one informal account, the member of a housebuilding cooperative purchases his apartment at a rate of 100 rubles ($110 at the official rate of exchange) per square meter. For an apartment measuring 60 square meters the full cost would thus be 6000 rubles. His down payment must cover 40 percent of the total cost, while the rest is paid off in 10 (or 15) equal yearly installments.[28]

Cooperative housing currently enjoys a notable degree of popularity with the Soviet public. The state construction agencies in the field, however, appear to be far less enthusiastic over this new form of housing construction and ownership. In a review of the results in this sphere of building for the year 1967, a *Pravda* editorial took note of the fact that "the construction of cooperative dwelling houses was very poorly organized in a number of places", and proceeded to explain it on the grounds that most contracting organizations of the Construction Ministry "look upon cooperative housing as second class projects and do not supply them adequately with materials, equipment and qualified personnel."[29]

In general, many problems still continue to plague this new form of apartment building. There are frequent delays on projects of this category, where the enforcement of schedules is particularly difficult, due to the lack of access by the cooperatives to prime building materials and to their own choice of contract organizations.

The task of allocating space in finished cooperative apartment houses also falls under the authority of the housing agencies of the local municipal councils. The latter are expected to use as the basis for

[25] *Pravda,* August 7, 1962.
[26] V. T. Robotov, *Financing and Crediting Housing Construction* (in Russian) Moscow, 1967, p. 108.
[27] D. Pudikov. *Ekonom. Gaz.,* No. 29, 1967, p. 29.
[28] *Washington Post,* September 19, 1968, p. G12.
[29] *Pravda,* January 12, 1968.

their decision such criteria as the nature of the work of each member of the family, personal rights to additional space, etc. In addition, the local authorities are responsible for enforcing some agreed upon "norm" for living space per person in a cooperative unit, usually in keeping with the available housing supply. Thus, for example, a family of two would be assigned to an apartment having a total floor space of, say, 24 square meters (264 square feet), which is considerably in excess of the "norm" for state housing. Under the rules of some local authorities, a member may be allocated an apartment in accordance with the size of his share, but the total floor space in such an apartment must not exceed 60 square meters (660 square feet).

A new family moving into a cooperative apartment house may, according to existing rules, leave behind some of its members who would continue to occupy the apartment (or room) formerly occupied by the whole family, if the space in question does not exceed the space allotment per person prevailing in the given city.[30]

In practice, conflicts of interest often arise between members of the home-building cooperatives and the municipal authorities. The latter are usually hard pressed to find housing space for people on their long waiting list. Accordingly, the local authorities appear to reserve to themselves the right to issue a certificate of occupancy to persons who are not members of the cooperative, if they can determine that a particular member is not in urgent need of new housing. In recent fairly typical instance, the City Fathers of Chernigov (in the Ukraine) justified their intervention on the grounds that the cooperative member whom they prevented from moving into his new apartment "lives in the private home of his wife's parents (4 rooms; 48.7 square meters), in which the parents occupy only two rooms. In view of this, the executive committee refused to issue a certificate of occupancy." [31]

By all accounts, the cooperative form of apartment ownership is still something of a new phenomenon in the Soviet Union. The municipal authorities, working in a climate of extreme stringency of dwelling space, still have to become accustomed to dealing with this type of property as falling outside their jurisdiction. They are, therefore, regularly reminded by the official press, as well as by the courts, to treat cooperatives as "public self-governing bodies" empowered by the law to establish and enforce their own rules of apartment occupancy.

During 1968, newly built cooperative housing came to a total of 6.9 million square meters, with a planned figure of 8.5 million for 1969. The amount of credit extended by the State to housing cooperatives during the year was reported at 410 million rubles, a figure that was raised in the plan for 1969 by 22 percent, namely to 500 million rubles. [32]

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[30] *Ekon. Gaz.*, No. 6, 1968, p. 28.
[31] *Izvestia*, March 16, 1968, p. 2.
[32] *Ekonomicheskaia Gazeta*, No. 2, 1969, p. 36.

VI. The Situation Today

A. ALLOCATED HOUSING AT LOW RENTS

Under present stringent conditions of supply, housing space in the cities of the Soviet Union continues to be rationed. Tenants of new apartments are alloted space, as a rule, on the basis of the size and need of the family. The authorities are currently using for that purpose a "housing norm," or ration, of 7 square meters of living space per person.[33] At the same time, the goal remains, as before, to provide a room for each adult and an apartment for each family. To achieve this goal would, according to official calculations, require a stock of housing comfortable enough to permit a "norm" of 15 square meters per person.

By way of compensation, however, rents are unusually low. The established monthly rate for residential space is 0.13 rubles per square meter. At this rate, a family of four assigned to an apartment measuring 30 square meters, for example, would pay some 4 rubles per month. Payment for utilities has to be made separately, but there is no systematic information on such charges in Soviet sources.

How does the monthly outlay on rent look in relation to average earnings in industry The average monthly wage in the economy as a whole was 103 rubles for the year 1967. Wages in industry were somewhat higher, averaging 113 rubles per month. At the present housing ration, therefore, rent for a small apartment for a family of four, excluding utilities, would absorb some 3.5 percent of the average monthly earnings of the worker in industry. Payment for utilities, according to available framentary information, would probably consume another 3.5 percent.

AVERAGE HOUSING SPACE PER URBAN INHABITANT IN THE U.S.S.R.

[Data as of end of year]

Year	Urban population (in millions)	Housing space (in million square meters)	Square meters per person: Gross (useful space)	Square meters per person: Net (living space)
1957	95.6	723	7.56	5.29
1958	100.0	832	8.32	5.82
1959	103.8	896	8.63	6.04
1960	108.3	958	8.84	6.19
1964	121.7	1,182	9.72	6.80
1965	124.7	1,238	9.93	6.95
1966	128.0	1,290	10.08	7.06
1967	130.9	1,343	10.26	7.18
1970[1]	145.0	1,556	10.73	7.51

[1] As calculated by V. T. Robotov, Finansirovanie I Kreditovanie Zhilishchnogo Stroitelstva, 1967, pp. 10–11.

Source: Economic yearbooks of the U.S.S.R., respective years.

The practice of subsidizing urban rents has been followed by the Government of the U.S.S.R., as a matter of public policy, throughout its existence. Such a policy has been officially justified on the following two counts: (1) It is the aim of Soviet society to provide all Soviet citizens with adequate housing, regardless of their income; (2) Under

[33] *Molodoi Kommunist,* June 1968, p. 69.

the present scale of wages in the U.S.S.R., some Soviet citizens would not be in a position to pay the full economic rent for the housing they occupy. One Soviet authority, who notes that "in our country rents are so low that apartment houses do not even pay for their maintenance," goes on to explain this practice as follows: "By no means all citizens have the means to pay for this [i.e. the full cost of construction maintenance, and repair], and Soviet society is striving to create normal housing conditions for all working people." [34]

The extent of subsidization is not clearly indicated in official Soviet sources. On occasion, individual Soviet authors have estimated that the degree of subsidization is in the vicinity of 80 percent.[35] If the 80 percent figure is correct, the full economic rent for the 30 square meters of housing space cited in the above example would come to 20 rubles per month, net of charges for utilities. For the industrial worker earning an average wage, namely 113 rubles, such an expenditure would involve an outlay of 17.7 percent of his monthly earnings.

B. THE MICRO-DISTRICT

According to current practice in the U.S.S.R., new housing projects are organized on the basis of a primary unit known as the micro-district. Typically, a micro-district consists of either (*a*) one enlarged city block measuring some 30 hectares (75 acres); or (*b*) a group of several blocks encompassing an area of 40–50 hectares. The population of a micro-district tends to range around 10–12 thousand persons, or in the case of a high-rise apartment area up to 18,000 persons. Each district is planned to include, in addition to the basic dwelling units, an assortment of buildings and facilities designed to serve the needs of the residents and their children, such as stores, laundries, cleaning and repair shops, restaurants, schools, kindergartens and nurseries.

The houses in such a micro-district are generally of the "free plan" type of construction. The buildings are planned to be so situated as to provide the rooms with a maximum of daylight, to allow for the proper ventilation of the area, and for the best use of the natural slope of the land.

A great deal depends on the density of dwelling units per given territory, i.e. on the relationship between the total land area and the amount of residential space to be provided. The lower the resident density, presumably, the higher will be the city's expenditures per inhabitant on such operations as the pavement of streets, water supply, sewer system, and other utilities. By the same token, the less dwelling space per acre of land in a given district the more land area will be required to provide the necessary housing for a given number of urban residents.

The residential as well as the service buildings of a given micro-district are generally located in areas adjacent to the main thoroughfares which are usually well served by urban transportation facilities. Where necessary, the micro-district itself is provided with local bus service. Under approval plans, lanes for vehicle and walks for pedestrian are kept apart from one another, thus avoiding as far as possible, the intersection of automobile traffic and the movement of children to and from school.

[34] V. Svetlichny in *Kommunist*, No. 6, 1965.
[35] *Voprosy Eknonomiki*, No. 10, 1964, p. 7.

C. SOME OFFICIAL CRITICISMS OF THE HOME-BUILDING INDUSTRY

Housing construction in the U.S.S.R., as would be expected, is at all times under the careful scrutiny of the central authorities. Most officials concerned with this critical area of public welfare have made it clear, over the years, that they are proud of the scale on which the industry operates but that they are not entirely satisfied with the degree of efficiency with which the affairs of the industry are managed.

The leaders of the industry are most frequently upbraided for failing to maintain an even flow of materials, equipment, technical documentation, transport facilities, and high-grade specialists to the building projects. They are criticized, furthermore, for permitting rushwork, excessive building costs, and poorly finished work. Disorders of this sort, according to the official press, are generally brought about by a failure to adhere to building schedules, with the result that many contracting organizations deliver between 40 and 50 percent of their completed buildings during the fourth quarter of the year.

A recent editorial took the industry to task for contributing only some 14 million square meters of dwelling space built by the large-panel method in 1967, "when the industry is known to have a capacity for adding yearly more than 19 million square meters of housing.[36]

Another point made by official critics of the industry is that "there is a serious shortage of engineers, technicians, and workers on the building sites"; and that, moreover, the scope and level of the training and skills of those on the job "are not in accordance with the tasks of capital construction work."

In a special decree issued on February 16, 1968 to cope with this problem, the Soviet Government instructed the Ministry in charge to expand its facilities for training specialists in modern construction techniques and, at the same time, to improve both the working and housing conditions of its trained personnel in order to cut down on the wasetful turnover of specialists engaged in building and assembly operations.[37]

In the opinion of one well-informed public commentator, the Soviet home-building industry had experienced its full measure of false starts and mistakes, due to the failure to prepare in advance an adequate pool of specialists trained to cope with the sectional method of construction. During the early years, for example, the industry worked on what he describes as "immature standard designs" which resulted in many structural defects. Some of these defects, he pointed out, are still being eliminated today at great expense to the state.

Among some of the more serious defects of the early models of large-panel housing construction, which are still being cited in the complaints of the residents, he lists the following: "In some houses it is cold; corners freeze, as do sometimes the panels over the entire surface of the wall as well; gaps appear at the joints of the walls, through which the wind blows and dampness penetrates. Quite often, window tracks freeze; in some houses the ceilings are cracked and the floors sag." [38]

Most of these defect the author ascribes to the lack of experience reflected in the early architectural designs. He characterizes them as

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[36] *Pravda*, January 12, 1968.
[37] *Pravda*. February 19, 1968.
[38] V. Svetlichny, in *Kommunist* No. 6, 1965.

"the result of the premature introduction of mass construction of standard houses not previously tested under operational conditions."

On the whole, however, he remains optimistic about the large-panel method of building, but he warns that a great deal of work remains to be done to establish the reputation of this method more firmly. He cites, in particular, the need for ever better standard designs, more experimental verification, equipment of higher precision at the plant level, higher quality structural components, and a more dependable supply of weatherproofing, heat-insulating, and sound-proofing materials.

D. THE OUTLOOK

The current scale of new residential construction in the Soviet Union is both large and impressive. Urban housing facilities are being augmented at a rate never before experienced in that country. The allocation of state funds to the program for providing the urban population with adequate housing has grown to a substantial annual outlay, accounting for 14 percent of all new capital invested in the national economy.

Real progress in this area of social betterment continues, however, to be slow. If we measure this progress by the margin by which housing space available per inhabitant has increased during the most recent 10-year period (1957–67), we find that the gain registered during this period amounts to no more than 3 percent, namely from 5.29 to 7.18 square meters of living space, an improvement of 3.1 percent a year. On this point, Soviet experts tend to comment soberly that "despite the unprecedented scale of construction, the increase in housing per city dweller is proceeding slowly." [39]

The reason for this slow pace is not hard to find. The urban population of the Soviet Union has been growing recently at the rate of 3.5 million persons per year. This means that in order to cover the needs of the new contingent of urban residents alone, the building industry, according to one Soviet expert, must provide an annual addition of 45 million square meters of "useful" housing space.[40] Then, too, allowance has to be made for the attrition of old housing, which is now taking place at a rate equal to 0.8 percent of the total housing stock. The figure for attrition has been estimated by the same authority at 8 million square meters of dwelling space.

In light of these figures, the Soviet expert concludes that by 1970 [the end of the present 5-year plan] the U.S.S.R. will have at its disposal in the cities about 1,556 million square meters of useful housing space, as against an expected urban population of 145 million persons. Given these constraints, the inhabitants of the nation's urban settlements will be entitled to a "norm" of 10.7 square meters of useful housing space per person. Such an allocation would still be below the official Soviet minimum "norm" for housing adopted in 1927, namely 12.85 square meters of useful space, or 9 square meters of living space.[41]

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[39] Svetlichny, in *Kommunist*, No. 6, 1965.
[40] V. T. Robotov, *Financing and Crediting Housing Construction* (in Russian) 1967, p. 10.
[41] *Ibid.*, p. 11.

EXCERPTS FROM REPORT OF THE NATIONAL COMMISSION ON URBAN PROBLEMS

Hon. PAUL H. DOUGLAS, Chairman

[Part V. Chapter 2]

REDUCING CONSTRUCTION COSTS

For every dollar saved in basic construction costs, there are added savings to the ultimate consumer in reduced construction profits and overhead, interest on loans, tax assessments, and other costs that traditionally relate to construction costs such as architects' and engineers' fees and real estate fees. It is imperative, then, that every promising avenue of construction cost saving be followed up to the point at which the cost saving techniques begin to change the nature of the products in the undesirable ways, or significantly reduce the durability, usefulness or level of amenity, or increase other ownership costs.

THE NATURE OF THE BUILDING INDUSTRY

Home building in the United States, in many of its aspects, is an example of the small-scale, handicraft type industry. As industry after industry has been industrialized,[1] work has become more finely subdivided. More capital per worker has been provided, and production has increased for each combined unit of labor and capital. The material standard of living has risen. While some of these changes have come into building, more than almost any other industry it produces under conditions similar to those common a half-century ago.

The "building industry" is a loose conglomeration of small participants who come together on a project-by-project basis. The initiator of the construction process brings together architects, engineers, and a general contractor for a given building development. In the past almost all private residential construction was initiated by a merchant builder, who built a small number of units for sale, or by an individual owner, ordering a single house for his own use. While this pattern continues to predominate, more recently the building function has sometimes been divorced from the development function—with a developer buying land, planning its development and then calling in builders to perform the construction function.

The typical contractor still builds only a few houses each year and farms out a large part of his work to specialized subcontractors. He might take charge of the foundations and the shell himself, but will have separate subcontractors for the plumbing and the electrical work.

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[1] As in the United States, "industrialization" takes a variety of forms and degrees. In general, as used in this section, it refers to the use of components, sections, panels and modules constructed off-site.

He hires painters and bricklayers and numerous other craftsmen to perform specialized tasks. Sometimes he lets these jobs out on subcontract, while remaining responsible for the purchase and flow of materials and for the general conduct of the work. When each participant completes his particular role, he leaves. Generally speaking the organization is assembled for one job only.

Size of Firms

The building industry is composed of thousands of small firms. A preponderant number of construction firms are under sole proprietorship and employ few or no full-time employees. Workers in construction tend to establish their own businesses when opportunities are available and to return to working for others when such opportunities decline. It is quite common that small construction contracts are carried out by skilled craftsmen simultaneously with regular employment.

Although firms engaged in "contract construction" are not the only ones in the building business, an analysis of their operations illustrates the characteristics of the industry. The statistics for this category of work do not include the operative builders who construct on their own account for sale or lease or investment builders who construct buildings for rental. Those in contract construction include contractors primarily engaged in the erection of buildings, general contractors in heavy non-building construction, and special trade contractors.

In mid-March, 1966, there were 322,781 firms with one or more employees engaged in contract construction. General contractors engaged in constructing buildings numbered 93,148 firms, with 937,384 employees. There were 199,917 special trade contractors, employing 1,538,150, with the largest engaged in plumbing, heating and air conditioning; painting and paper hanging; electrical work; masonry, stone work and plastering; and carpentry and wood flooring.

Most firms in the building business are quite small. In 1966, 174,356 contract construction companies, or 54 percent of the total, had one to three employees. Only 10 percent of the total had twenty or more employees. By contrast, 25 percent of the total number of manufacturing firms had one to three employees, and 36 percent had twenty or more employees.

A 1964 survey by the National Association of Home Builders, which claims that its membership produces 75 percent of all single-family houses and 65 percent of all new housing, indicates that the vast majority of its member builders maintain relatively small operations, with an average production of forty-nine single-family units a year. About 27 percent of the membership constructed eleven to twenty-five units, both single-family and multi-family, while another 37 percent produced less than ten units a year. Thus, over 64 percent of all NAHB members produced less than twenty-five units a year. Almost one-fourth of the members had no full-time employees; 61 percent had fewer than four salaried employees; only about one in nine had ten or more employees; and only one in twenty had more than twenty.

The larger builders do contribute a disproportionate share of total production. Thus, though only about 8 percent of NAHB members constructed over 100 units a year, they accounted for 52 percent of units produced. The .8 percent of NAHB members producing over 500 units a year accounted for 14.7 percent of all membership units constructed.

Business Failures

The volatility of the industry is reflected in its extraordinarily high rate of business failures. The number of failures in construction accounted for almost 19 percent of the total number of failures in all industries in 1967. Retail trade was the only major industry that exceeded contract construction in total number of failures. Failure among building subcontractors accounted for more than half of all construction failures. In 1967, building subcontractors, such as painters and plumbers, reported failures of 1,243 businesses out of a total number of 2,261 business failures for all construction contractors; general building contractors accounted for 867 failures; and "other" contractors, which include heavy construction work, such as highways, accounted for 151.

Employment

In 1966, there were an estimated 3,762,000 construction workers, employed in twenty separate crafts. Of course, any discussion of specific statistics on construction labor is subject to controversy. The high rate of entry and exit as well as seasonal fluctuations that characterize this industry make it extremely difficult to accurately measure the labor force. There is also a high degree of mobility in job status. An individual employee may alternate between working as a foreman and as a journeyman. A man who works as an employee may if the opportunity presents itself, become a contractor for a period and then return to the labor ranks when he completes his work.

More attention will be given to the characteristics of the construction labor force in Chapter 4 of this Part. For present purposes, however, a number of important features should be borne in mind. First, the labor force consists of skilled craftsmen. Second, the on-site nature of construction makes employment subject to substantial seasonal variation and to interruptions at almost any time due to weather conditions. Third, the nature of the industry itself—highly fragmented and organized on a project-by-project basis—makes for many uncertainties as to amount and duration of employment. As a result, hourly wage rates appear to be quite high compared to prevailing rates in many more "industrialized" industries.

PROSPECTS FOR REDUCING HOUSING COSTS WITH EXISTING TECHNOLOGY

Efforts to hold down the cost of building materials and to tie wage increases to increases in productivity are vital parts of any program to restrain rising construction costs. But, in addition, there may be new techniques, new ways of organizing and managing resources, and wholly new technologies which may produce important cost reductions. In this chapter we first consider the present state of the construction industry, examining those developments of new products and techniques which are now in use. In particular, we will consider (1) the role of *pre-fabrication* and (2) the role of *large-scale building*. Later in the chapter, we look toward the future and the prospects which advanced technology holds for reducing costs, improving quality and contributing to solving the nation's housing problems.

There is today a belief among many people that the greatest cost reductions, in the first cost of construction, can come about through in-plant technology. The particular focus here is prefabrication, a

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technique which has been used widely in the housing industry for many years. Of course, many people in the housing industry view prefabrication as that technique which applies to the finished parts of the shell of the house, not that technique which, in fact, applies as well to such items as appliances, which are also prefabricated. In the purse sense of the word, prehung doors, air conditioning units, roof trusses and mobile homes are all examples of prefabrication.

However, considering just the walls, roof and floors of dwelling units, both single-family and multi-family, the application of prefabrication in the building industry has grown phenomenally in recent years.

To date, most prefabrication in this country has been simply a matter of moving the process of conventional on-site building, as they pertain to the walls, roof and floors of the house, into a factory. Some of these factories are little more than open lumber storage areas with a few big tables for nailing together roof trusses. Others are fairly sophisticated assembly lines with a great deal of mechanical handling, nailing and stapling equipment.

Some attempts have been made to change the system completely inside the plant. Machinery has been used to foam plastic between exterior and interior skins, to create entire sandwich panel walls. A number of complete steel wall systems have been tried. For one reason or another, these more ambitious efforts have not generally taken hold.

Off-site assembly, encompassing primarily the "shell" elements of dwelling units but including some mechanical elements, has taken four basic forms:

1. *Prefabricated components.*—The off-site assembly of specialized structural and mechanical components is the most widespread form of prefabrication. Such components are shipped from the plant to the site for use in buildings which, in other respects, are constructed by conventional on-site operations. Today, virtually every new dwelling unit built in this country, both high-rise and low-rise, uses some prefabricated components.

2. *Manufactured homes.*—The off-site construction of almost all elements of the frame and shell is another form of prefabrication. Walls, floors and roofs are constructed as separate items and assembled on the site, or complete rooms and dwelling units may be constructed off-site in the form of modules. In this country, most of the important activity in this field has involved frame construction. Other materials, which have been more widely used in other countries and have been the subject of experiments here include plastic, brick and various forms of concrete.

3. *Sectionalized homes.*—These units are essentially manufactured homes for which the walls, floors and roofs have been assembled in the plant instead of being shipped as big components and assembled at the site. Each house section is usually limited to a twelve-foot width (for over-the-road hauling) and a maximum length of about sixty feet. Two sections are usually placed together on a conventional foundation (crawl-space or basement) at the site to make a finished dwelling unit. Sections are placed by crane or can be rolled, with winches and cable, from a low-bed truck right onto the finished foundation. Almost all sectionalized houses and manufactured homes in this coun-

try are built with exactly the same materials, used in the same way, as in conventional building.

4. *Mobile homes.*—One form of sectionalized home is the mobile home. Though the name implies temporariness, such homes have, in fact, become permanent residences for many and have, in recent years, become an important source of new housing starts. Because mobile homes are generally considered a separate industry, they will be dealt with after the discussion of other prefabrication products and processes.

THE NATURE OF THE HOME MANUFACTURING SECTOR

Information and official figures in this field are very difficult to obtain. An advisory committee to the Commission, established by the Home Manufacturing Industry, conducted a survey to obtain certain basic information and obtained the following results: There are approximately 600 home manufacturers, about 1300 builder-fabricators who construct homes and operate their own fabrication facilities, and about 2,100 component fabricators consisting of retail and wholesale suppliers of lumber and building materials operating their own fabrication facilities. Thus a total of about 4,200 plants producing prefabricated homes and preassembled components, are scattered all around the country. A special concentration of such plants, containing more than one-quarter of the total, is found in the states of the so-called "prefab belt"—Illinois, Indiana, Michigan, Ohio and Wisconsin. Of the 1.3 million nonfarm family homes started in 1967, an estimated 230,000 units, or 18.5 percent, were manufactured homes of one type or another (not including mobile homes).

Prefabricated Components

The most significant growth in prefabrication activities during the past decade has been shown by the component fabricators, though their activities are sometimes overlooked by construction industry critics seeking more dramatic departures from conventional methods. Among the most important examples of such components are the following:

1. *Trusses.*—Builder throughout the nation are now using shipfabricated trusses to support roofs instead of assembling rafters and ceiling joists on a piece-by-piece basis at the site. In fireproof construction, steel trusses have been used for half a century. The wood members of these trusses are now constructed with power tools and new types of fastenings, such as split-rings and metal plates. The most commonly used roof truss in single-family houses consists of an assembly of thin wood members, usually 2″ x 4″ and 2″ x 6″, which are assembled in the form of a triangle. The apex supports the ridge of the roof. The base of the triangle rests on exterior walls. There is usually a projection of the truss beyond the exterior wall, which forms an overhang around the side of the house.

2. *Plumbing "trees".*—Instead of connecting separate pipe sections to individual plumbing fittings and fixtures at the bathroom or kitchen in each house, builders are now installing shop assembled sections of plumbing systems. Standard dimensions for major plumbing sections permit their use in all houses in a builder's construction program, regardless of individual design variations.

3. *Pre-hung doors.*—Until recent times, the installation of doors followed the traditional practice of first erecting a frame around the sides and head of each doorway, to cover the exposed sections of the wall construction. The door was then installed by carpenters within the frame and adjustments were made with hand saw and plane to enable the door to open and close easily. The final step on the site was the installation within the door and frame of the hardware, consisting of hinges, door knobs and lock assembly in the door and frame. In order to reduce installation costs, builders now purchase or produce door assemblies that arrive at the site already installed within their frames. The entire assembly is then installed before the wall is finished. (Prehung and/or pre-engineered doors and their casings (doors and bucks) of steel have been in common use in high-rise construction for at least a generation.)

4. *Molded fiber glass tubs-and-enclosures.*—These one-piece, jointless and seamless units first appeared on the market about ten years ago and after hundreds of code controversies are now accepted in many parts of the country.

5. *Precast concrete wall and floor panels.*—In fireproof construction such components are popular today in many parts of the country. Thomas Edison developed the first such components for use in housing in about 1906, but they gained little market acceptance at that time.

6. *Heat-pumps.*—These compact units, combining both heating and cooling functions have been used in housing for about a decade. The heat pump extracts, or exchanges, heat from one ambient atmosphere to another (usually via a refrigeration cycle) to either heat or cool. The basic system of a heat pump was first used in commercial application about World War I with the introduction of the gas-absorption refrigerator.

Manufactured Homes

The off-site construction of entire houses is a more striking form of prefabrication. The technique of prefabricating panels and walls for homes has been used sporadically for generations. However, home manufacturing came into widespread use in the period following World War II. Home manufacturers now produce a package of precut, pre-assembled components of the shell or major structural elements. The home purchaser pays additional costs for land, site improvements, interior furnishings, fixtures, etc.

Home manufacturers produce a variety of housing types, including single-family detached houses, row houses and garden apartments. Of the home manufacturing industry's production in 1967, 70 percent went to the construction of single-family homes and 30 percent to low-rise garden apartments. Single-family dwellings generally range in size from 980 to 2,000 square feet of enclosed living space.

Frame construction is the predominant form of manufactured homes. A few firms are, however, attempting to use other materials. For example, pre-cast, load-bearing concrete panels have been used by firms in California, Arizona, New Mexico, Texas and Florida. Other firms are experimenting with fabricated brick panels, extruded asbestos cement panels and aluminum plastic sandwich panels.

Several manufacturers sell directly to the consumer, but the customary practice is for the manufacturer to sell to builder-dealers at the local market. Local builder-dealers receive supporting services from the manufacturer, including assistance in site design, land acquisition and improvement, financing through subsidiary acceptance corporations, and administration. Crews and equipment to perform on-site erection of the prefabricated home package are also provided by the manufacturer in some instances. The average franchised builder-dealer sells from ten to twenty houses per year. Only about 4 or 5 percent of this industry's annual output is sold directly to the consumer, particularly in small towns and rural areas.

Home manufacturers, builder fabricators and component fabricators are generally small-scale operators as compared with many other manufacturing concerns, but tend to be larger and have more regular employees than conventional builders.

Apart from a few firms that market and distribute their products across the nation, the home manufacturing industry is, for all practical purposes, based upon regional manufacturing-distribution systems. Most home manufacturers operate one or two plants. Their market is generally limited to a 300-mile radius of their point of production. Some producers have attempted to obtain national distribution, but they are dependent upon regional plant operations.

The Costs of Prefabricated Houses and Components

Manufactured homes vary substantially in price reflecting differences in size, style, level of amenity, etc. Manufacturers of homes generally quote prices FOB factory. Transportation and erecting fees are added on, depending on distance and house size. The total selling price to the consumer, of course, will also include land and site improvement costs and dealer's fees. As an example of the price structure, one manufacturer provided the following figures:

TABLE 1.—PRICE COMPONENTS OF MANUFACTURED HOMES PRODUCED BY A LEADING MANUFACTURER

	Size gross area (square feet)	Factory price to buyer	FOB factory price (dollars per square foot)	Maximum delivery cost[1] (dollars per square foot)	Foundations and utilities connections[2] (dollars per square foot)	Erect at site (dollars per square foot)	Total cost erected (dollars per square foot)
Model:							
A	960	$9,274	$10.13	$0.19	$1.03	$0.35	$11.70
B	1,175	9,867	8.40	.17	.95	.35	9.87
C	1,435	10,610	7.39	.13	.52	.35	8.39
D	1,633	14,526	8.89	.11	.89	.35	10.24
E	2,199	17,683	8.07	.08	.74	.35	9.24

[1] $0.60/mile, maximum economic distance is 300 miles.
[2] Estimated average.

Source: Data submitted to the Commission by the manufacturer.

Table 2 presents cost estimates for a 1,000-square foot house assuming various construction methods in Toledo, Ohio, which is a high cost area. The figures assume no code restraints. The figures for conventional construction are for a small-scale builder of about twelve houses a year.

As the table indicates, site costs, including footings, foundations and basement slabs, are identical for the three houses. Major differences arise, as expected, in construction costs. Considering shell and frame, mechanicals and appliances as a group, conventional construction costs $9,855, partial fabrication $9,367, and total fabrication $8,237. Only $530 is required for on-site work (erecting the sections and connecting the plumbing and heating systems) in the total prefabrication process. Other savings on the totally manufactured home are a result of eliminating interim financing and reducing the construction and site costs on which other charges—such as sales commissions, points, closing costs, and profits—are based. Thus, in the case of the sectionalized house, a $1,618 reduction in construction costs, combined with a major saving of time, results in a $3,333 reduction in sales price, or a saving of $3,533.

TABLE 2.—ESTIMATED DEVELOPMENT COSTS FOR COMPARABLE SINGLE-FAMILY HOUSES OF CONVENTIONAL CONSTRUCTION, PARTIAL FABRICATION, AND TOTAL FABRICATION

Cost components	Conventional construction	Partial fabrication [1]	Total fabrication (sectionalized) [2]
Land, acquisition	$2,300	$2,300	$2,300
Lot preparation and excavation	289	289	289
Sewer line to street	90	90	90
Concrete garage, porch, walks, drives, steps	560	560	560
Finish grading	50	50	50
Landscaping	75	75	75
Subtotal, preparation	1,064	1,064	1,064
Subtotal, land costs	3,364	3,364	3,364
Footings	192	192	192
	704	704	704
	360	360	360
Subtotal	1,256	1,256	1,256
Framing material or package	3,100	5,245	7,707
Field carpentry	1,560	675	260
Roofing	228	228	(3)
Siding	338	(3)	(3)
Subtotal	5,226	6,148	7,967
Floor and underlayment	530	530	(3)
Drywall	571	571	(3)
Painting	600	600	(3)
Ceramic tile around tub	108	108	(3)
Subtotal	1,809	1,809	(3)
Heating	580	580	95
Electrical work and fixtures	530	530	(3)
Plumbing (1 bath)	1,050	[3] 300	175
Subtotal	2,160	1,410	270
Kitchen cabinets	500	(3)	(3)
Appliances	160	(3)	(3)
Preliminary costs	230	230	230
Contingency	100	100	100
Supervision and overhead	250	250	250
Interim financing	800	780	(4)
Sales commission	1,000	975	850
Mortgage points	1,000	975	580
Closing costs	500	488	425
Builders profit	1,800	1,755	1,530
Subtotal	5,680	5,553	3,965
Sales price	20,155	19,540	16,822
Savings versus conventional		615	3,333
Percentage		3.1	16.5

[1] Partial fabrication differs from conventional construction in its use of preassembled wall panels.
[2] Total fabrication consists of factory production of entire housing sections.
[3] This item, or part of this item is included in "Framing material or package."
[4] Total fabrication permits preclosing. No interim financing needed.

Source: Data submitted by the manufacturer.

The Commission has also collected cost data from other industrialized housing manufacturers. They indicate that in the upper Midwest, an all-weather, single-family dwelling unit of approximately 1,000 square feet can be built and delivered to the site for approximately $4,000, about $1,000 of which represents the margin to the manufacturer for profit, overhead, and selling cost. Freight is approximately $100.00. The costs at the site for foundation, painting, finish, carpentry, site improvements, electrical and plumbing subcontracts, permits, crane rental, etc., add about $3,500. The local builder representative adds about another $4,000 to the selling price for advertising, other sales costs, closing costs, points, interest, and profit, making a total sales price of about $11,500, exclusive of land.

Cost Advantages

Reductions in costs through off-site construction techniques are attributable to a number of factors. *First,* labor costs per unit of output are reduced. In strong trade union areas, switching from traditional craft workers to industrial workers generally results in lower hourly wage rates. Further, on-site construction requires a complete trade skill and, correspondingly, a high hourly wage, especially when union labor is involved. When the bulk of the work is done in the factory, skills can be more finely divided and a lower average rate results. Where craft workers are not unionized, as is the case in many non-central city areas, the switch from craft to industrial workers may actually result in higher hourly rates. Even in this situation, however, labor costs per unit of output can be reduced, since prefabrication provides many possibilities for man-hour reduction through the use of power driven machinery, greater specialization, and repetitive operations.

Second, since a much larger proportion of the work is done under cover, less time is lost and less cost incurred because of bad weather. Delays add directly to the costs of interim financing. Uncertainties caused by the vagaries of the weather reduce the ability to make accurate judgments about the proper timing of material shipments, increase rehandling, and causes standby time. Labor productivity is reduced where workmen must perform in wet or cold weather. Moreover, the wage rates of the construction industry now reflect the likelihood of interruptions due to weather conditions. If this likelihood is eliminated by moving the work indoors, future wage rates can begin to reflect added job security.

Third, and in addition to the time saved by eliminating interruptions due to weather, the prefabrication process itself can save a great deal of time. Building a single family house by conventional methods, for example, may take from three to six months; building by prefabrication can be a matter of weeks or even days. The prefabricated house still requires a certain amount of on-site work. A foundation must be prepared; water, sewer and electrical connections must be made; and the house components must be assembled. Standardized procedures, however, simplify on-site assembly; and a small crew can easily assemble many such structures in one or two days. On-site erection fees can thus be held to a minimum.

Obstacles to the Use of Prefabrication

Despite the apparent advantages of prefabrication techniques, companies engaged in home manufacturing and off-site construction of components face a number of important problems, most of which are unrelated to any technological weaknesses. The most important are the following:

First, home manufacturers report major marketing problems. Prefabrication is seen by many as a "gimmick." Many potential buyers also believe manufactured homes are aesthetically undesirable or structurally unsound, even when this is clearly not the case. The picture of a group of standardized dwelling units comprising a monotonous community is understandably abhorrent to home buyers; and this is the picture which many Americans associate with prefabricated houses.

The unsavory image which many have of prefabricated homes has been proved erroneous where care has been taken in house and site design. Lafayette, Indiana, a city of 55,000 where the main plant and home office of one major producer is located, is a good illustration. Over the years, some 4,000 prefabricated homes have been built and erected in this city and now house approximately one-quarter of the population. The general appearance of Lafayette is superior to that of the average small American city. Its residential sections are pleasing and harmonious, and provide living proof that prefabricated housing need not mean deadening uniformity.

The working class town of Romeoville, a few miles northeast of Joliet, Illinois, also illustrates that industrialized housing can be equal to or superior in aesthetic quality to conventional housing. The houses there are virtually all prefabricated and within a fairly close price range. They are not only pleasant and convenient to live in, but afford accommodations which cannot be matched locally at the prices charged. The community as a whole makes a better appearance than most other towns in the state.

Second, problems of building codes and other necessary product approvals plague both the home manufacturers and the makers of preassembled components. In far too many jurisdictions, various preassemblies are rejected outright. In others, inspection methods effectively exclude them. If electrical connections are installed inside preassembled panels, for example, they are subject to the possible demand of building inspectors, who often represent either local craft or building interests, that they be taken out and locally installed or that a panel be removed to permit inspection at the site. Costly delays and alterations can result.

These problems are by no means unique to prefabricated products. Even where the most high-minded men and motives are involved, approval for new products and processes is a grueling affair. The only special problem posed by off-site assembly appears to be the need for inspection at the time assembly takes place rather than at the time the component is installed at the site. In some jurisdictions procedures have been established which allow inspection at the place of assembly. Approval is then evidenced by a stamp which later can be accepted by the on-site inspector. But the exclusion of preassembled components remains a serious problem in many localities.

Perhaps even more significant, though not precisely measurable, is the deterrent effect of existing code restraints on the development of new preassembled components and houses. Investors are understandably reluctant to expend large amounts on research and development when they fear that even technically successful innovations will not be allowed to reach the potential market.

Third, there is the problem of transportation costs for heavy or bulky items. Where construction takes place off-site, assemblies must be transported to the site for erection. Where the parts are heavy and the distance great, this cost can be crushing. Transportation costs have been a major obstacle to the use of prefabricated concrete construction, an otherwise promising technological advance. In frame construction, the problems are much less burdensome, but they have the effect of limiting the geographical market which a factory can economically serve. Generally speaking, home manufacturers do not find it advisable to extend their sales area beyond 300 miles from the factory. If other problems of marketability could be overcome, such a limit would not appear to be a major obstacle to a profitable scale of production. With limited marketability, it is.

One major effect of all of these obstacles is to severely limit the scale at which prefabricators must operate. The advantages and prospects of large-scale housing production—on and off-site—are considered later. Here, however, it should be noted that, in the view of many, the future success of prefabrication—with existing technology and with technologies yet to be developed—depends on a high volume of production and sales. The major advantages of industrialization require that capital costs be spread over a large number of units of output and that production be sufficiently large and constant to allow workers to operate on a production line basis.

If production and sales are low, the overhead cost per unit will be high. And it is upon this rock that so many prefabricated housing ventures have floundered. If only a few scattered sales are obtained, machinery stands idle most of the time, workers lack steady jobs and tend to leave, and unit costs are high. With building so decentralized between tens of thousands of contractors and sub-contractors, it is at present almost impossible to obtain the volume of orders necessary to reduce costs, improve quality, and encourage additional research and development.

The Industry Record

To date, the profit record of U.S. home manufacturers has not been inspiring. One of the largest companies in the industry, for example had sales of 23,000 units in 1959; last year's sales were 15,000 units, a decline of almost one-third. Earnings on sales in 1967 were only one-tenth of one percent on investment. Many other companies, usually much smaller, have experienced similar or worse profit margins, and many have gone under. Those companies which have stayed in business, including the very largest, are often able to do so only because of profits on land and home financing.

The limitations appear to be less those involved in production and technology than those concerning site location, design, local zoning or code restrictions, marketing, and sales.

The Future

Prefabricated components, such as roof trusses and plumbing trees, have been an important factor in the industry in recent years, and additional advances in the technology of such components are to be expected. Conventional builders recognize their value and are among their leading advocates. Unfortunately, local building code officials have not given them their wholehearted support and continue to block their use in far too many places.

Prefabricated or industrialized houses have been less enthusiastically received, though they have achieved important cost reductions. They continue to encounter major problems of marketability and institutional resistance. Early and, in some cases, continuing lack of attention to the importance of design—both in the structure itself and in site layout—has plagued the industry. For a variety of reasons communities and building officials often resist the introduction of such structures. In addition, marketing activities, vital to the success of the industry, have suffered either from being left in the hands of the producers, who have had little experience in the industry, or from being placed in the hands of alleged experts in home building who in reality have been no more expert than the producers.

The City of Chicago is now involved in a dramatic program to use manufactured homes for moderate-income families. During the summer of 1968, the city negotiated an agreement with a major home manufacturer to factory prefabricate homes at an expected rate of 2,000 a year, employing an estimated 165 men on a full-year basis. Certain building code provisions were waived. Union cooperation was obtained through the company's agreement that the Chicago factory would be a union shop and that erection would be supervised by union men who would also train neighborhood labor. The unions, for their part, agreed to be more flexible on jurisdictional claims and work practices. In addition, six leading building trade unions agreed initially to contribute one-third of the cost of constructing the new plant, which was estimatesd at a total of $2 million. A number of industries pledged another third, and a group of insurance companies the remainder.

The houses are to sell at a price ranging from $11,500 to $14,500, thus opening up the market to those in the $4500–$5500-a-year income bracket. Down payments are expected to range from $200 for a two-bedroom house to $400 for one with four-bedrooms. Stoves, refrigerators, furniture and even carpeting are included in the price.

Mobile Homes

One form of prefabricated dwelling unit which has achieved amazing success in recent years is the mobile home. It has emerged as a major source of housing within a single generation.

More than 4,650,000 people now live in mobile homes, 80 percent of which are located in mobile home parks. There are now over 13,500 such parks in the United States, each containing an average of sixty to seventy-five home sites. New parks are being developed at an estimated rate of more than 1,000 a year. These newer areas normally are planned for more than 100 mobile homes.

In the post-War period, about 2.5 million mobile homes have been produced. According to the Mobile Home Manufacturers Association, production in recent years has grown rapidly, with annual production in 1967 of slightly over 240,000 units, four times that of 1947.[2] Table 3 shows figures on annual production for 1962–1967.

[2] Unfortunately the Department of Commerce does not collect data on mobile home production and no official government statistics are available.

TABLE 3.—*Annual production of mobile homes in the United States, 1962–67*

Year:	*Approximate number produced (thousands)*
1962	120.5
1963	153.9
1964	195.9
1965	222.0
1966	222.7
1967	240.4

Source: Mobile Homes Manufacturers Association.

In 1967 mobile home production equalled 23 percent of all single-family, nonfarm housing starts.

The importance of mobile homes in the overall housing picture is suggested not merely by their growing numbers but also by the market they serve. While they are still bought by many people as second homes or vacation homes, they are today an important source of primary residences. The largest market for mobile homes, accounting for 43 percent of the total, is among the under-34 age group. The largest portion of this group consists of newly married couples who have limited space needs and find that the average monthly payment of $150 or less is within their budget, especially when additional payments are not needed for furniture. Another important segment of the market is for old people who do not want the cares of a conventional home and whose children have grown up and are living elsewhere. When all this can be combined with retirement in a warm or moderate climate, it can be especially attractive.

Mobile homes grew out of the earlier "trailers"—small, simple bedrooms-on-wheels which could be attached to an ordinary automobile. Trailers were truly mobile and were used primarily by vacationers on long distance drives to avoid dependence on hotels. As they grew in popularity, "camps" were developed in vacation and tourist spots for the temporary quartering of these trailers. Minimum services, such as water and sanitary facilities, were provided, but little else.

After World War II, builders of trailers began to recognize the potential of their product in helping to meet the nation's large backlog of housing needs. The "trailer" became a permanent abode; and with the change came a new name—"mobile home." Even this name is a misnomer, for it has been estimated that more than 60 percent of all mobile home owners have never moved the unit they currently occupy. The Mobile Home Manufacturers Association reports that the average stay in one location by mobile home owners is fifty-eight months, which is about the same as for owners of conventional housing. About 70 percent of the more than 2 million mobile homes produced since World War II have been used as permanent dwellings.

The mobile home of today is far different from its predecessor travel trailer. From their original 30x8 foot dimensions, new mobile homes were built in much larger sizes. Generally limited to twelve feet in width by state highway regulations, trailers have been substantially lengthened, so that in 1967, 84 percent of all units produced measured at least 12x60. Moreover, a number of manufacturers have begun producing units which can be joined with another unit, or can be otherwise expanded at the site, thus allowing sizes of up to nearly 1,500 square feet. And more imaginative use of space has resulted in increased living areas within a given size unit.

Changes have also taken place in mobile home parks. In addition to water and waste disposal facilities, the modern park provides underground electrical connections, landscaping, paved streets and sidewalks and, in some cases, recreational facilities of various kinds. Investors have found that mobile home parks can not only produce satisfactory returns from current rentals, but can also provide means of speculating in land. Since permanent above-ground facilities are minimal, land can be readily converted to more intensive development when the market permits.

While perhaps still not the vine-clad, rose-embowered cottages of which the returning World War II G.I. dreamed, mobile homes can provide decent shelter with some privacy and many or most of the amenities which people associate only with conventional houses.

The production of mobile homes is achieved entirely off-site. The construction consists of a wood wall, floor and roof members, resting on a steel frame which is supported at one end by wheels and at the other by a trailer hitch assembly that can rest on the ground. Most units are covered on the outside with aluminum. Interior walls are usually covered with natural finished wood panels.

Some of the advantages of prefabrication—lowered unit labor costs, elimination of vandalism and bad weather interruptions, etc.—are available to mobile home manufacturers. Partly for this reason, some manufacturers are able to arrive at construction costs as low as $6–$7 a square foot, where costs include complete furnishings. Some of their savings over much conventional construction, however, are attributable to the shorter life for which structures are designed. While the life of a mobile home can vary substantially depending on make and model, climate and the care taken by its occupants, some indication of its expected life is suggested by the typical financing period of seven years, as compared to twenty to thirty-five years for conventional construction. And unlike many houses, the mobile home loses almost all its resale value at the end of a relatively short period.

The cost of the average 12 x 60 foot unit is $5,700, fully furnished and equipped. Some unfurnished units can be purchased for $4,000. The larger units of more than 1,000 square feet in floor area range from $8,000 to $12,000.

The buyer of a mobile home can finance it as he would his automobile. Although a third of the purchasers pay cash, the majority of the purchases are financed with down payments ranging from 20 to 30 percent of sales price. The usual length of financing is seven years, with some taking as long as ten years. This short term, as compared with the much longer term for conventional home mortgages, and the need to pay rent on the site, means that monthly costs are not significantly cheaper than those for conventional housing. Table 4 shows a typical monthly cost breakdown for the mobile home owner, as supplied by the Mobile Home Manufacturers Association.

TABLE 4.—*Estimated monthly cost of owning and occupying the average mobile home*

Debt service (principal and interest)	$76.00
Rent (site)	$35– $40.00
Utilities	$20– $30.00
Maintenance	$5.00
Garbage collection	$2– $4.00
Taxes	$3– $4.15
Total (rounded out)	$140–$160.00

Source: Mobile Home Manufacturers Association.

In 1966, 220 firms were producing mobile homes in 354 plants throughout the country. Ten companies, reporting sales of over $20 million, are now publically held corporations. About 30 percent of total production is concentrated in the "Prefab Belt" discussed earlier. There are about 7,000 retail outlets selling mobile homes throughout the nation.

The Future

Major obstacles are still encountered by the industry in overcoming the old "trailer" image and meeting demands of building inspectors. Perhaps even more important than building codes in limiting the use of mobile homes are zoning ordinances, which either exclude such dwellings entirely or force them to locate in industrial areas.

While mobile homes in their present form will not become the standard American dwelling unit, it seems likely that the market will continue to expand and that they will grow in importance both as second homes and as primary residences. To date, this growth has been so rapid that some companies have been unable to keep up with demand. As a result, many companies have not had the time nor felt the need to invest in basic research and development to improve substantially on existing production techniques. Thus, while they have been able to achieve certain economies associated with prefabrication, their techniques remain less efficient than might be expected. The production line approach has only begun to be adopted, and many mobile home "factories" are in reality more like handicraft shops.

New uses for mobile homes and extensions of mobile home technology are only now being explored. One important aspect now being examined is the vexing problem of relocation. As noted elsewhere in this Report, temporary housing is in urgent demand during large-scale urban renewal and neighborhood rehabilitation efforts, as well as during highway construction and other public works projects. Vigorous housing code enforcement can also lead to temporary displacement of households where adequate replacement housing does not yet exist. Even where demolition or rehabilitation is accompanied by plans to relocate displaced households in the same location once new housing is built or rehabilitation is completed, long intervals are required before such a return is possible; and past experience suggests that only rarely do those forced to move come back.

Atlanta is now using mobile homes as temporary quarters for families displaced by urban renewal. Once the project is completed, the families would be able to move back into new low-income housing built on the site of their former residences. The mobile homes can then be used in connection with another project requiring temporary relocation.

Other important potentials for mobile home technology are being explored. Much of the progress in the past has been directed toward improving the use of limited space in the mobile home and finding ways of increasing its size. More recent experiments have been concerned with use of mobile homes as multi-family structures, primarily through various "stacking" techniques. Two-story row houses, for example, have been built by stacking. Another logical extension of mobile home technology, of course, is the construction of "non-mobile" sectional houses; and some mobile home manufacturers have been experimenting with such houses, which are factory built and factory assembled and then transported to the site on flat-bed trailers.

Large-Scale Production

Whether construction be by conventional on-site processes or by prefabrication, there is much evidence to suggest that a crucial determinant of costs is the scale at which building takes place. We have already noted the importance attached to a minimum volume of production by potential and actual experimenters with new construction techniques. The substitution of capital for labor, and particularly the use of large power tools and equipment, requires some minimum scale of operations. Unlike many workers in the construction trades, equipment cannot be employed for one job and then dismissed. The use of more equipment means greater fixed costs, which must be spread over a sufficiently large number of units of output in order to make for economic production.

There are many other important opportunities for cost savings which large-scale production makes possible. *First*, large-scale production permits savings on material costs through volume purchases. The large buyer can break through the outer ring of retail prices and buy directly from wholesalers or manufacturers, and can obtain quantity discounts. Such savings can amount to 15 to 25 percent of the cost of materials purchased. Moreover, large-scale builders are often in a position to buy at the most propitious moment in view of market conditions. Savings are possible on services as well as materials. Title and mortgage companies, lawyers and others are more likely to give favorable terms to the large builder, who is able to provide them with a large volume of business arising out of a particular project or projects.

Second, the large builder is in a better bargaining position vis-a-vis unions and government officials. By being in a position to offer a large volume of continuous work, he is far more able than a smaller builder to negotiate a project agreement which includes more efficient work practices. Similarly, both as a result of added knowledge and of his importance in the overall construction picture, he can often cut through the bureaucratic and political red tape which plagues the industry.

Third, the large builder can enjoy the benefits of an ongoing, integrated organization, providing its own specialized services on a salary basis rather than on a basis of fees. The costs of services of lawyers, designers, accountants, architects and engineers can therefore be significantly reduced.

Fourth, the firm producing on a larger scale can accommodate greater specialization among its employees and greater standardization of materials and work practices. Up to an optimum size, the larger the work force, the more the work can be subdivided. Men can specialize in those things which they do best, and can perform their repetetive tasks more quickly and with greater skill.

A Large-Scale Development

As the facts presented earlier show, few builders of conventional single-family housing operate at a scale exceeding even 100 units per year. Only a handful produce more than 500 units per year. The experience of the few large-scale builders indicates, however, that substantial cost reductions are being achieved. The very largest builders of conventional houses have been able to bring direct costs for the structure down to as low as $6 a square foot in some cases. Table 1 in the preceding Chapter shows structure costs of $6.24 per square foot and "construction" costs (selling price less site costs) of $10.20 for a project of one large-scale builder. Similar cost savings can be realized by builders of multi-family structures. The large-scale builder, whether of single-family or multi-family units, uses a system of mass production at the site. Great management skill is applied to scheduling and organizing work into a continuous, highly specialized construction process.

In the case of single-family homes, the building unit is not the single house but a cluster of similar houses ranging from seven to a dozen. These are substantially in the same price range but with a sufficient variety in design so that there is no monotony of appearance. Harsh rectangles are avoided in the laying out of streets. The effort throughout is to decrease the amount of traffic which goes by the houses.

The first step in actual construction is the laying of a concrete slab which serves as the foundation. Full basements are avoided, but partial ones for storage are often included. Connections are made with the water and sewer pipes which serve as units in the respective distributing and collecting functions and which can be located either in the front or rear of the homes. Wherever possible, the basic slabs contain some of the basic electrical connections.

While this is going on at the site, important changes in scheduling and distributing the needed material are taking place in the local administrative offices, and in the warehouses and assembly yards. A master list has been prepared for each house which identifies each building piece to be used, the number of units required of each, and the sequence in which they are to be used. Then a truck is loaded in the warehouse with the total number of units of Piece 1 in Sequence A. An assembly crew is set up for each house in the cluster and is assigned a station around a circular assembly line away from the site. The truck drops at each station the number of units of Piece 1 that are required by that type of house. This is followed by another truck which does a similar job for Piece 2, and so on. At the end, the assembly crew at each station has the required number of units of each piece within the required sequence. This becomes the "package" of prepared frame materials for the first house in the cluster, which is then transported to the site of the house by truck. The "packages" are deposited near each of the prepared slabs. The carpenter crew then begins the erection of the frame with baseboards, studs, ridge poles, trusses, etc. After the carpenters have finished this work with the first house, they move on to the nearby second house where they repeat the same process with similar but somewhat differing combinations of pieces. The crew of carpenters then moves house by house down the line.

In their wake comes the crew which installs the pre-cut and pre-hung doors and windows, each generally containing the needed glass. They also move in sequence behind, and press fast upon, the carpenters. Then comes a crew which puts in the side walls, generally in the form of a "hardwall" often composed of gypsum or masonite. This crew does its work and then moves on, treading fast upon the heels of the previous crew. Close behind come the painters, working with spray-guns, broad brushes with long handles, etc. The plumbers install a previously assembled plumbing or bathroom "tree." They are followed by those who lay floors of the bathroom and other rooms. Then come the electricians (although they sometimes precede the plumbers) who lay the wiring and make the connections. The heating apparatus is put in and, where air conditioning is used, those facilities are installed as well. The stove and the refrigerator are installed. If wall-to-wall carpeting is included in the final house to be delivered, that is put down.

The land in the cluster is also developed. Grass is sown and watered. Shade trees and shrubs are planted in front of each house, and fruit trees in the rear. The house owners can, of course, add to this on their own according to these tastes and income.

In the process, as the community grows, general community facilities can be started and enlarged. In this way each year's installment of families can be served while large investments in presently unneeded facilities are avoided. A shopping center including a grocery and a drug store is started first. Specialty stores can be added as the community grows. It is a good practice to have a generous mall or open-space and dignified surroundings for the shopping center, for this necessarily becomes the social center for the community. In addition the community will need elementary schools and playgrounds, including swimming pools, tennis courts and ultimately a golf course. A library can be added as the need develops, and space should be reserved for a local park. In some cases, especially in the early period, these are donated by the builders. Later, as the community gets on its feet and acquires a tax base, the facilities are sold at cost, with the developer merely charging his original purchase price for land without taking any increase in land values.

The principle behind all this is obviously that of applying the moving assembly line to the peculiar nature of building. Instead of the factory system where men are placed at stationary points along the assembly line with parts and materials flowing by them for assembly in sequence, the house is, of necessity, stationary. The various groups of specialists do their work and then move on to repeat the same process elsewhere. Men are in motion, while the materials and parts to be assembled are relatively stationary once they have been deposited on the sites.

Large-Scale Multifamily Dwellings

The advantages of large-scale are not, of course, limited to builders of single-family houses. Substantial cost savings have been effected by producers of large, multi-family projects. An important example is the work of the United Housing Foundation in building cooperative housing in New York City.[3] Rochdale Village, a project of the Foundation, is the largest completed cooperative apartment development ever built in this country.[4] Located in Queens, Rochdale Village contains 5,860 cooperative units in 20 buildings, with a total cost of $100.2 million under the New York Limited Profit Housing Law.

The excellent cost results obtained by the Foundation may be seen in Table 5, which compares the costs of Rochdale Village with costs of management cooperatives built under the FHA 213 program.

TABLE 5.—COST COMPONENTS OF SELECTED FHA 213 PROJECTS AND ROCHDALE VILLAGE

Component	FHA 213			Rochdale Village
	High	Median	Low	
Total development/unit	$41,269	$27,129	$15,073	$17,098
Structures/unit, residence, other [1]	31,391	21,031	9,604	12,678
Area/unit, square feet	2,004	1,376	1,202	1,290
Residential building cost/square feet	$16.58	$15.07	$10.71	$9.78
Site cost/unit	$4,318	$2,796	$2,375	$1,334
Construction dates	(2)	(2)	(2)	1961–65
Location	(3)	(3)	(3)	(4)

[1] These figures include the costs of constructing a powerplant and shopping and community centers to serve Rochdale Village. The powerplant includes generating equipment and provides 100 percent central air-conditioning throughout all buildings in this development. The estimated cost savings on electricity alone is $220,000 per year. Income from the shopping centers is used to offset part of the operating costs and to hold down the carrying charges for each apartment. The cost breakdown for these additional facilities is shown in the following table:

SELECTED COST ITEMS FOR ROCHDALE VILLAGE

Item	Cost per apartment	Cost per rental room	Percent
Land	$1,334	$295	7.8
Residential buildings	12,678	2,805	74.2
Powerplant	2,030	449	11.9
Shopping centers	707	156	4.1
Community center	349	77	2.0
Total	17,098	3,782	100.0

[2] Fiscal years 1962–66.
[3] New York City, Miami, San Francisco, Los Angeles.
[4] Queens, N.Y.

At $9.78 per square foot of residential construction, the project is impressive. It should be kept in mind that the buildings are all fourteen story high-rises located in a high construction cost area.

Part of the cost saving story of Rochdale Village is based on the nonprofit nature of the builder sponsor. The National Housing Foundation charged fees of less than 2 percent of total development cost, only one-tenth of the amount permissibe under the law. The fees on the FHA 213 projects represented in Table 5, on the other hand, ranged from a low of 9.8 percent to a high of 16.9 percent. In addition, it is generally recognized that the Foundation personnel directing the project are highly dedicated and competent. But, clearly there were substantial cost reductions due to the very large scale of the project. The builders, for example, attribute significant savings to quantity purchasing. Moreover, the repetitive nature of much of the work helped reduce construction costs and fees. Each of the twenty

[3] For a more complete description of the make-up and activities of the United Housing Foundation, see Part II, Chapter 4 and the Commission hearings, Vol. IV.
[4] Co-op City, which is now under construction in the Bronx, also built by the Foundation and costing an estimated $293 million, will be the largest cooperative when completed.

buildings is identical. While this may be questioned by some on aesthetic grounds, it does permit costs to be reduced in a large-scale project. Furthermore, the tri-core building design is a relatively low-cost form of high-rise construction.

The large-scale of the project, combined with the civic importance of the Foundation, also enabled savings to be realized in labor and other costs. With its close union ties,[5] the Foundation was able to negotiate a project agreement which included efficient work practices with the craft unions involved in construction. Time and money were saved when the requirement of a performance bond was waived; and government red tape was slashed throughout the construction process

The Future

Diverse code standards and finance practices within a market area, problems of land assembly, resistance to large-scale developments by local communities, and the uncertainties of the market continue to be serious impediments to undertaking large-scale, long-term projects. Nevertheless, it seems highly probable that the scale at which building takes place will grow. As the nation begins to appreciate the dimensions of the task before it in fulfilling national housing goals, an atmosphere far more conducive to undertaking large-scale projects than the present one should develop among present builders and companies not now willing to enter the market. Improvement in codes and assistance and encouragement for large-scale developments will be important. Equally or more important, however, are the creation of a stable mortgage market and the adoption of public policies to allow long-term planning and commitments for housing programs.

POTENTIAL COST REDUCTIONS THROUGH ADVANCED TECHNOLOGY

Thus far in this chapter we have been discussing the cost savings attributable to various existing construction products and processes. There are many who believe that more ambitious departures from present patterns and major technological breakthroughs are the wave of the not-very-distant future. Engineering and architectural journals are filled with new ideas for revolutionizing the construction process and for applying advanced systems approaches to the problems of meeting the nation's housing needs.

A vision of the future is necessarily speculative, and many judgments about the potential savings and advantages of the construction technology of tomorrow remain acts of faith. Talk of major technological breakthroughs is not new; it has been part of the just-around-the-corner school for forty years. This is not to say that progress has not been made in construction technology. The growing use of prefabricated components continues to be significant. While much has been done to industrialize both the product and the process, the revolutionary transformation of construction has, in fact, not occurred.

The Problems

The cost of research and development, tooling, production, and marketing is so great that it is difficult to expect companies to under-

[5] See Part II, Chapter 4.

take major programs of innovation purely on a basis of speculation. This is particularly true in an industry where each project has been regarded as a custom situation. For example, the peculiar nature of the competitive bidding process in this industry has made it difficult, if not impossible, to use innovations effectively. New ideas have had to be available from at least two other manufacturers before they could legitimately be incorporated into design. This procedure makes it very difficult to bring a major innovation to the market.

Another major obstacle to the introduction of new products has been the relatively small size of traditional individual building programs. The learning process makes for increased costs. Unless one has substantial markets for the amortization of these learning costs, initial projects tend to cost more than the eventual use of a system would require. However, it is difficult to find the people willing to pay more for a given project on the basis that future projects will be cheaper. Industry is reluctant to pay these costs, because there is no assurance that future designs will use the products which have been developed. Because of these and other constraints on volume production, it is important to develop a systematic approach which provides for research, development, tooling, production, and construction of buildings in an organized way. An effective method must be provided for the delivery of the new technology. The technology lag in construction is due primarily to the lack of significant markets and mechanisms for proper introduction of the work. This has resulted in the financial failures of many new approaches, which in turn has reduced the interest of companies in making further investments.

Problems of codes and restrictive building practices also contribute to the difficulties. Potential innovators are understandably reluctant to undertake major research when they fear that technically successful results will be unmarketable or of only limited marketability because of such institutional factors.

In some areas codes are being upgraded. Developments towards performance specifications, as opposed to material specifications, are becoming more evident. The four basic national codes are extending their areas of influence and it is hoped that in this respect, the Commission's recommendations for more objective standards and greater uniformity will provide the means for mass production methods to function. The basic codes do permit opportunities to deviate from specific material requirements if appropriate testing can be done, although localities have inordinate power to veto nationally accepted changes. The creation of markets which permit large-scale development programs on a feasible financial basis should afford the opportunity to finance these testing programs. The Model Cities program, for example, should provide an opportunity to rationalize code requirements within a variety of cities as a prerequisite for Federal funding and support for specific Housing projects.

Organized labor has cooperated effectively with a number of building systems programs, and it appears that such cooperation can be continued and expanded in the future. There are two essential requirements for this cooperation: (1) that participation begin at the time that a program's objectives are understood, and (2) that the level of construction volume continue to increase, resulting in greater labor stability.

Foreign Experience With Industrialized Building Systems

Many experts in this country cite various European building operations as evidence of the success of industrialized techniques. Problems arise in attempting to compare European and American costs and quality and in attempting to assess the transferability of foreign processes and procedures into the American institutional setting. Nevertheless, it is clear that much useful information can be gained from foreign experiences, and that such information can be important in attempting to develop cost-reducing construction techniques in this country.

Certain generalizations about European activity in "industrialized" building should help to place the subject in perspective:

First, it is clear that European experience with various prefabrication processes has been far more extensive and varied than our own. Approximately forty effective industrial building systems are operating in Europe. Denmark alone, with a population of 4,750,000, presently builds 40,000 low-cost flats per year using industrialized techniques. In the United States, the equivalent production would be 1,600,000 units per year.

At the close of World War II, Europe's housing needs were even greater than our own. The pre-War depression and the war itself drastically curtailed production of housing. Moreover, many homes were destroyed in the war. The "industrialization" of building, which took place after the war, reflects not only this great need for new housing but also a recognition by the governments of the various nations of their major responsibility for closing the gap. Their massive intervention in the construction process—whether through direct public construction, as in Eastern Europe, or through large and continuing subsidies for privately-built housing—opened the way for basic research and large-scale experiments with new building techniques.

Second, major efforts have been made in Europe to develop prefabrication techniques for multi-family dwellings, and concrete has been used extensively as a basic building material. Concrete construction generally takes one of two forms: (a) panel construction, in which load-bearing concrete walls are used along with pre-cast or poured concrete floors and (b) modular construction, using pre-cast concrete boxes.

Third, in the effort to catch up on the backlog of housing needs, many European countries have given little or no weight to aesthetic considerations and to amenities. Repetitive and simple designs have allowed rapid and efficient production, but the product has often been drab and uninviting. More recently, efforts have been made to introduce variations in shape, color, and texture. In panel construction, for example, a variety of shapes and sizes can be produced by modifying the ways in which the panels are ultimately assembled on the site, without changing the factory process itself.

Fourth, as in the United States, institutional obstacles in Western Europe have been significant in slowing down the introduction of industrialized techniques. Union practices and building codes have been especially troublesome in a number of countries.

Fifth, while progress has been made toward producing lighter forms of concrete and other materials, transportation limits remain significant. On-site factories have been employed successfully in a number of countries.

European industrialized techniques have developed in a variety of ways—organizationally, for example. There are client-specific and manufacturer-controlled component systems, capital-intensive designed for both factory and site fabrication. Three examples are noted below.

The *Colgnet* system is a French industrialized building system fabricated in highly sophisticated factories which utilize expensive precision casting machinery and techniques. The system consists of high-precision pre-cast concrete floor, wall and exterior panels.

SECTRA is a French industrialized building system involving a sophisticated on-site construction process, as well as the use of prefabricated components. Demountable site formwork units with integral hot-water curing and aligning mechanisms are used for floor slabs and exterior walls, while interior partitions, staircases, ductwork and plumbing are prefabricated.

The *5M* low-rise housing system is a derivative of the *CLASP* schools system, which utilizes factory-made components, developed as a package and site-assembled. The system includes steel columns and joists, wood infill panels, and a variety of claddings.

Evaluating the cost savings of these experience is extremely difficult. Even where relatively comparable systems exist for collecting data and assigning costs, enormous problems are encountered in evaluating levels of amenity and durability. What evidence we have suggests that certain European systems, when operating at sufficient scale, have realized significant cost reductions as compared with non-industrialized construction in a particular country. Whether these systems would have produced such results in this country, given differences in on-site labor productivity, for example, is not clear.

Conclusions

There can be little doubt that prefabrication techniques and large-scale production (on- and off-site) have produced cost savings in the past and should continue to do so in the future. Such savings are not merely theoretical; they have been proved. At the same time, no dramatic, industrial "break-through" has occurred in this country.

The production of new products for the construction industry, experimentation with new materials and new production techniques, and exploration of advanced systems approaches to building, should be encouraged. Every effort must be made to eliminate roadblocks consistent with protecting health and safety. In the short run the greatest savings will be realized through increased scale and the use of existing prefabrication techniques at large-scale. In the long run, wholly new systematized approaches may be forthcoming.

In view of the fragmented nature of the present building industry and the institutional restraints on innovation, it is important that the government and public-spirited private organizations take action to encourage and promote research and experimentation. In the past such action has largely been lacking.

There is some evidence that a growing recognition of the nation's staggering housing needs is producing a new attitude. Section 108 of the Housing and Urban Development Act of 1968, the Proxmire Amendment, first proposed by the Chairman of this Commission in testimony on the Act, directs the Secretary of HUD to undertake a program aimed at encouraging and testing new technologies in housing construction. The program provides for the Secretary to approve up to five plans, submitted by private or public bodies, which use new housing technologies and are appropriately designed. Recognizing the importance of experiments conducted at a scale sufficiently large to promote interest and to enable a fair evaluation of cost savings, the Act provides that each plan be tested by the production of at least 1,000 units a year for five years. These tests are to be conducted on Federal land, or other land on which local building regulations will not hinder the use of new technologies. The Secretary is to report to the Congress the results of such experiments at the earliest practicable date.

The Proxmire program is responsible the long-standing claims of potential innovators that they must have a guaranteed market of 1,000 units a year to test their systems properly. It represents not only a program for testing five systems, but a clear expression of Congress's concern with construction technology. Unfortunately, HUD was not favorable to this provision of the bill, and its enthusiasm for the Act is less than complete.

The Act *directs*, not merely authorizes, the Secretary to carry out this program. The Commission urges the Secretary to act with all due speed on this. It also urges private companies to submit plans and take vigorous roles in the competition. Here at last is the opportunity that so many organizations have sought, and their actions can now reflect their past statements of concern and ability.

Other encouraging signs have also appeared in recent months. HUD's "In-Cities" program is an attempt to employ new building techniques in some twenty cities participating in the Model Cities program. The Department of Defense has also exhibited an interest in experiments with new technologies in the military family housing program. Public officials, at all levels of government, have made statements expressing their interest and concern in the technological advancement of the building industry. This new atmosphere should help to encourage renewed efforts to explore and test the potential contribution of technological innovation to solving the nation's housing crisis.

[Appendix follows]

APPENDIX

Selected Data of European Experience With Industrialized Building Systems

Much has been said about the benefits of industrialized building in Europe, but few figures are available to judge actual performance. Differences in general price levels, accounting systems, and data collection and compilation make international comparisons extremely difficult.

The National Building Agency provided the Commission with a detailed report of its experience with industrialized housing and furnished additional material requested by the Commission. The material gathered by NBA was based on data assembled by government agencies concerning publicly-owned or sponsored housing.

The NBA provided the Commission with a detailed report of housing innovations in the United Kingdom, describing advances in technology and government programs. It reported that 40 percent of construction in the public sector used industrialized construction techniques as compared with 20 percent in 1964. The cost benefits of such construction techniques were found to be concentrated in housing of more than four stories.

Tables 1 and 2, provided by the NBA, give cost comparisons between industrialized building systems and traditional building practices. Table 4 is a comparison between the costs of conventional and industrial types of building in Great Britain between 1964 and in the first half of 1967. It should be noted that there are large fluctuations in the percentage of savings from time to time. Savings reached their peak when the use of industrialized building systems produced an average cost per square foot which was 9.5 percent cheaper than the construction costs of building projects using traditional techniques.

Table 2 compares the cost data of four projects in the Manchester area, two of which were built traditional methods and the other two by industrialized techniques. Scheme A, a project of 210 apartments using traditional methods, was built at an average cost per square foot of 121 shillings, 10 pence, excluding land, for an average dwelling of 499 square feet. This is $14 to $15 a square foot. A project built in the same year containing 428 apartments and using the Jespersen system, which originated in Scandinavia, produced a dwelling unit of 550 square feet at a cost of 91 shillings and 8 pence or about $11 or about twenty-five percent.

A project containing 53 houses of two stories each, shown as traditional Scheme C, was constructed at a cost of $66 shillings and 8 pence per square foot. But another development of comparable size and characteristics, using industrialized building systems, was constructed at a cost of 61 shillings, 11 pence or a reduction of seven percent.

One of the most significant cost benefits attributed to the industrialized building systems was the reduction in construction time. The NBA made a comparison of the savings in financing for land and construction loans and found that a reduction in interest costs of 36 percent, which would mean a savings of 2.08 percent could be produced in the construction of a 50 unit project by reducing construction time 6 months, as shown in the following detailed example contained in the NBA's report:

Example:

Scheme of 50 units of accommodation.
Land purchase 600 per unit.
Construction, fees, legal and other costs, 3,400 per unit.
Interest rates: land 7⅞ percent; building 7⅝ percent.

(a) Calculation of capitalized interest for average scheme:

Land purchase 30,000 at 7⅞ per annum for 21 months equals	4, 134
Building work—half remainder 85,000 at 7⅝ per annum for 15 months equals	8, 101
	12, 235

(b) Calculation of capitalized interest if construction time reduced by 6 months:

Land purchase 30,000 at 7⅞ per annum for 15 months equals	2, 953
Building work half remainder 85,000 per annum at 7⅝ percent for 9 months equals	4, 861
	7, 814

Saving in interest	4, 421
Scheme cost as (a)	200, 000
Interest	12, 235
Total	212, 235

Therefore saving represents

$$\frac{4{,}421}{212{,}235}=2.08 \text{ percent.}$$

The foregoing example assumes:

(i) that the pre-contract work takes the same length of time in (a) and (b).

(ii) that the construction time for 50 units can be reduced by six months.

(iii) that the overall building and fees costs are equal.

(iv) that there is a demand for the dwellings by the earlier date.

(v) that it is physically possible to arrange the letting of tenancies immediately upon handover by the building contractor.

The following is an extract from the NBA material which indicates that additional cost benefits may be obtained through early occupancy of projects resulting from faster construction time with industrialized building systems:

EXAMPLE OF SAVINGS FROM EARLY OCCUPANCY

Rent income through early occupancy

A recent example in which potential savings were possible, concerned an NBA development project for Harlow New Town. Whilst the tender period of 340 single and two story dwellings was stipulated as 24 months the second lowest tenderer offer a 22 month contract. Subject to the dwellings handed over during the shorter contract period being occupied at a rent of £4 a week the client could obtain an increased rent income of about 10,000 when compared with the stipulated contract period. The potential saving in interest charges on payments for work carried out but not completed could amount to between £500–£750 depending on actual rate of handover achieved. These sums represent about 1.0 percent and .05 percent respectively of the contract value. The difference between the lowest and the next tender was in fact greater than the potential savings offered and for this reason the lowest tender was accepted.

In this case the potential time saving between tenderers for system building was about 8 percent. When compared with traditional building, savings of up to 50 percent of a contract period are possible.

Another NBA project designed with speed of erection particularly in mind has a contract period of 18 months for 400 two-story houses. The first handovers are due to take place after four months with a planned rate of handover of 10 houses a week thereafter. It is estimated that to have built this project by traditional means would take 3½ years with a rate of handover of 2½–3 houses a week.

The surveys conducted by Mr. Rothenstein* for the Commission found that industrialized building systems produced higher cost savings in countries on the European continent than in the United Kingdom. Two building systems companies, Jespersen and Sectra, operating both on the Continent and in the United Kingdom, reported savings that were two to three times greater on the Continent than in the United Kingdom. Table 3, page 54, gives the average number of man hours for construction of 1000 square feet of dwelling and indicates that more man hours are required to produce housing in England than in the continent or in the U.S.

On the basis of a comparison of industrialized building operations in Italy, the United Kingdom, Denmark, France, Germany and Sweden with conventional construction methods, as reported by building contractors, a direct building cost savings of up to 12.5 percent in England and 16 percent on the European continent were claimed. These companies reported that construction time had been reduced in countries on the European continent by 20 to 35 percent for projects between 200 and 500 units. The United Kingdom has reported that construction time was reduced by 17 to 50 percent in projects containing 200 to 2000 units.

The difference in savings between the United Kingdom and countries on the continent was attributed to the relatively short experience with new systems building and lower labor productivity in the United Kingdom. In some instances, only 20 percent of the total contract is built with industrialized construction techniques whereas some systems on the continent reported that 80 percent of the total work on a given project used industrialized techniques.

In order to determine cost benefits of using European industrialized building systems in the U.S., Mr. Rothenstein supplied cost studies on two specific projects. One study compared the cost of a "system-built" structure with one using conventional construction techniques for garden apartments in Rochester, New York. Another study compared costs for a 16 story apartment house in New Haven. Both studies were prepared by the Balency-MBM Associated Construction Company of Milan, Italy.

As shown in Table 4, it was found that an industrialized building system for a low-rise apartment house in Rochester could produce a cost savings of 19 percent for the building shell and a 7 percent savings in total direct project construction costs. Table 5 indicates even higher savings in construction costs by using the industrialized building system in a high-rise apartment structure. It was estimated that the

*"Investigation of Potential Savings in Total Building Cost of Multi-Family Housing Built by Industrialized Building Systems."

cost of the building shell could be reduced by 38 percent with the industrialized building system and the total direct cost of construction of the building could be reduced by 16 percent.

As shown earlier in Table 3, industrialized building systems on the European continent require an average of 762 manhours per 1000 square foot of multi-family dwelling. The total average time required for the same amount of housing in the U.S., as reported by the Department of Labor and the New York City Housing Authority, is an average of 1314 manhours. The total number of manhours required for industrialized building systems used in the United Kingdom are higher than those in Europe and conventional systems in the U.S. The average of 2062 manhours required for comparable multi-family dwellings probably accounts for the lower cost savings reported from the United Kingdom.

The total construction time for projects built with industrialized building systems on the continent is below the average for projects of comparable size in the U.S. As shown in Table 6, it takes an average of 17 months to construct 1000 units on the continent as compared to 22 months in the U.S., a savings of 23 percent. The experience of European building systems indicates an average construction time for projects with 2000 units would take 25 months, as compared to 31 months required to construct the same number of units in the U.S. Here again, reports from the United Kingdom indicated longer construction time for projects built in the United Kingdom.

The conclusions from an investigation of the cost of housing built in the U.S. by conventional methods and a comparison of the major cost factors in the U.S. with European industrialized system building are given below. The summation indicates a potential savings ranging between twenty-three and twenty-seven percent if building systems were constructed in the U.S.

The results can be summarized in the following tabulation of potential savings through industrialized system building:

		Percent
(1) Net labor savings for all trades		11.0
Material savings in shell		5.0
Shortening of construction time: Potential of 6 months at ¾ percent per month		4.5
Architect-engineer cost		1.0
Overhead, profit, contingency, capital turnover		1.5
Total		23.0
(2) Using the findings of analyzing a fully enclosed and partitioned shell table II–3 indicates net labor savings of		7.0
Material savings in shell		5.0
Mechanical and electric work:		
Plumbing	4.8	
Heating/Ventilating	2.0	
Electric	2.3	
	9.1	
Deduction for industrial expenses (tooling and royalties)	1.1	
		8.0
Shortening of construction time. Potential of 6 months at 34% per month		4.5
Architect-engineer cost		1.0
Overhead, profit- contingency, capital turnover		1.5
Total		27.0

NOTE.—The average potential savings is 25 percent.

Source: Rothenstein, ibid.

Additional details and comparisons from the Rothenstein study are given in Tables 7 and 8.

The most dramatic example of the use of industrialized techniques in building is found in the Soviet Union. With institutional impediments at a minimum and an incredibly large backlog of housing needs at the end of the war, the opportunity and desire for mass production techniques in the Soviet Union has been unparalleled. In the period 1959–65, 15,000,000 units of new housing were produced. One plant in Moscow produced 30,000 units per year.

Dr. A. H. Bates of the National Bureau of Standards gave the Commission the benefit of his extensive knowledge of Soviet construction. Taking a basic four-room apartment with a total of 560 square feet and using from 14 to 16 pre-cast panels to an apartment, he estimates that a crew of 12½ will erect in Russia two apartments a day. Giving skill and wage differentials ranging from $1 for the laborers to $6 for the crew chief he arrives at an average American wage of $4 an hour, or $32 a day and $400 for a crew day. This would bring the costs of erection at Russian efficiency to $200 per apartment, or a little more than 40 cents a square foot. The finishing crew of 11¼, it is estimated, can do one apartment a day at a total cost of $400. Capital cost at the factories producing the panels was fixed at $190 per apartment and factory labor cost at $540. This was contingent, however, upon the factory operating at a rate of 10,000 apartments and 750,000 panels a year. Adding material costs both on the site and in the factory at $1430, $630 for miscellaneous items and overhead, plus $150 for transportation and delivery costs would entail a total cost of $3560, or $6.40 a square foot. The wage for common labor was based at only about $1.35 an hour which is much below that what the American scale is and should be. Probably some of the other differentials could be reduced in the United States. Dr. Bates believes, moreover, that still further reductions in cost are in process and will be released.

It should be noted again that most cost comparisons fail to take into account even very basic differences in quality. It is clear, for example, that the Soviet construction program has aimed for a simple but safe housing unit, with no frills. Quality in design and amenties have yielded to cost considerations. By middle class American standards, much of this housing would be totally unacceptable. Nevertheless, cost figures help to provide some idea about the impact of industrialization techniques and to suggest the significance of particular cost-reducing techniques.

TABLE 1.—COMPARISON OF INDUSTRIALISED AND TRADITIONAL BUILDING—FLATS IN 5 OR MORE STOREYS

Annual returns	Industrialised (Average per square foot) s.	d.	Traditional (Average cost per square foot) s.	d.	Percentage industrialised building cheaper than traditional
1964	94	4	96	8½	2.5
1965	99	3½	104	4½	4.9
1966	106	½	109	11½	3.6
Quarterly returns:					
1966:					
1st quarter	98	6	108	10	9.5
2d quarter	105	2½	110	9	5.0
3d quarter	107	7	109	6½	1.8
4th quarter	107	11	111	1	3.6
Average	106	½	109	11½	
1967:					
1st quarter	99	11	105	8	5.4
2d quarter	107	2	110	2½	2.8

Source: Table 20, "Housing Statistics, Great Britian."

TABLE 2.—EXAMPLES OF COST SAVINGS WHEN USING INDUSTRIALISED BUILDING (COMPARISON OF 4 SCHEMES IN THE MANCHESTER AREA)

	Traditional scheme A	I.B. (Jesperson system) scheme B
Contract sum	£637,968	£1,759,084.
Tender date	January 1967	May 1967.
Contractor	Direct Labour Group Manchesfer Corp.	John Laing.
Number of dwellings	210 flats in 9-storey blocks	428 flats and maisonettes in blocks of 3, 4, and 6 storeys.
Average dwelling size	499 square feet	789 square feet.
Average occupancy	2.04 persons per dwelling	4.12 persons per dwelling.

	Scheme A s.	d.	Overall scheme s.	d.	1 bedroom, 2-person flats only, 550 square feet s.	d.
Average cost per square foot:						
Superstructure	109	5	87	8	82	8
Substructure	9	8	6	8	4	4
Siteworks	2	9	4	11	4	8
Total	121	10	99	3	91	8

	Traditional scheme C	I.B. (Simms CDA) scheme D
Contract sum	£162,241	£161,568.
Tender date	October 1966	November 1966.
Contractor	Partington	Simms Son & Cooke (West Pennine Group).
Number of dwellings	53 houses	54 houses.
Number of storeys	2	2.
Average dwelling size	899	920.
Average occupancy	4.3	4.5.

	Scheme C s.	d.	Scheme D s.	d.
Average cost per foot:				
Superstructure	51	3	46	4
Substructure	5	4	5	2
Siteworks	10	1	10	5
Total	66	8	61	11

TABLE 3.—APPROXIMATE MAN-HOURS PER THOUSAND SQUARE FEET OF MULTIFAMILY DWELLING

	U.S. conventional			Western Europe industrialized: England			Western Europe industrialized: Continent		
	Low	High	Average	Low	High	Average	Low	High	Average
Onsite	850	1,480	1,165	[1] 1,525	[1] 1,850	[1] 1,687	[1] 325	[1] 600	[1] 462
Offsite	128	170	149	375	375	375	200	400	300
Total	978	1,650	1,314	1,900	2,225	2,062	525	1,000	762

[1] Includes transportation of offsite produced assemblies to site.

Note: Average man-hours for industrialized building on European continent are 170 percent below English average and 72 percent below U.S. average for conventional construction.

Source: Commission Research Report by Guy Rothenstein.

Sources systems, United States: New York City Housing Authority, U.S. Department of Labor; England: Bison, Easiform Jespersen, Sectra; Continent: Balency, Jespersen, Larsen & Nielsen, Omnium.

TABLE 4.—"LOW RISE" ROCHESTER APARTMENTS—2 STORIES, 840 SQ. FT./D.

	Cost per square foot of building: Labor cost, shell	Material cost, shell	Total cost, shell	Total direct cost building
Conventionally built	[1] $2.55	[2] $2.35	[3] $4.90	$14.00
Industrially built	[2,4] 2.29	1.71	4.00	13.10
Difference	.26	.64	.90	.90
Savings (percent)	10	27	19	[5] 7

[1] Man hours per square foot of shell are: 0.33.
[2] Includes labor cost for mixing concrete.
[3] At the average labor rates, the number of man hours (factory and site) per square foot of shell are: 0.37.
[4] Cost breakdown per square foot as per appendix "2" is as follows:

	Square foot	Percent
Engineering	$0.05	2
Factory work	1.00	44
Site work	1.24	54
Total	2.29	100

[5] Labor 2 percent; materials 5 percent.

Note: Comparison of conventional precast and prestressed concrete construction, with drywall partitions and, industrialized construction with precast walls and partitions and site-cast slabs. Labor cost average: Factory, $3.80 per hour, site $7.80 per hour.

Source: Commission Research Report by Guy Rothenstein.

TABLE 5.—"HIGH RISE" NEW HAVEN APARTMENTS—16 STORIES, 915 SQ. FT./d

	Cost per square foot of building: Labor cost, shell	Material cost, shell	Total cost, shell	Total direct cost, building
Conventionally built (average 2 New York projects)	[1] $3.67	[2] $2.40	$6.07	$14.07
Industrially built	[3] 2.02	1.76	3.78	11.78
Difference	1.65	.64	2.29	2.29
Saving (percent)	45	27	38	[4] 16

[1] As the cost breakdown for the conventionally built New Haven shell was not available, average figures of projects of similar New York construction were used. Man hours per sq. ft. of shell are: 0.51.
[2] Includes labor cost for mixing concrete.
[3] Using the ratio of factory to site labor and the above average labor rates, the number of man hours per sq. ft. of shell is 0.34 M/H.
[4] Labor 11 percent, materials 5 percent.

Note: Comparison of conventional concrete frame construction using masonry and drywall partitions and industrialized construction using precast walls and partitions and site cast slabs. Labor Cost Average: Factory $3.75 per hour, site $7.15 per hour.

TABLE 6.—CONSTRUCTION TIME FOR PROJECTS OF VARIOUS SIZES (IN MONTHS)

	U.S. conventional			Western Europe industrialized					
				England			Continent		
Number of units	500	1,000	2,000	500	1,000	2,000	500	1,000	2,000
Low	8	18	20	16	20	24	8	11	12
High	18	24	36	24	30	36	16	24	36
Average	15	22	31	25	27	32	13	17	25

NOTES

England's average is in every instance above U.S. average.
Continent's average for 500 units is 13 percent below U.S. average.
Continent's average for 1,000 units is 23 percent below U.S. average.
Continent's average for 2,000 units is 19 percent below U.S. average.

Sources systems, United States: New York City Housing Authority, HUD, FHA; England: Bison, Easiform, Jespersen, Sectra; Continent: Balency, Jespersen, Larsen & Nielsen, Omnium, Sectra, Skarne.

TABLE 7.—RANGE OF COST PER SQUARE FOOT OF MULTIFAMILY HOUSING[1]

	QE-1 (Europe)		
	Housing built by industrialized systems	Housing of comparable rating built conventionally	QU-1 (United States)—Housing built conventionally
Walkup apartments	$5.20 to $9.90	$6.30 to $11.50	$7.90 to $9.32.
Elevator apartments	$5.00 to $9.90	$6.60 to $11.50	$11.77 to $19.21.

[1] Based on exchange rate of May 1968 for projects in United Kingdom, Denmark, Sweden, France, Italy, and the FHA, New York City Housing Authority, New York City Housing and Redevelopment Board, and New York State Division of Housing in the United States.

TABLE 8.—RANGE OF AVERAGE NUMBER OF MAN-HOURS FOR CONSTRUCTION OF 1,000 SQUARE FEET OF DWELLING

	QE-2 (Europe)		
	Housing built by industrialized systems	Housing of comparable rating built conventionally	QU-2 (United States)—Housing built conventionally
Walkup apartments:			
Offsite	200 to 450		
Onsite	350 to 2,100[1]	1,750 to 2,600[1]	
Elevator apartments:			
Offsite	200 to 350		
Onsite	300 to 1,850[1]	1,750 to 2,900[1]	850 to 1,486.

[1] High figures are reported from Great Britain.

* * * * * * *

Use of Industrialized Housing

Savings in housing costs can be made by moving to more efficient methods of production.

An important way of saving time (and thus money) is to use the PERT or Critical Path Method. In essence this is a system of working backward on a time scale from the completion date, so that all activities which must be performed fall in place in the proper order and with the minimum of lost time. By charting out all operations, it becomes possible to track out items that are off schedule and put on pressure soon enough to avoid delay to the whole project.

In addition, even the smallest conventional builder uses many products and processes that are factory-produced. This is now done in varying degrees and with varying results.

The production of panels or larger parts in the factory and their assembly on the site can provide a degree of additional efficiency, depending upon the amount of fabrication done in the plant.

Beyond that, factory production methods are used on the site itself. This is essentially what a large-scale, mass builder does.

The production of entire housing units within a factory takes at least two forms. One of these, in the case of mobile homes, uses more or less conventional methods of construction but performs them in the factory. Some savings come about as a result of the specialization of workers. Carpenters, for example, move from one mobile home to another, much as carpenters at the construction site of the largest merchant builders move from one house to the next and repeatedly perform the same operation. The savings result largely from specialized production performed the year-round. These savings may be offset by transportation costs, however. Savings may be as great at the site itself.

A further refinement is the use of machines and the substitution of capital for labor in the actual production of the parts, whether they be panels assembled later at the site or parts assembled in the factory, but produced by machines, not by men.

One finds various combinations of these methods of industrialized production.

The following is a list of the advantages which can result from some or all of these methods of larger scale or mechanized production:

Reduction in hours of labor needed. One factory-mechanized production company estimates that it can produce units in a factory with half the hours of labor as are needed on the site.

Substitution of industrial for craft labor. In metropolitan areas where housing is to be erected in the central city, savings should result from the substitution of industrial labor in the factory for craft labor at the site. The differences in hourly costs range from industrial labor at $2.90 to $3.00 per hour to craft labor at a minimum of $5.00, but often at $6.00 or $7.00 and sometimes as high as $10.00. Industrialization should require fewer hours at lower hourly rates. The capital and overhead costs of moving labor inside a plant would reduce the amount of these hourly differentials. The savings come from the greater specialization in the use of labor.

Work independent of weather. Work inside the factory would be independent of the weather and not interrupted by snow, rain, or extreme cold.

Quantity purchases. Large-scale factory production means savings on material costs, both through discounts for quantity purchases and through direct purchase from producers and the elimination of middlemen. These savings could also be made by large-scale conventional builders.

Savings in interim financing. Because of the savings in time, there is a reduction in the cost of interim financing. The time savings can range anywhere from three to six months, depending upon the type and volume of construction. Present carrying charges range from 4 to 5 percent, and some of these could be reduced.

Lower builder and professional fees. A reduction in other elements of construction costs will normally result in lower charges for fees, which are tied to construction costs. In addition, the creation of a high volume, stable level of production will eliminate some of the risks and uncertainties reflected in the present level of fees and profits. The use of industrialized building techniques, and particularly production at a large scale, will allow for spreading these costs over a large number of units and for the more efficient use of professional services.

Savings on vandalism. A major cost of conventional site construction is vandalism during the period of building. This is greatly reduced under factory construction methods.

Absence of extras. Industrialized housing does not permit the numerous last-minute changes which bring increased costs.

No delay because of lack of materials. With factory production, delays at the site caused by the lack of some specific item or material, are eliminated.

Reduction in some maintenance costs. Because of the nature of the materials, there may be some reduction in maintenance costs as a result of factory production.

Conclusions. Not all of the potential savings listed here flow from factory production. They result from large-scale and more efficient production brought about through a variety of methods. But their application over a wide scale can bring savings.

Large-Scale Production

In the past, industrialized housing production has lacked a mass market because of code, zoning, and marketing limitations, or other restrictions. It is important that the Proxmire amendment in the 1968 Housing Act, calling for the production of 1,000 units a year for five years of five different well-designed housing prototype, be carried out. This should demonstrate whether costs can be reduced, and by how much. The successful housing units could be used in the large-scale public programs authorized in the Act to provide 500,000 housing units a year for low- and moderate-income families.

Improvement of Work Practices

The Commission has suggested a number of important approaches to the problems of uncertain labor conditions which result in restrictive work practices and high hourly wage rates. We have recommended government efforts to reduce seasonability in employment by awarding contracts and scheduling construction work during lull periods. Our recommendation to allow HUD to enter long-term contracts with qualified local housing agencies should help to assure more continuous work for local labor. More broadly, our recommendation concerning the volume of housing needed over the next decade, the various means for achieving that volume, and the reduction of major cyclical variations in construction through national fiscal and monetary policies, all point toward a more assured position for construction labor. Reducing uncertainties will help to assure that increases in wage rates are geared to increases in productivity and will eliminate the resistance of labor to new forms of construction which may appear to threaten jobs in the short run.

Financing Costs

The cost of financing—permanent and interim financing and closing costs—is one of the major elements of the price of housing. Moreover, the availability and cost of money have broad effects on the stability and level of activity in the building industry, and therefore, on the costs of labor, entrepreneurial services and other cost elements and on the attractiveness of investment in new materials and processes which might result in reduced costs. The Commission has suggested the following approaches to reducing and stabilizing financing costs:

Opening up new sources of capital for the mortgage market. The Commission believes that the authority of the Federal Home Loan Bank Board to issue long-term bonds with the proceeds going to expand the lending activities of the home loan banks is important. More generally, negotiable bonds issued by financial institutions and backed by government-insured mortgages are needed instruments. Both will attract mortgage funds from sources that have hitherto been reluctant to invest in them because of the time and complexity involved in managing the investment. One particular source, which to date has been largely untapped, is pension funds, for which such bonds might prove most attractive.

Expanding the flow of mortgage funds from all sources. The Commission has urged throughout this report that housing must no longer be relegated to afterthought status in the formation of national economic policy and that strong efforts be made to reduce the general level of interest rates. The establishment of a national housing goal, stated in terms of actual numbers of units to be constructed, and the requirement of an annual housing message by the President should help to improve the situation and attract mortgage funds from widespread sources. We have also recommended action to modernize state usury laws to bring them into line with the realities of modern interest rates and allow the mortgage market to attract needed funds. Revision of cumbersome foreclosure law provisions which deter investment in home mortgages, to the extent that it can be done without infringing on important safeguards for occupants, should also help.

Improving local record-keeping relevant to title searches. The Commission has recommended, as the most important step in reducing closing costs, the improvement of local land record systems. Better indexing and filing can be important. This is an area where the nature of the problem is such that it lends itself to the use of computers.

Cooperatives

Many of the savings available to members of housing cooperatives are not unique to cooperatives as such. The deduction of interest and property taxes from the Federal income tax of the resident, savings due to the initial production of a large number of units, savings on closing costs or legal fees which the cooperative receives by acting on behalf of a number of people, etc., are savings which others receive or which result from production on a large scale and not merely from the cooperative form of ownership. However, these savings would not be received by those in cooperatives except for the fact that they organized together in this form of endeavor.

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If they rented, they would not get interest and tax deductions. Savings from large-scale production would go to the original owner or landlord instead of the tenant. Thus, the cooperative form of organization can provide housing at less cost to those who take part in it than would otherwise be available.

Extension of this form of ownership could, therefore, bring a reduction in housing costs.

Other Costs

The Commission's major concerns have been with the cost items just discussed. This focus should not suggest, however, that we consider other items of cost either unimportant or not susceptible to reduction. Every effort should be made to reduce costs of maintenance and repair, insurance, heat, electricity, furniture, and other items which are essential parts of the cost of a dwelling unit.

We are also aware of the costs involved in municipal services, the costs and benefits to be derived from jobs, health, and education, and numerous other areas related to housing and the urban environment. These, however, were not under our direct jurisdiction and we have not, therefore, addressed them in the same manner as the numerous and detailed items summarized in this chapter.

RECOMMENDATIONS

In addition to the many proposals to reduce costs made throughout the Report, many of which are summarized in Chapter 5, the Commission makes the following recommendations with respect to the subjects discussed in this part of the report.

BUILDING PRACTICE RECOMMENDATIONS

The Commission believes that an increase of manpower and the wider use of prefabricated approaches to construction can be accomplished by relating them to the opportunities for increased housing construction. This increased total volume should provide a basis for new agreements encompassing more efficient work rules and building practices from both management and labor in return for contractual arrangements which provide for continuous employment of workers and volume production by builders.

The essence of what we propose is a trade-off, with society finding ways through public policy to assure abundant and steady work in return for the relaxation or elimination of rules that obstruct the advance of technology.

RECOMMENDATION No. 1: *Reducing Seasonality in the Construction Industry*

The Commission recommends that Federal, state and local governments undertake programs to reduce the seasonal fluctuations affecting the construction industry by (a) awarding contracts and scheduling work during that part of the year in which construction is at a low level in order to spread construction work and to achieve the maximum stability of building activities, and (b) providing incentives for winter operations by basing schedule and work progress on alternate bids.

Seasonality of building activity is one of the significant contributing factors to contractual arrangements which limit some otherwise desirable practices because of job security. By providing construction work wherever possible over the entire year, an increase of work could raise employment for the average construction worker from 1,400 hours to 2,000 hours annually. It is hoped that the assurance of year-round work would provide the climate for changes in practices based on previous insecurity of employment.

RECOMMENDATION No. 2: *Reduction in Restrictive Work Practices*

The Commission recommends amendment of the National Housing Act to provide that state and local agencies applying for or receiving Federal assistance for the construction of housing or community facilities be authorized to promulgate, between construction managment and labor, specialized agreements covering specific large projects or multiple smaller projects and approve such agreements for inclusion in the construction contracts to be awarded. These agreements would be of a type to insure efficient, economical and safe work practices and conditions, allow and encourage new technology and foster adequate training of mechanics, apprentices and residents of the area. Should such pro-

> cedure fail to arrive at an agreement to exclude from the work specifications of construction contracts for such housing or facilities such labor and work practices, then the Secretary of Housing and Urban Development, after consultation with the Secretary of Labor and following public hearings and subject to judicial review, shall exclude work practices considered to be unnecessary and undesirable additions to the cost of such housing and facilities.

With the enactment of the Demonstration Cities and Metropolitan Development Act of 1966, the Congress for the first time decided to employ the leverage of a Federal grant program to secure concessions in local labor and work practices on behalf of the long-range objective of urban rehabilitation. Under its provisions, the Secretary of HUD and the Secretary of Labor have negotiated with trade unions regarding certain phases of the Model Cities program. This recommendation would extend the same approach to the general problem of housing costs.

RECOMMENDATION NO. 3: *Prompt Initiation of Special Technology Demonstration Program*

> The Commission recommends that HUD promptly carry out the Congressional authority to construct 25,000 dwelling units in a special technology demonstration program which this Commission recommended and which its chairman proposed to the Congress. Under the Proxmire Amendment the Secretary of Housing and Urban Development is directed to contract for the construction over a five-year period, at a scale of 1000 units a year, of a limited number of different housing construction systems which would promote construction techniques to seek substantial reductions in construction costs of desirable design quality. If successful, the cost reductions found possible should be applied to public housing, to low-interest-rate programs, and to other programs authorized by the 1968 Act.

The primary objectives of this program is to stimulate technological innovation. Contracts would be awarded on the basis of proposals that aim to achieve economies through mass-production without sacrificing the goal of well-designed, quality housing. The choice of areas for such projects would be based upon the readiness of communities and community groups to waive restrictive building regulations and current work rules in those instances where the proposed technological innovations otherwise would be inhibited.

A necessary part of this experimental approach would be to provide for a committee of impartial appraisers to make design and cost comparisons between the various experiments and between the experiments and conventional construction.

RECOMMENDATION NO. 4: *Long-term Housing Programs in Exchange for More Efficient Building Practices*

> The Commission recommends that Congress amend the Housing Act to authorize the Secretary of Housing and Urban Development to enter into long-term commitments (up to a cumulative ceiling over a ten-year period) with local public housing agencies where there is agreement, to eliminate local building practices that increase construction costs, to use new labor-saving methods and

materials, and to provide employment opportunities to residents of slum areas. Under this program, the Secretary of Housing and Urban Development would be authorized to arrange with state and local housing authorities, or groups of local housing authorities, or metropolitan housing authorities, for long-term large-scale housing to stabilize housing construction, reduce costs, and provide greater employment opportunities by minimizing seasonal and cyclical fluctuations and by assuring private enterprise of a continuous, receptive market over long periods.

Selection of the urban areas that would take part in such a program could be based upon findings by the Secretary of Housing and Urban Development that there is a severe local housing shortage for low-income families, that local construction costs exceed the national averages, that there is high unemployment of residents in local blighted areas, that local governments are ready to waive restrictive provisions of codes and regulations that cause excessive costs, and that representatives of local building industry are willing to enter into project agreements to waive practices causing excessive costs, or that prohibit the use of new labor-saving methods and materials, or deny employment opportunities to residents of local slum areas.

Under this program, it would be possible for a local housing authority, or a group of authorities, to contract with one or more successful low bidders for construction over long periods, to a maximum of ten years, under appropriate conditions such as an adjustment of costs in later years on the basis of an accepted building cost index, or other local cost yardsticks, incentives to builders to achieve cost reductions, arbitration mechanism for resolving work practice rules causing excessive costs, and agreement by local officials to accept new methods and materials approved by the National Institute of Building Sciences. The unique feature of this program is that a single contractor, or a joint venture, would be assured of continuous work under the above-described conditions. Inasmuch as the work force would also be assured of long-term employment, present costly building practices could be eliminated.

Furthermore, those types of housing construction which were successful under the provisions of Section 108 of the 1968 Act—the Proxmire Amendment—could be used extensively in such a long-term program as proposed here.

* * * * * * *

INDUSTRIALIZED BUILDING—A COMPARATIVE ANALYSIS OF EUROPEAN EXPERIENCE*

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*Special Report: Division of International Affairs, Department of Housing and Urban Development, Washington, D.C., April 1968.

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INTRODUCTION

A long standing problem of increasing urgency has been how to provide low-income groups with decent permanent housing. Since the beginning of the century, many have regarded industrialized building methods as the most promising means of solving this problem if mass production techniques applied so successfully to automobiles could be applied to residential building. It is only since World War II, however, that programs have been undertaken in Europe on a sufficient scale and for a sufficient period of time that some practical evaluation of these methods can be attempted.

Actually, European building methods have been becoming industrialized for a long time. The broad scope of what is commonly understood by industrialization of building is suggested by the United Kingdom Ministry of Housing's definition which includes:

"* * * all measures needed to enable the industry to work more like a factory industry. For the industry this means not only new materials and construction techniques, the use of dry processes, increased mechanization of site processes, and the manufacture of large components under factory conditions of production and quality control; but also improved management techniques, the correlation of design and production, improved control of the selection and delivery of materials, and better organization of operations on site . . . . For this purpose, industrialized building, can include schemes using fully rationalized traditional methods." [1]

A leading Hungarian housing expert suggests that industrialized building methods include some or all of the following characteristics:

1. Large-scale use of machines;
2. Large-scale use of factory-produced standardized building components;
3. Large-scale projects constructed by repetitive processes;
4. Coordination of management leading to efficient planning, programming, and control of projects;
5. Continuous research in design and production systems.[2]

In practice, therefore, while industrialized building is diametrically opposed to traditional building employing only handicraft methods, it is not altogether different from rationalized conventional methods.

It may also be useful to regard contemporary European building systems as falling into four main categories, all of which are industrialized to some degree: (1) rationalized conventional; (2) modern *in situ;* (3) partial prefabrication; and (4) total prefabrication.[3]

Rationalized conventional systems, while relying mainly on the traditional skilled building trades, incorporate various industrialized techniques, such as on-site mechanization, improved work-site organization, and use of small prefabricated elements. *In situ* building systems refer to the casting of reinforced concrete buildings on the site utilizing sophisticated multi-use forms, powerful mechanical aids, and work programming. Prefabrication systems involve the transfer of building operations to an on-site or off-site factory, where continuous production processes may be employed. The extent to which assembly, erection and finishing operations remain to be performed on the site distinguishes partial from complete prefabrication.

Although rationalized conventional building is commonly regarded as being industrialized, the central concern of this report is with the systematic application of industrial technology to the building industry. Therefore, the term "industrialized building systems" will be used hereafter to refer only to advanced prefabrication and *in situ* systems, thus excluding rationalized conventional construction.

The fact that industrialized building methods are defined in so many different ways obviously poses difficulties. Not only are detailed

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[1] United Kingdom, Ministry of Housing and Local Government, *Industrialised Building* (London : H.M.S.O., 1965), p. 1.

[2] G. Sebestyen, "Future Aims and Present Stages of Industrialization", *Towards Industrialized Building,* 3rd Congress of International Council of Building Research, Studies and Documentation, Copenhagen, 1965 (New York: Elsevier, 1966), p. 37.

[3] National Building Research Institute, *Bibliography of Industrialized Building* (Pretoria, South Africa, 1966), p. 1.

data on various aspects of industrialization hard to obtain, but the lack of uniform definitions and units of measurement makes comparative statistical analysis highly tenuous.[4] Nevertheless, the report does attempt to give a meaningful interpretation to the available data, fragmentary and inconsistent though it sometimes may be.

A word should be said about the source materials used in preparing the report, the most important of which are mentioned in the Annotated Bibliography. We do not consider that sufficient economic data is presently available in the United States to make a reliable cost analysis of any European industrialized building system. Indeed, such data is often lacking in Europe as well. For example, a leading European building company has been unable to obtain strictly comparable cost data on the operations of ten plants in countries other than it own that it has licensed to produce its components.[5] Consequently, though conclusions regarding the economies achieved by various European systems are based on both the best data immediately available and on judgments of experts on European building, they should be regarded as tentative.

The first chapter of this report provides a description of European experience with industrialized building techniques and a survey of the current state of activity. Successive chapters analyze these techniques from technological, economic, design, political and social points of view, including an attempt to define the concept of optimum operations. The final chapter states the conclusions of the study.

I. A Survey of European Experience

The impetus behind large-scale innovation in industrialized building techniques in postwar Europe came from three major factors: the grave shortage of shelter after World War II, particularly for low-income groups; the shortage of skilled building workers; and the belief that industrialization of building could bring about a significant decrease in the traditional high cost of construction.

A. The General Position of Industrialized Building

The rate and type of development of industrialized systems has varied greatly among the European countries. As might be expected, they have tended to develop most rapidly in highly industrialized urban areas and in countries with a planned economy or a strong social housing policy.

The most advanced development is found in East European countries (Table 1). After a slow start during the 1950's, by 1966 industrialized building had risen to a position of preeminence in total national housing construction of the relatively highly industrialized countries of Czechoslovakia and East Germany. It is still relatively less important in Bulgaria, Hungary, Poland, Rumania and Yugoslavia, though it appears to be expanding rapidly in the urban housing sector in Hungary and Poland.

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[4] United Nations, *Annual Bulletin of Housing and Building Statistics for Europe, 1966* (New York, 1967), pp. 12–76.

[5] Statement of Sepp Firnkas, President, Techcrete Company, Cambridge, Massachusetts. See also United Nations, Economic Commission for Europe, *Cost, Repetition, Maintenance: Related Aspects of Building Prices* (ST/ECE/HOU 17) (New York, 1963), p. 19.

TABLE 1. INDUSTRIALIZED BUILDING AS A PROPORTION OF NATIONAL HOUSING OUTPUT OR OF OTHER RELATED DATA IN SELECTED EAST EUROPEAN COUNTRIES, 1956-66 ACCORDING TO VARIOUS SOURCES

[In percent]

Country	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
1. Bulgaria: Medium size panels [1]	(2)	(2)	(2)	(2)	(2)	1.2	2.3	2.9	6.7	10.2	14.7
2. Czechoslovakia:											
Medium size panels and room-sized panels as percent of multidwelling houses [1]	(2)	(2)	7.6	9.6	26.2	39.5	46.9	47.3	71.2	72.9	76.7
Blocks of panels; panels [3]	(2)	10.1	14.9	18.8	26.1	39.5	46.2	(2)	(2)	59.0	(2)
Large panel [4]	(2)	(2)	(2)	(2)	(2)	(2)	53.0	(2)	(2)	(2)	(2)
3. East Germany:											
Concrete blocks up to 750 kilos [1]	(2)	(2)	(2)	(2)	(2)	(2)	(2)	50.6	52.0	48.4	43.4
Story high concrete blocks; concrete blocks up to 5,000 kilos [1]	(2)	(2)	(2)	(2)	(2)	(2)	(2)	25.6	35.3	46.1	53.0
Large panel [4]	(2)	(2)	(2)	(2)	(2)	(2)	81.0	(2)	(2)	(2)	(2)
4. Hungary: Lightweight concrete large blocks and room-size panels as percent of multidwelling houses [1]	(2)	(2)	(2)	(2)	(2)	6.8	14.2	20.9	27.9	32.9	35.0
5. Poland:											
Panels [5]	(2)	(2)	.1	(2)	3.0	(2)	(2)	11.0	(2)	(2)	(2)
Industrialized housing as percent of urban housing [6]	3.0	(2)	(2)	(2)	11.5	(2)	24.4	28.0	(2)	38.0	(2)
6. Rumania: Large panel as percent of state-financed construction [7]	(2)	(2)	(2)	(2)	(2)	(2)	(2)	13.0	13.0	(2)	(2)
7. U.S.S.R.:											
Large panel	(2)	(2)	(2)	(2)	(2)	(2)	[4 8] 35.0	(2)	[9] 14.4	(2)	(10)
Do [11]	(2)	(2)	(2)	(2)	(2)	(2)	8.0	(2)	(2)	(2)	(2)
8. Ukranian S.S.R.:											
Prefabricated housing [12]	(2)	(2)	35.0	(2)	(2)	(2)	80.0	(2)	(2)	(2)	(2)
Large panel as percent of total state and co-operative construction [13]	(2)	(2)	(2)	(2)	3.2	9.8	17.3	(2)	(2)	(2)	(2)
Prefabrication [11]	(2)	(2)	(2)	(2)	(2)	(2)	19.4	(2)	(2)	(2)	(2)
9. Yugoslavia: Nontraditional [1]	(2)	(2)	(2)	(2)	(2)	(2)	(2)	3.8	13.0	2.9	5.6

[1] United Nations, Economic Commission for Europe, Annual Bulletin of Housing and Building Statistics for Europe: 1966 (New York, 1967), table 6.

[2] Not available.

[3] United Nations, Industrialization of Building (E/C.6/70), (New York, 1967), p. 19.

[4] United Nations, Industrialization of Building (E/C.6/70/add. 1) (New York, 1967), p. 112.

[5] Edward Kuminek, "Changes in the Output of the Building Industry as a Factor in the Development of Home Building" in A. A. Nevitt, (ed.), The Economic Problems of Housing (London: Macmillan, 1967), p. 232.

[6] Monograph of Poland, Prague Seminar, vol. II, p. 536.

[7] United Nations, Industrialization of Building, (E/C.6/70/add.1 ,)op. cit., annex I, p. 85.

[8] 200,000u nits.

[9] United Nation s Industrialization of Building (E/C.6/70,add. 1, annex I) (New York, 1967), pp. 101, 104. The 14.4 percent has been derived by dividing the national housing output of 2,300,000 by the 1964 large panel production of 330,000.

[10] Not available, but (same source s footnote 9) 450,000 units were planned.

[11] Analytical Report of G. Blachere, Prague Seminar, vol. I, p. 223.

[12] Monograph of Ukranian S.S.R., ibid., vol. III, p. 644. Ibid., p. 645.

[13] Ibid., p. 645.

Note: Figures above that are from different sources are based on different, often overlapping categorizations of building processes. The yearly percentages for each country are therefore non-comparable, nonadditive, and in some instances conflicting.

Information on the U.S.S.R. is scanty and rather conflicting. While it is reported that large panel construction constituted only 17.3 percent of total state and cooperative housing in the Ukrainian U.S.S.R. in 1962, at the same time 80 percent of all housing was reported as being prefabricated (Table 1). In the U.S.S.R. as a whole, large panel construction with an absolute volume of 200,000 units was reported as being 35 percent of total housing production in 1962. It was also reported that in 1964 330,000 dwelling units out of a total national housing output of 2,300,000 were produced by large-panel methods. The 35 percent for 1962 may therefore have actually been of urban, rather than total, housing. In 1966 the U.S.S.R. housing plan called for the production of 450,000 dwelling units which in quantitative terms is the largest industrialized building program in the world (Table 1).

Among West European countries, there is an even greater conflict in existing data, which at best are fragmentary (Table 2). Industrialization of the building industry would appear to have proceeded farthest in Denmark, France, and the United Kingdom. In other West European countries, while prefabricated components are used widely in conventional construction, complete prefabrication systems remain of secondary importance in national housing production.

TABLE 2.—INDUSTRIALIZED BUILDING AS A PROPORTION OF NATIONAL HOUSING OUTPUT OR OF OTHER RELATED DATA IN SELECTED WEST EUROPEAN COUNTRIES 1956-66 ACCORDING TO VARIOUS SOURCES

[Percentages and other relevant data]

Country	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
1. Belgium: Prefabricated dwelling [1]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	1.8	(*)	(*)	(*)
2. Denmark:											
Large panel [2]	(*)	(*)	(*)	(*)	(*)	(*)	21.4	(*)	(*)	(*)	(*)
Prefabrication [3]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	33.0
3. Finland:											
Prefabrication as percent of collective housing [4]	(*)	(*)	(*)	(*)	(*)	(*)	10.0 (1961-62)	(*)	(*)	(*)	(*)
Mainly prefabricated elements as percent of all apartment building [5]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	25.0
4. France:											
Large panel terra cotta in situ concrete [6]	(*)	(*)	(*)	(*)	(*)	(*)	25.0	(*)	(*)	(*)	(*)
Units						(100 000 1961-62)					
Concrete panel [7]	(*)	(*)	(*)	(*)	(*)	(*)	3.1	5.1	4.7	8.0	(*)
Large panel [2]	(*)	(*)	(*)	(*)	(*)	(*)	5.8	(*)	(*)	(*)	(*)
Units							(25,000)				
Principal large panel systems [7]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	4.0	(*)
Units										(15,000)	
5. Italy:											
Concrete frame or panel prefabrication [8]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	1.2
Capacity of prefabrication plants, 1966 10,000 [9]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	
6. Netherlands: With aid of prefabrication methods [10]	(*)	7.0	11.0	11.0	13.0	11.0	10.0	10.0	13.0	15.0	17.0

7. Norway: Share of prefabrication [11]	(*)	(*)	(*)	(*)	(*)	(*)	2.0	4.0	(*)	(*)	(*)
8. Sweden:											
Element construction [12]	(*)	(*)	7.4	(*)	(*)	4.2	3.2	(*)	(*)	(*)	(*)
Units	(1,434)	(2,204)	(3,340)	(2,885)	(2,823)	(2,257)	(1,738)	(2,074)			
Large panel [2]	(*)	(*)	(*)	(*)	(*)	(*)	2.6	(*)	(*)	(*)	(*)
Share of prefabrication [13]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	3.0	(*)
Units (average)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(3,000)	
9. Switzerland: Share of prefabrication [14]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	8.0
10. United Kingdom:											
Industrialized [7]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	26.0
Industralized systems as percent of public housing sector [15]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	36.0
11. West Germany:											
Large sized building elements [7]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	3.7	4.7
Prefabrication as percent of residential building licenses, January–October 1966 [16]	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	4.2

[1] Monograph of Belgium, International Federation of Building and Public Works (IFBPW), "Social Aspects of Prefabrication in the Construction Industry" (Paris, 1967), p. 2.

[2] United Nations, "Industrialization of Building" (E/C.6/70, add. 1) (New York, 1967), p. 112.

[3] Monograph of Denmark, IFBPW, op. cit., p. 1.

[4] Analytical report of G. Blachere, Prague seminar, vol. I, p. 222.

[5] Monograph of Finland, IFBPW, op. cit., p. 1.

[6] Analytical report of G. Blachere, op. cit.; United Nations Economic Commission for Europe "European Housing Trends and Policies in 1961 and 1962" (New York, 1963), ST/ECE/HOU/11, p. 54; monograph of France, IFBPW, op. cit., p. 2.

[7] Airgram A-1716, from American Embassy, Paris, March 3, 1966.

[8] United Nations, Economic Commission for Europe, "Annual Bulletin of Housing and Building Statistics for Europe: 1966" (New York, 1967), table 6.

[9] Monograph of Italy, IFBPW, op. cit., p. 1.

[10] Monograph of Netherlands, ibid., p. 1.

[11] Monograph of Norway, ibid., p. 1.

[12] Monograph of Sweden, Prague seminar, vol. III, pp. 632, 634.

[13] Monograph of Sweden, IFBPW, op. cit., p. 1.

[14] Monograph of Switzerland, ibid., p. 1.

[15] Monograph of United Kingdom, ibid., p. 1.

[16] Monograph of West Germany, ibid., p. 1.

*Not available.

Note: Figures above that are from different sources are based on different, often overlapping categorizations of building processes. The yearly percentages for each country are heretore noncomparable, nonadditive, and in some instances conflicting.

With respect to the future, most East European countries are planning continued increases in industrialized building. In Czechoslovakia, the volume of prefabricated construction is expected to double the 1962 level by 1970, and to be almost four times as high in 1980.[6] The planned development in Poland is less ambitious, with the proportion of industrialized construction expected to rise from 34.6 per cent of the total national housing production in the 1966–70 period to 45.2 per cent during 1971–75, and to reach 50 per cent during 1976–80.[7] East Germany and the U.S.S.R. would appear to be fully committed to industrialized building in the urban area.

Among West European countries, there is a general expectation that industrialized methods will continue to expand, though at a less rapid rate. The United Kingdom is perhaps typical of many of the highly industrialized countries struggling against the ceiling of physical resources, with its 1970 program calling for construction of 500,000 houses per year. At the present level of productivity, the Ministry of Housing and Local Government estimates that this would involve bringing 100,000 more workers into the home building industry. Since this manpower is not expected to be available, the only recourse is to increase productivity greatly. The projection, therefore, is that approximately 40 per cent of the public housing sector will need to be industrialized by 1970.[8]

Another significant indication of trends is to be found in the 1966 report of the Neue Heimat, which is one of the largest home building organizations in West Germany. The percentage of dwelling units that it has built from prefabricated components rose from 11.7 in 1964 to 27.8 in 1965 and 41.8 in 1966.[9]

The only major divergence from the general trend toward continued expansion of industrialized building is perhaps to be found in Sweden. Here prefabrication rose steadily until 1958 when it reached 7.4 per cent of the national housing output, after which it declined to 3.2 per cent in 1962. The trend was again reversed in 1963, but no more recent information is available (Table 2). The fact that Sweden is the only highly developed West European country that has not provided special assistance to industrialized housing systems may be a partial explanation for this fluctuating trend.[10] On the other hand, a government investigation has concluded that prefabrication capacity will rise to 13,500 apartments in 1970, giving prefabricators a capability for producing some 12 per cent of total housing output. The same report projects a further increase in capacity to 35,000 apartments in 1975, or 25 per cent of total output.[11]

More than fifty industrialized building systems are currently in use in Western Europe,[12] of which sixteen have been selected as representative (Table 3 and Appendix, pp. 1–48). From Eastern Europe we shall discuss five major systems (Table 4 and Appendix, pp. 49–67).

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[6] United Nations, Economic Commission for Europe, National Monograph of Czechoslovakia, *Proceedings of the Seminar on Changes in the Structure of the Building Industry Necessary to Improve its Efficiency and to Increase its Output*, Prague, April 1964 (ST/ECE/HOU 13) (New York, 1964), Vol. II, p. 293. *Proceedings* cited hereafter as Prague Seminar.

[7] Monograph of Poland. Prague Seminar, Vol. III, p. 537.

[8] United Kingdom, Ministry of Housing and Local Government, *Industrialised Building* (London, HMSO, 1965), Circular No. 76/65, pp. 1–2.

[9] "Neue Heimat's Report on Anno 1960", *International Housing Bulletin* (International Federation of Building and Woodworkers, Copenhagen), October 1967, p. 271.

[10] Analytical Report by G. Blachere, Prague Seminar, Vol. I, p. 227.

[11] Monograph of Sweden, International Federation of Building and Public Works, *The Social Aspects of Prefabrication in the Construction Industry* (Paris, 1967), p. 1.

[12] R. M. E. Diamant, *Industrialised Building* (London: Iliffe Books, 1964), Vol. I, p. 14.

TABLE 3.—SUMMARY OF MAJOR STRUCTURAL FEATURES OF 16 SELECTED WEST EUROPEAN BUILDING SYSTEMS [1]

[On-site=On-site factory; Off-site=Off-site factory; In situ=In place.]

Name of system, country, and major material [2]	Structural system		Where cast						Where finished						Mechanicals installed					
			Floor			Wall			Floor			Wall			Floor			Wall		
	Facade wall load bearing	Cross wall load bearing	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ
Bakelite (plastic): United Kingdom	X	X		X			X				X		X				X			X
Balency: France	X	X			X		X				X		X				X		X	
Barets: France	X	X	X			X			(?)			(?)					X			
BMB: Netherlands	X			X			X			X			X			(?)			(?)	
Camus: France	X			X			X			X			X			X			X	
Costamagna: France	X		X			X			X			X					X			X
Estiot: France	X	X	X			X			X			X			X			X		
Heart-Skansa: Sweden	X	X		X			X			X			X			X			X	
Jesperson: Denmark		X		X			X			X			X			X			X	
Larsen-Neilsen: Denmark		X		X			X			X			X			X			X	
Nenk (Steel): United Kingdom	[3]				X		X				X		X				X			X
Ohlson Skarne: Sweden		X	X			X			X			X			X			X		
Reema: United Kingdom	X			X			X				X		X				X		X	
Sectra: France		X			X			X			X			X			X			X
Tracoba: France		X	X			X			X			X			(?)			X		
Truscon: United Kingdom		X		X			X				X			X		X			X	

[1] R. M. E. Diamant, "Industrialised Building" (London: Iliffe Books, 1964), vols. I and II.
[2] All systems concrete unless otherwise noted.
[3] Load bearing columns.

TABLE 4.—SUMMARY OF MAJOR STRUCTURAL FEATURES OF 7 SELECTED EAST EUROPEAN CONCRETE BUILDING SYSTEMS

[Onsite=onsite factory; offsite=offsite factory; in situ=in place]

Country and name of system	Structural system		Where cast						Where finished						Mechanicals installed					
	Facade wall load bearing	Cross wall load bearing	Floor			Wall			Floor			Wall			Floor			Wall		
			On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ	On-site	Off-site	In situ
East Germany:[1] Panel flats		X	X			X					X			X			X			X
Czechoslovakia:[2] TO8B and TO6B (panel systems)		X		X			X			X			X			X			X	
U.S.S.R.:[3]																				
Lugatenko		(?)		X			X				(?)			(?)		(?)			(?)	
Heavy room-size box	X	X		X			X			X			X			X			X	
Monolithic upturned box	X	X		X			X			X			X			X			X	
Lightweight box	(4)	(4)		X			X			X			X			X			X	

[1] R. M. E. Diamant, op. cit., vol. I, p. 119.
[2] Jiri Franek, "Housing in Czechoslovakia" (Prague: Research Institute for Building & Architecture, 1967), p. 24.
[3] Diamant, op. cit., vol. I., p. 124, vol. II, p. 45.
[4] Concrete load bearing columns.

The following features of these systems will be considered: functional and structural design; standards of comfort; production planning; production organization and operations; and erection procedures.

B. STRUCTURAL AND FUNCTIONAL DESIGN

Designing a house that can be satisfactorily produced by an industrialized building system presents complex problems. In addition to satisfying the client, the structure needs to lend itself well to mass production and to simplified erection procedures. Attempts to solve these problems are more than half a century old and originated with architects in many countries—e.g., Gropius in Germany, Parret in France, and Le Corbusier in Switzerland.[13] Today the idea of constructing a building composed of standard products produced by industrialized methods in gaining wide acceptance in European housing practice.

The development of prefabricated systems has followed somewhat different courses in Western and Eastern Europe. In France, for example, the approach has been materials and technique oriented. The civil engineer mentality has dominated development of the systems, often as a result of the fact that the engineer was the owner of the enterprise. The limited flexibility of design resulting from this approach, however, significantly slowed consumer acceptance of the product. Swedish and Danish prefabrication systems, originating in national traditions of excellent cooperation between architects and engineers, have achieved greater variety in design and are generally more appealing to the consumer. Likewise in the United Kingdom the design of industrialized publicly financed housing, which has been mainly in the hands of balanced professional teams, has received general consumer acceptance.

In Eastern Europe industrialized building designs have been prepared by national design institutes. In the early stages, emphasis was placed on construction of wholly standardized buildings, but in recent years the approach has become more flexible. Greater use of component technology now permits freer design of individual apartment elements and groupings.[14] Russian housing design, however, continues the early emphasis on standardized buildings and consequently retains a relatively high degree of inflexibility.

The process of design may be divided into two main phases, the structural system and the supplementary systems for mechanical and sanitary utilities. Several different structural systems have been worked out.

Eastern Europe has employed large panel building systems based on interior transverse load-bearing concrete walls and concrete prestressed floor panels. The self-supporting or suspended exterior walls provide only thermal insulation (Table 4). The maximum weight of individual elements approaches four tons, and the maximum span of floor panels is approximately twenty feet. Early Russian panel systems encountered a number of problems, particularly with jointing. When grout proved unsatisfactory in sealing panel joints, reliance

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[13] Nicholas Pevsner, *An Outline of European Architecture* (New York: Penguin, 1963), pp. 399, 401, 414.

[14] J. Franek, *Housing in Czechoslovakia* (Prague: Research Institute for Building and Architecture, 1967), p. 21.

was placed on caulking. Caulking, however, has been found to be either of poor quality or excessively expensive.

Gradually, the Russian large panel systems evolved into box designs by the assembly of panels into box shapes. When the new system also developed jointing problems, factories began to cast two-room flats as a unit. Since these two-room boxes weighed 13 tons, heavy gantry cranes were required for on-site handling. To reduce crane size, room-size box units were developed weighing no more than five tons each. The latest box design provides for a concrete slab floor and a cement asbestos wall and ceiling stretched over concrete ribs. The inside of rooms so constructed has somewhat the effect of a large covered wagon.[15]

Of the West European systems analyzed, four use load-bearing walls only for the facade, with all interior walls being non-load bearing. Six use only load-bearing cross walls, while five can use either exterior or interior load-bearing walls (Table 3). When interior load-bearing walls are used, the facade panel can be non-structural and thus less costly. Such a system tends, however, to break the building into a series of pigeon holes, thereby limiting flexibility in functional use of space. On the other hand, making the facade wall load-bearing allows more flexible floor plans for individual flats but results in a heavier, more costly facade. Systems that can use either type of load-bearing wall interchangeably permit the architect to choose the optimum balance between flexibility and cost advantage.

While use of industrialized methods to construct the structural framework of a building is basic to an industrialized building system, the opportunities for cost reduction presented in this part of the building operation are limited. The structure is comparatively simple from a design point of view, and uses relatively little skilled labor in the construction process.

As regards mechanical and sanitary utilities, it is common practice in Eastern Europe to design many parts, such as kitchen and bathroom facilities, as separate core units without reference to a particular project. Cores are then carried in catalogs, ready for order. West European systems have not followed a uniform practice in this respect. Fewer than half of the selected systems provide for complete prefabrication of mechanical and sanitary cores (Table 3). Although the weight, size, and complexity of such cores militate against their complete prefabrication, a few systems, e.g., the Swedish Skansa and the French Camus, do use them. Ten West European systems install only pipes and conduits in prefabricated walls and floors, leaving fixtures to be installed on-site by conventional methods.

Two major approaches have been adopted in design of industrialized buildings: the "model" approach and the "component" approach.[16] The model approach consists in the design, production and erection of the whole structure as an end product. It offers a comparatively limited choice in design at any one time, since the emphasis is on achieving mass production of those models regarded as most important. The principal exponent of this approach has been the U.S.S.R.

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[15] See pictures and detailed exposition, Appendix, pp. 63–67.

[16] R. Walters, *General Principles for Industrially Made Building Components*, paper for United Nations, Economic Commission for Europe, Second Seminar on the Building Industry, held in Paris, April–May 1967 (HOU/INDUSTRY/B. 13) (Geneva, 1966), p. 5. This Seminar will be cited hereafter as Paris Seminar.

The model approach is based on a design technique called "typification". Typification involves first the preparation of standard plans for various types of buildings, and second the preparation of standardized structural units and building products which are in turn incorporated to the greatest extent possible in the typical building designs.[17] By concentration on type rather than on individual designs, a close collaboration is achieved between client (developer), designer, manufacturer of building materials and building organization.[18] By fixing design for a definite period of time, the economies of large-scale production can more fully be achieved.

The component approach to industrialized building consists in standardizing the design and production of construction components, leaving to the ultimate user the decision how these are to be combined in a complete structure. Component systems may be open or closed.

Open systems are characterized by acceptance of a common set of standards, particularly in regard to coordination of dimensions and joints. In such systems the functions of building design and construction are handled separately. Architects may use either the predesigned components or custom materials to design different kinds of buildings. Thus, interchangeability of components is the key feature of open systems. Of the systems selected, the British Nenk and French Camus most closely approach being open.

In closed component systems, much like in the model approach, the functions of design and construction are combined in an integrated operation. The components of one system are unique to that system and are not used with any other system. Moreover, each system has its own method of joining components. Thus, basic cost competition is among systems, not among designers. Typical of systems, which may be compared to making buildings in kit form, are Estiot and Tracoba in France and Reema in England.

Most component systems in Western Europe are closed and are of the panel, rather than the box, shape. Several, e.g., the Dutch BMB, employ large panel units weighing more than two and one-half tons, while others, e.g., the Danish Jespersen, use smaller panels weighing less than two tons. Increasing component size theoretically makes it possible to eliminate more on-site operations and, consequently, to achieve greater economies from mass production. Decreasing the size of units tends to increase design flexibility but also to increase cost. The Jespersen system has been particularly effective in using small panels without incurring unacceptably higher costs (See Appendix, pp. 28–33).

It is increasingly apparent that in order to obtain the full advantages of industrialization there must be increased interchangeability among different open systems.[19] The French Government, an early pioneer in promoting industrialized building, is now encouraging the movement from closed to open systems.[20]

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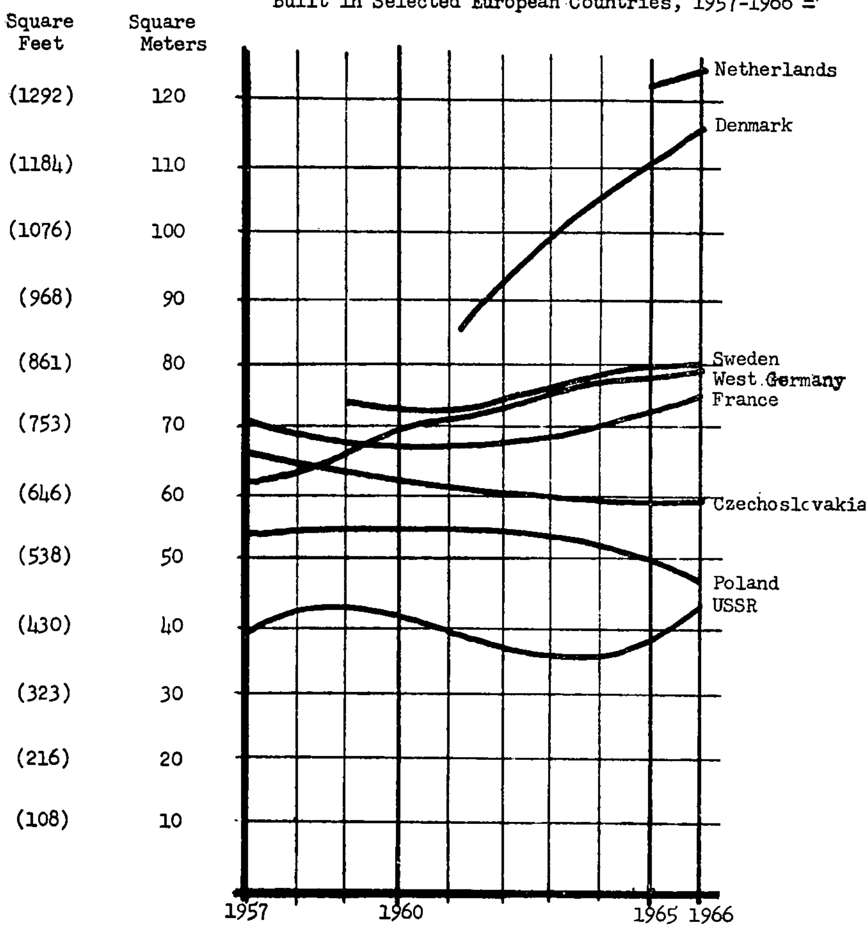
[17] National Monograph of Czechoslovakia, Prague Seminar, Vol. II, p. 293.
[18] J. Bogusz, Rapporteur from Poland, *ibid*, Vol. I, p. 43.
[19] V. Cervenka, *The Use of Industrially Made Building Components*, HOU/BUILD/27/Add. 3, Paris Seminar, pp. 52–53.
[20] National Monograph of France, Prague Seminar, Vol. II, 379.

C. STANDARDS OF COMFORT

Minimum space standards for housing tend to vary inversely with the gravity of the national housing situation and directly with the general level of economic development in the country concerned. Post-war European trends in the average useful floor space per dwelling are shown in Figure 1. In Western Europe the average useful floor

Figure 1

Average Useful Floor Space per Dwelling Built in Selected European Countries, 1957-1966 1/



1/ United Nations Economic Commission for Europe, Annual Bulletin of Housing and Building Statistics for Europe, 1966 (New York, 1967), p. 22-32.

space per dwelling has been greater than in Eastern Europe, with the highest level being in The Netherlands and the lowest being in the U.S.S.R. Denmark has shown the most rapid rate of increase.

The U.S.S.R. presents a special case. Timothy Sosnovy has calculated that the U.S.S.R. urban population increased from 21.6 million in 1923 to 74.5 million in 1950, while over the same period the stock of urban dwelling space rose from 139 to 297 million square meters and space per capita fell from 6.4 to 4.0 square meters. While war damage and the interruption of construction occasioned by the war were obviously major factors in explaining this decline, another major factor is to be found in the generally low priority which housing occupied in the national investment program. On this basis Gregory Grossman in a foreword to the Sosnovy study suggests that in effect the Russian Government was able to obtain two years of industrial investment by permitting a reduction of some 40 per cent in the housing standards of urban workers.[21] This background helps to explain the importance which the U.S.S.R. has attached to its national housing program during the late 1950's and the 1960's, and in particular the vigor it has applied to the industrialization of the building industry.

D. PRODUCTION PLANNING

Production planning is an extremely important factor in ensuring the success of industrialized building. If planning is poor or inadequate in a conventionally produced project, any economic loss is minimal, since such projects generally involve only a small number of units. But in a mass-produced system, the economic loss can be serious because of the substantial investment required in prefabrication plant and in large scale projects often involving many thousands of units.

In Czechoslovakia there is a 10 year cycle for development and exploitation of a single model. Five years are devoted to research, testing, and overall planning; the other five years are devoted to production. During the second half of one cycle, the development of new models for the next cycle is undertaken.[22] The U.S.S.R. follows a similar pattern.

In the centrally planned economies, production planning of industrialized building systems also has a second and broader aspect as an element in national economic planning. For example, the industrialization of construction in Czechoslovakia is being carried out in two phases. The first phase during 1962–1970 is characterized by the mechanization of all building operations and the introduction of partial automation. The second phase during 1970–1980 will be devoted to extension of automation and program control and evaluation throughout the construction industry.[23]

Because of their different economic approach, coupled with the absence of government-sponsored typification programs West European housing ministries have generally not become involved in production planning. One exception is the United Kingdom, where the Ministry of Public Building and Works has developed an open build-

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[21] Timothy Sosnovy, *The Housing Problem in the Soviet Union* (New York, Research Program on the USSR, 1954). Foreword.
[22] National Monograph of Czechoslovakia, Prague Seminar, Vol. II, p. 287.
[23] *Ibid.*, p. 297.

ing system, the Nenk. This system is founded on modular coordination which is the fundamental basis for an optimum industrialized building operation. The 5M CLASP system, developed by the British Ministry of Housing and Local Government is an open low-rise system available for use by private developers. It is particularly interesting because the government charges private bodies 0.25 per cent of the construction cost in order to recoup development expenditures.[24] Other West European Governments have offered financial incentives to promote private long-range production planning.

E. PRODUCTION ORGANIZATION AND OPERATIONS

The process of industrialization of European building methods has been promoted by organizational concentration and increased scale of operation.

In the centrally planned economies, the principal means of achieving unity of operations has been the setting up of "combines" that carry out the functions of both the prefabricated component factory and the building organization which assembles and finishes the structure. The amalgamation of all these functions into a single construction combine ensures continuity of the production process from the manufacture of the components right up to the moment when the occupant takes possession.[25] It also provides for an effective feedback of shortcomings in building methods that can be corrected, a feature that is not as well developed in West European systems. Recent Czech experience demonstrates that there are, however, limits to the efficient size of these combines.[26]

In Eastern Europe there has been a far-reaching reorganization of the construction industry toward larger firms.[27] Individual national enterprises employ as many as 15,000 persons, while the labor force in factories producing components varies according to the type of product.[28] In Hungary, during 1951–1961 the number of national undertakings was reduced by more than 50 precent (from 324 to 153), while the average number of persons employed per firm almost doubled (from 573 to 1,000). During 1961–1963, the number of independent building firms was again reduced from 152 to 129, with accompanying increases in the staff employed.[29]

The trend toward concentration is also evident among industrialized building firms in West European countries. It has not advanced as far, however, because the instability and the uncertainty of the market have tended to limit the size of firms and factories below the optimum (see Chapter V).

While industrialization has promoted a vertical concentration in the building industry, it has also stimulated greater specialization in order to achieve precision in the prefabrication of all types of components. In Czechoslovakia, narrowly specialized factories are being built completely independent of the construction industry to produce a wide

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[24] W. L. Hooper, "Mission Report" (Washington, D.C.: Office of Science and Technology, 1967), manuscript, p. 18.

[25] National Monograph of the U.S.S.R., Prague Seminar, Vol. III, p. 661.

[26] V. Cervenka, "Organizational Measures Ensuring Industrialisation of Building in Czechoslovakia" in *Towards Industrialised Building, op. cit.*, pp. 15–16.

[27] Prague Seminar, Vol. I, p. 248.

[28] National Monograph of Czechoslovakia, Prague Seminar, Vol. II, p. 279.

[29] National Monograph of Hungary, *ibid.*, Vol. II, p. 410.

range of prefabricated components, such as plumbing cores and wall panels. These components are generally made of fully finished materials that can be transported economically over rather long distances.[30]

A similar trend toward specialization in the fabrication of components exists in Western Europe. Some panel manufacturers (e.g., Larsen and Nielsen) have used their idle capacity to produce components for sale to other firms. One of the significant results of specialization in the production of building components has been the increasingly large market possibilities for international trade in these items. Growing international agreement on dimensional coordination based on the 10 centimeter module will further encourage both specialization of production and trade.

There is considerable flexibility in the type and size of prefabrication factories as shown in Tables 10 & 11. In urban areas most off-site plants tend to be highly mechanized and automated. Their cost generally runs between $500,000 and $1,000,000, depending on the sophistication of equipment such as use of steam-heated molds or pneumatic lifting devices. A Larsen and Nielsen factory with an annual capacity of 1500 flats costs $896,000.[31] Seven on-site and off-site factories are described in the Appendix.

In the U.S.S.R. centrally located factories are larger and involve a proportionately greater outlay of capital. A typical block box plant produces some 3500 flats per years. In less densely populated areas, the Soviets use smaller portable plants located at the building site in order to avoid the prohibitive cost of long-distance transport. The equipment cost of a Russian on-site plant producing 600 flats per year is reported to be $84,000.[32]

West European systems, such as the French Costamagna, Barets and Tracoba, also use relocatable on-site plants to fabricate wall and floor panels. A Costamagna on-site plant costing $62,000 produces sufficient panels for at least 500 flats each years.[33] On-site plants are generally less mechanized than centrally located factories. The most significant difference, however, is that central factories, unlike on-site plants, can produce sophisticated kitchen/sanitary cores as well as wall and floor panels.

Factory crews in a highly mechanized and automated central prefabrication plant tend to be small. In a typical mechanized Russian panel plant there are two shifts of sixteen men each, as compared to a fifteen-man crew in a highly automated Danish Jespersen plant and a twenty-six man crew in the less mechanized British Truscon plant.[34]

F. ERECTION PROCEDURES

Probably the most promising opportunities for cost reduction are in streamlining and reducing on-site operations. Consequently, industrialized systems have stressed the development of new plans for work programming and organization that can complement the efficiency of the factory assembly line.

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[30] National Monograph of Czechoslovakia, *ibid.*, Vol. II, p. 289.
[31] Diamant, *op. cit.*, Vol. I, p. 79.
[32] *Ibid.*, Vol. I. p. 125.
[33] *Ibid.*, Vol. II, p. 18.
[34] *Ibid.*, Vol. II, pp. 13–15, 40–41.

The first major innovation has been in developing the "flow-line" method. In this method, construction is divided into a series of operations, each of which is undertaken by a separate team at a specific work station.[35] Insofar as possible, the performance time at each work station (or spot on the construction site) is made as nearly as possible the same for all teams. In the simplest case, therefore, after the first team has completed its job at the first work station the second team begins at the first work station and the first team moves on to begin work at the second work station. The teams thus operate in a continuous fashion, with an interval between starting times being equal to the constant performance time, that is, cycle time per station. The method is being widely followed throughout Europe.

A second major change has been the greatly increased use of mechanical power on the work-site. While this trend is also associated with rationalized traditional construction, it has been suggested by one European expert that perhaps the increase in mechanical power is the best practical measure of industrialization of the work-site.[36]

A major index of mechanization is the utilization of tower cranes. Table 5 shows the increase in the number of tower cranes from 1955 to 1962 in selected European countries. A tower crane is generally either mounted on a rail track so that it can traverse the building site or mounted in a stationary fashion within the building. It is then referred to as a "climbing crane" since it goes up with the building.

TABLE 5.—NUMBER OF TOWER CRANES IN USE IN SELECTED COUNTRIES, 1955–62 [1]

Country and year	Number of tower cranes in use	Number of units in multidwelling structures completed	Tower cranes per thousand units in multidwelling structures completed
Bulgaria:			
1955	19		
1961	31	14,688	2
Czechoslovakia:			
1955	2,527	33,902	75
1962	3,908	58,089	67
East Germany:			
1955	188		
1960	1,257	80,500	16
Finland:			
1955	35		
1962	550	23,562	16
France: 1962	12,000	194,607	62
Hungary:			
1954	93	[2] 38,400	
1961	123	[2] 67,500	
Poland:			
1956	818	62,652	13
1961	1,895	90,846	21
Sweden:			
1955	280	40,896	7
1962	1,200	50,317	24
U.S.S.R.:			
1955	28,900	619,920	47
1962	67,000	1,528,100	44
West Germany:			
1955	4,441	301,336	15
1961	15,547	277,134	55

[1] United Nations, Economic Commission for Europe, Prague Seminar, vol. I, p. 112.
[2] Represent total dwelling units.

[35] P. Bredsdorff, *Production and Assembling of Industrially Made Building Components*, Paris Seminar (HOU/INDUSTRY/B.15), (Geneva, 1967), pp. 18–23.
[36] G. Blachere, Prague Seminar, Vol. I, p. 54.

Use of modern cranes and hoists allows an increase in component size. Loads of two tons in Western Europe and 4 tons in Eastern Europe are generally considered to be most economical.[37] To handle heavier components requires use of costly gantry cranes traveling on specially laid tracks.

Utilization of crane equipment is also important. In Bulgaria, studies show that crane utilization time must reach 60 per cent to cover costs.[38] In Russia, blocks of flats constructed of heavy boxes are erected back to back to allow for more efficient crane use.[39] The Swedish Ohlson and Skarne project at Nasbydal is composed of eight buildings located around the rim of an elipse, so that a traveling crane on a track forming the rim may move from site to site. (See Appendix, p. 40.)

A third important change has been the institution of schemes for training on-site workers to apply industrialized methods. Practically all of the highly developed countries have set up training schemes for assemblers, who tend to be multi-skilled workers capable of taking on highly specialized, though lower-skilled, work. Accelerated training courses for machine operators, supervisory staff, and technicians are also increasingly common.[40]

The rationalization of on-site operations has, as might be expected, greatly speeded up erection time. Some known erection times are as follows: 2 weeks for 136 flats in the Russian block box system; one week for 12 flats in the French Barets system; one and one-half weeks for 16 flats in the British Truscon system; one month for 100 flats in the French Estiot system; and 35 days for 63 flats in the French Sectra system. Data are not available concerning either the relative sizes of the work forces on these projects or the time required for finishing once the erection is completed.

G. EVOLUTION IN POSTWAR BUILDING PRACTICES

In broad terms, it may be said that prefabrication is passing through a three-stage evolutionary process.[41] During the first stage in the early 1950s, prefabricated building often cost more than conventional construction. Nevertheless, it was believed necessary and desirable to push ahead with industrialized methods, not only to supplement traditional methods but also to reach a level of technology and a scale of production that would bring about the hoped for reduction in total costs. During this period, national and local authorities intervened in the building process, not only to assure continuity in demand but also to backstop programs of research and production in a wide variety of ways—for example, by loans, interest subsidies, capital subsidies special forms of contracts (such as serial contracts and negotiated contracts), fiscal exemptions, and establishment of reserved sectors for public housing.

The second stage, during the late 1950s and early 1960s, was characterized by a weeding out of many systems that were found to be non-

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[37] Diamont, Vol. II, p. 39, and J. Franek, *op. cit.*, p. 24.

[38] G. Ganev, "Rational Coefficients in the Use of Erecting Mechanisms with Respect to Their Housing Capacity", in *Towards Industrialised Building, op. cit.*, p. 250.

[39] Diamant, *op. cit.*, Vol. II, p. 126.

[40] International Labor Office, *The Social Aspects of Prefabrication in the Construction Industry* (Geneva, 1968), Ch. IX.

[41] United Nations, *Industrialization of Building* (E/C.6/36) (New York, 1965), pp. 29–31.

competitive and not accepted by consumers. At the same time, those that proved successful were consolidated and given further support.

In the third stage, the late 1960s, concerted efforts are being made to apply scientific methods to the engineering design, production, distribution, and erection of prefabricated structures, with the goal of bringing total industrialized building costs to a level significantly lower than conventional building costs.

II. Technological Considerations

As engineers, architects, planners and production managers set about in postwar Europe to industrialize the building industry, they were confronted with a number of technological questions. Is an industrial technology really applicable to building? In striving to apply such a technology, is building construction really attempting the impossible by trying to emulate the production techniques of the automobile industry? Do conventional methods have a survival value because they are most efficient in meeting the special locational problems of the building process that other types of industry do not have to meet? European experience provides some provisional answers to these questions.

Technological problems fall into two main categories: product technology and building systems technology. This chapter is divided accordingly.

A. PRODUCT TECHNOLOGY

There are a number of unresolved issues regarding the choice of materials suitable for industrialized building. Wood is scarce in Europe, and Europeans do not consider it suitable for structural use in multistory urban construction. Currently, silicate and clay-based materials—chiefly concrete, but including structural clay products—occupy a dominant position in European industrialized building systems. The question arises: to what extent is it desirable to shift to components based on metal and plastics that may have less weight, more efficient insulating properties, better surfaces, and greater possibilities for mass production? [42] Concrete has demonstrated consumer acceptability; it compares well with traditional thick stone walls and further is fire-resistant. Metals and plastics, being higher priced and in greater demand by other industries, have yet to be widely used as a principal material in European building systems.

In European research and development on building materials, concrete has received the most attention. It is easily formed into different shapes. The chemical process of curing has been speeded up by additives and special heating techniques so that components can be taken out of molds within short time-intervals. Innovations in prestressing techniques, while not yet widely used in panel construction, have yielded a great increase in tensile strength, with sharp reductions in concrete mass. Successful development of light weight concrete has both facilitated the transportation of pre-formed elements and increased their workability on the job site. Thus, although much research remains to be done, it can reasonably be concluded that problems in concrete technology no longer pose fundamental difficulties for the industrialization of building methods.

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[42] V. Cervenka, Prague Seminar, Vol. I, p. 18.

B. BUILDING SYSTEMS TECHNOLOGY

Once the problems of product technology have basically been mastered, the second stage in the evolution of industrialized building processes involves the development of a building systems technology that promotes industrialization. In the past, three central features of the traditional organization of the building process have tended to discourage industrialization: (1) proliferation in building parts and supplies: (2) limited materials-handling capacity of hand tools; and (3) individualized site-operation schedules. The postwar world has, however, witnessed a lessening of these obstacles—even within the conventional sector.

The extreme proliferation in traditional building materials and equipment is well known. For example, it is estimated in France that there are several hundred different types of piles and bricks, 200 models of doors, 60 models of bath tubs, 1,000 models of faucets, and 52 different types of flap seats for toilets.[43] In the United Kingdom, a study has shown that there are about 200 separate dimensions for existing standard components between the intervals of 0 and 100 inches. Generally, there is a lack of dimensional order among different groups of components, both in the actual sizes used and in the relationships between the sizes.[44] Clearly, the lack of standardization in building supplies is a deficiency that admits of a ready remedy, namely dimensional coordination.[45]

Dimensional coordination is a system that reduces the dimensions of all building components, and of buildings themselves, to multiples of one basic dimensional unit—the basic module. The module must be small enough to provide the necessary flexibility in design, but large enough to promote simplification in the number of sizes for various components. Dimensional coordination based on a module of 10 centimeters has been widely promoted in Western Europe through the European Productivity Agency and the International Organization for Standardization, in Eastern Europe by the Permanent Committee on Building of the Council for Mutual Economic Aid, and for all of Europe through the Committee on Housing, Building and Planning of the United Nations Economic Commission for Europe and the International Council for Building Research, Studies and Documentation (CIB). While international agreement on all details has not yet been reached, the 10 centimeter module is already widely used throughout Europe. The development of dimensional coordination has provided the industry with a system that facilitates industrialization and moreover provides the basis for interchangeability among various component systems. It is also an important factor in promoting international trade in building materials and components.

The second non-industrial feature of traditional building, the limited materials-handling capacity of hand tools, has been completely altered by postwar developments. Not only have trucks been developed that can easily transport large, box-sized components from the factory to the worksite (see Appendix pp. 13, 36 and 67) but, as indicated in Chapter I, tower and rail cranes with a lifting capacity of 100 foot-

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[43] American Embassy, Paris, Airgram A-1716, March 3, 1966.

[44] European Productivity Agency, *Modular Coordination in Building* (Paris: Organization for European Economic Cooperation, 1956), p. 54.

[45] Lennart Bergvall, *Modular Coordination in Building* (ST/SOA/62) (New York: United Nations, 1966).

tons are commonplace on worksite throughout Europe (see Appendix, pp. 10, 12, 23, 40 and 62).

Finally, individualized site operations schedules in traditional building have been an impediment to the development of a modern building systems technology. If introduction of prefabricated components actually increases the complexity of the conventional building system, or if work gangs cannot be efficiently organized on the building site to assemble components without adjustments, then the economies of industrialized production of the components may be cancelled out by the inefficiencies of non-industrialized techniques on the building site. Means are available, however, to avoid such inefficiencies. The twentieth century managerial revolution that has swept the industrial world in general has, during the postwar period in Europe, also penetrated onsite operations in the building industry through the use of, among others, the critical path and flow-line construction methods.

Following the flow-line method, management has, as discussed in Chapter I, divided construction into a series of operations, each of which is undertaken by a separate team.[46] Eventually perhaps a basic principle in modular design will be to develop operational alternatives that are compatible with and facilitate the division of the construction process into equivalent work contents. In this way, the optimum allocation and use of production resources can be assured.

While postwar technological and managerial developments have combined to promote adoption of industrialized building methods, there is still one outstanding unresolved technological problem, namely that of joints. For any given function, a variety of components of different design systems and of different materials should be available, each perhaps with different tolerances and safety margins. But in order to bring such elements together successfully, methods of on-site jointing need to be developed that will serve the same function as mortar in traditional building. Such methods will allow the designer to bring together the components of his choice without having to make special arrangements with the manufacturer, and the manufacturer in turn will be free to develop new types of components without being tied to the limitations of a particular building system.[47]

In the absence of satisfactory low-cost dry jointing techniques, most European concrete building systems still use wet joints, that is, grout.[48] These joints pose two principal difficulties: first, they slow up erection, particularly in damp and cold weather, in waiting for the joint to gain structural strength; and second, subsequent moisture penetration creates difficult maintenance problems, particularly in the case of components with wide tolerances. Consequently, a fully satisfactory building systems technology awaits the development of an effective and economical means for dry jointing. While comparatively little research has as yet been done on dry joints, the United Kingdom in particular is planning to concentrate future efforts on their development.

Experience would seem to demonstrate, therefore, that except for jointing the main problems of developing a building systems technology have been resolved. The development of this technology, both

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[46] See above, p. 29.
[47] R. Walters, Prague Seminar, Vol. I, p. 23.
[48] Some typical concrete wall joints are illustrated in the Appendix for the Costamagna, Jesperson, and U.S.S.R. Light Weight Box Systems.

in the factory and on the work site, is most advanced in Eastern Europe. In Western Europe, the large number of competing closed building systems has made it possible to test readily a wide range of technological alternatives. The rationalization that is an essential condition for interchangeability of components among open building systems has not yet taken place.

III. Special Design Problems

Having seen in the previous chapter that there are no fundamental technological constraints on the expansion of industrialized building, an examination will now be made of the special design problems created by use of industralized building systems and the possible solutions that have been worked out or are emerging. There are four major design objectives to consider: (1) achieving harmony within housing projects; (2) ensuring compatibility of housing projects with nature and adjoining neighborhoods; (3) ensuring that the projects make a significant contribution to the cityscape; and (4) creating well integrated new towns.

While urban construction utilizing conventional methods has by no means always been successful in realizing these four objectives, it is nevertheless largely free from some of the design constraints that are implicit in the ue of industrial technology. The greater the number of buildings using the same construction system, the larger the size of components, and the fewer the alternative components in terms of texture and material, the more difficult is the design problem. Design of existing industrialized housing projects has often fallen short of overcoming these constraints.

A. Harmony Within Housing Projects

Experience in designing industrialized projects has shown that several major principles govern the degree of harmony that is achieved within a project. The first is that variety is essential in the design of a single industrialized building. It can be accomplished in various ways. Changing one of the dimensions of the standard elements gives variation in shape. Variation in texture can be obtained by introducing regular or irregular patterns into the mold facing, and variety of color can be achieved by simple addition of color to the concrete or by inserting a new material into the forms at the time of casting.

Second, disturbing repetition must be avoided in the grouping of buildings contained within one urban space. It is necessary to achieve a certain coherence within a variety of building volumes and forms. That is, everything should be subordinated to one central organizing theme, so as to give the impression of correlated movement. From this coordination each building and group of buildings derive a personality.

Third, the development of special areas such as courtyards, gardens, squares, alleys, walks, and greenbelts is essential. Not only do they relieve the relative barrenness of man-made materials, but they perform a necessary function in helping to integrate the various segments of the project into a harmonious whole.

Finally, there is a counterbalancing principle of avoidance of too much variety in shapes and masses. Excessive contrasts between shadow and light, between various colors, and between large and small shapes lead to confusion and chaos that produce visual fatigue.

During the early stages of development, industrialized housing projects often suffered from great rigidity in design.[49] Examples of such rigidity are the multi-family projects at Behren and Farebersville, France, constructed with the Camus system. These projects, composed of 5,200 units in four story blocks, were begun in 1954. While the design of their master plan followed an interesting two-dimensional pattern, its failure to take into account the third dimension resulted in an overall monotony.[50] In Eastern Europe, industrialized housing projects constructed in the early rigid forms of typification displayed a drabness that has been widely criticized not only in foreign circles but also within the U.S.S.R., Hungary, and Czechoslovakia.[51] A conspicuous example is the series of 10-story blocks in Plazen, Slovby, Czechoslovakia.[52]

More recently, large-scale industrialized projects in Invalidovna, Czechoslovakia; Salgotarjan, Hungary; Nowe Tychy, Poland; Valling by Sweden; and Ghiorgiu-Dej, Rumania, and smaller scale, less industrialized projects in the Netherlands and the United Kingdom have succeeded in achieving a greater degree of harmony within the project.

B. COMPATIBILITY WITH NATURE AND ADJOINING NEIGHBORHOODS

Another major criterion of good urban design is that the project must be compatible with nature and the existing neighborhood. Industrialized building presents substantial problems in this respect for two major reasons. Since industrialized projects tend to be much larger than conventionally built projects, the sheer size of the mass magnifies the problem. Also, the size of elements and the kind of materials used in large panel construction tend to diverge from those found in neighboring communities built according to conventional methods. Therefore, special attention needs to be paid to several basic principles.

First, compatibility may be provided by continuing into the fringes of the new project the materials used in the existing community. For example, if brick predominates in the existing community, the use of brick facing in the panel construction helps to integrate the two. Then as one moves into the heart of the new project these materials can be dispensed with.

Second, effective transition from the existing to the new community can be achieved by varying the scale of the elements. If in the existing community small elements dominate, then some similar elements might be introduced into the industrialized construction in the area of contact between the two developments. In the interior of the project the quantity of these elements can be reduced.

Third, landscaping is an important factor in facilitating the transition from the existing community to the new project. Open spaces,

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[49] Guy Oddie, "The Future—Can We Face It?", *The Architectural Review*, November 1966, p. 322.

[50] France, Ministere de la Construction, "Behren and Farebersville", *Urbanisme en France* (Paris, undated).

[51] M. D. Chagin, "The Use of Industrially Made Building Components", paper for Paris Seminar, Document 49, pp. 3–4; National Monograph of Hungary, Prague Seminar, Vol. II, p. 414; National Monograph of Czechoslovakia, *ibid.*, pp. 290–1.

[52] Jiri Franek, *op. cit.*, p. 55.

continuity of greenery, and utilization of the same types of tree or shrubbery planting are useful means of achieving compatibility.

Finally, particular attention needs to be given to the transition in function. If the project is large, inclusion of social amenities such as shopping facilities, schools, and community centers may be useful in helping to integrate it with the adjoining community. Placing such facilities on the border between the new and old areas may tend to establish an artificial line of demarcation, whereas placing them just inside the new project gives them an integrating role in community life.

Special problems, the solutions of which require highly skilled designers, are presented when contemporary projects are located close to historically important sectors of a city.[53] Two successful examples of wedding the new with the old are to be found in Florence, Italy, near the church of Santa Croce and in Nowe Tychy, Poland, at the square in front of an 18th century church.

C. THE CONTRIBUTION OF HOUSING PROJECTS TO THE CITYSCAPE

Residential areas constructed by conventional methods tend to grow in a piecemeal manner and often produce a chaotic and exaggerated variety in design. On the other hand, there is the danger that, because of their size, large-scale industrialized housing projects will produce monotony in the cityscape. This danger has become particularly acute in some East European countries where industrialized housing projects completely dominate city skylines. The application of certain principles is particularly important, therefore, to help insure that design of industrialized housing projects contributes to rather than detracts from the skyline.

First, design of a new project should help to develop urban spaces around existing focal points. Focal points may exist in the natural topography, such as hills, rivers, lakes and ravines; or they may be man-made, such as cathedrals, public buildings, monuments, commercial centers, and squares. One of the secrets of the architectural greatness of almost all old European cities is that they grew up in accordance with this principle.[54] Thus, if special care is not taken, large-scale, high-rise industrialized construction may physically overwhelm and destroy existing special features of the city.

Second, large industrialized housing projects may themselves create new central points of interest in a city. When a project involves more than 1,000 dwelling units, it has reached the scale where this potential can be realized. A skillful application of this design principle may be found in the "la Defense" project in Paris, developed at the extension of the axis of the Louvre and the Champs Elysees, which includes accent towers and the dome of the Industrial Exhibition pavillion.[55] Another successful application is in the satellite town of Lormont—Cenon—Floriac near Bordeaux, which is developing on the hills across the river from the metropolitan center and is composed of five clusters of residential towers.[56]

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[53] See United Kingdom, Ministry of Housing and Local Government, *Historic Towns, Preservation and Change* (London: HMSO, 1967), *passim*.

[54] United Kingdom, Ministry of Housing and Local Government, *op. cit.*, p. 29.

[55] France, Ministere de la Construction, "La Defense", *Urbanisme en France* (Paris, undated).

[56] France, Ministere de la Construction, "Lormont—Cenon—Floirac", *Urbanisme en France* (Paris, undated).

D. NEW TOWNS

To cope with the rapid processes of urbanization, many governments have, concurrently with the restructuring of existing cities, adopted a national policy aimed at the development of new towns. As a result, new towns have often become a testing ground for planned urban growth and the use of industrialized building systems. In these towns the problems of urban design become very complex and different from those presented by the addition of one new neighborhood to an existing city constructed by traditional methods. The central question in new town design is how to avoid monotony in the urban character when all buildings use the same gray concrete as the basic material and often use repetitive plans.

In Western Europe, the British new towns policy adopted after World War II represents a significant advance in this field. The programming, planning, design, and construction of the British new towns constitute a completely new pattern of urban growth. Nevertheless, a continuity with the character of old English settlements has been maintained, with low height, low densities, and openess of design composition. Furthermore, greenbelts, protected by legislation, help to maintain the traditional English relationship between residence and country. Some defects, such as the frequent drabness of the industrial sectors and the far-from-satisfying character of the tall building, may reflect the reluctance of local governments to assert their authority over esthetic development.

Postwar new town developments have been less successful in France where, following the government decision in 1950 to decentralize urban growth, many housing projects of several thousand units each have been undertaken in various parts of the country. While the economic rationale of such projects was sound and interesting, and large complexes of industrialized housing were built, the frequently mechanistic character of their design created dissatisfaction, and the projects seldom developed the social organization of a town. Moreover, the rigidity of the square urban pattern used in their construction tended to create a cold atmosphere, and the integration of the new communities with their natural surroundings has generally been regarded as inadequate.

Among East European countries, the U.S.S.R. has built a number of its new towns almost entirely by industrialized methods. While Russian planners have succeeded in providing basic social facilities in a well-integrated community plan, they have not as yet worked out an altogether creative architectural solution to the special problems of new towns. Contrary to their early contentions that communist society would take a more appealing form than capitalist society, and to their more recent professions that new towns should fit local conditions from tundra to desert, Russian planners have made extensive use of unimaginative standard layouts and standard buildings. Typification has been extended to cover the bulk of new construction. Planners are now planning cities for 500,000 people which will present even greater problems. For example, Togliatti, the new town to accommodate the Fiat plant scheduled to open in 1971, will be expanded from its 1966 population of 150,000 to 500,000.[57]

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[57] Ada Louise Huxtable, "Building the Soviet Society", *Architectural Forum,* November 1967, p. 38.

Another type of architectural problem has arisen in the urban design of the new town in Poland, Nowe Tychy. Here there has been too much change in design principles between the initiation of the project in the early 1950s and its completion during the 1960s. In the early stages, architects relied on the classical forms of Stalinist Historicism, probably contrary to their own convictions, while in the later stages they adopted the most advanced contemporary style.[58] Even though variety is desirable in individual structures, it is necessary to provide an overall urban design scheme in order to achieve a close interrelationship among all parts of a new town.

Experience with industrialized housing has shown clearly the dangers of excessive repetition in design. Generally, such repetition, particularly in Eastern Europe, stems from an overriding insistence on achieving the largest total output and the lowest unit cost. On the other hand, the greatest measure of success has been achieved in design when broadly educated, well-balanced professional teams are charged with the design of buildings and town planning. Another key factor has been to have administrators at national, provincial and local government levels who possess a deep understanding of the social and physical aspects of urban growth.

IV. Economic Considerations

This chapter analyzes the major economic factors that determine the relative cost structure of various European building systems. It examines the following seven major factors: the building system; the level of technology; the density of the housing market; the scale of plant; the structure of the building industry; the organization of the work site; and working conditions. It then reviews and weighs the postwar performance in these respects of both conventional and industrialized systems.

A. MAJOR FACTORS DETERMINING BUILDING COSTS

(1) *The Building System*

The building system plays a strategic role in determining costs in many different ways. An important distinction was drawn in Chapter I between "open" and "closed" systems. The principal advantage of a closed system is that reliance on a single, exclusive design method promotes unified management control over costs. By contrast, since open systems provide for interchangeability of components in order to introduce greater architectural flexibility, they tend to involve some sacrifice in unified management control.

The number of models in an industrialized system is an important cost factor. Some systems, particularly East European ones, have utilized comparatively few building models. Typification has, as indicated in Chapter I, been rigorously applied in Eastern Europe in order to maximize physical output at the lowest unit cost.

On the other hand, since West European systems must appeal to consumers in competition with conventional construction systems, most have tended to build a large number of relatively dissimilar

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[58] H. Adamczewska, *Maistroprojekt Nowe Tychy 1955–1965* (Katowice, Poland, 1965), *passim*.

buildings (composed, however, of standard individual apartment models). The multiplicity of systems in Western Europe increases greatly the variety of residential building types on the market as compared to East European countries. For example, in France there are at least eight major industrialized building systems, each having a number of different apartment models. Since West European markets have been relatively limited in size, the multiplicity of systems has made it difficult to achieve the lowest possible dwelling unit cost and still produce a wide variety of residential building.

The frequency and degree of change in models is a further factor affecting costs. In Eastern Europe, it has been a common policy to freeze models for periods of five years, while in West European systems, design changes have been more frequent. Not only are small improvements constantly being introduced, but frequently systems will be adjusted to a single large project. Since design change involves an increase in overhead costs, the more frequent the change the higher the unit cost. On the other hand, certain design changes in new materials or a more efficient structural system may introduce economies that will offset in whole or part the additional costs involved in making the change.

Another important cost factor is the size and type of building components utilized by a particular building system. For example, if small-sized floor panels are replaced by larger units, a more efficient use of molds and curing chambers can be achieved, with production increasing by perhaps as much as 25 per cent. While materials costs would rise in proportion to element size, overhead costs and wages remain roughly constant.[59] Similarly, changes in the facing material, such as from concrete to ceramic tile, tend to increase costs.

The size and costs of production runs differ from one family of components to another. In some production lines, e.g., automated concrete floor-panel factories, the set-up cost and delay time associated with switching the line from one component to another are not substantial. In other production lines using general purpose machinery, e.g., window, door and curtain wall factories, the costs and delays between production runs may be considerable.[60]

The design principles of the building system are a relevant cost variable in still another way. Decisions concerning components and jointing, for example, have a direct effect in developing the flow-line work method on the building site, as discussed later in this chapter. In fact, future designers of buildings based on assembly of components may be obliged to take as one of their objectives the development of a system that will facilitate the organization and control by production engineers of operations on the building site.[61] The development of more complicated components which eliminate certain traditional shaping and finishing operations onsite, such as plastering and painting, will reduce on-site labor requirements substantially.

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[59] P. Bredsdorff, *Establishment of Component Factories and Design Production Systems for Assembly On-Site,* Paper for United Nations, Economic Commission for Latin America, Seminar on Prefabrication of Houses for Latin America, Copenhagen (New York; United Nations, 1967), Working Paper No. 3, p. 9. Seminar cited hereafter as ECLA Seminar.

[60] *Ibid.*, p. 9.

[61] *Ibid.*, p. 16.

(2) *Technology*

The state of technology is a second important factor determining costs; the more advanced the applied technology, the lower are the unit costs. This principle has long been applied in the production of many building materials, such as cement. But the special locational aspects of the building process have tended to thwart its application to the remainder of that process.

In general, the more highly capital-intensive the technology, the higher the level of output required to reach the break-even point. That is, to pay off the rising investment costs of a centrally located factory it is necessary to have a larger number of units to which an allocation of overhead costs can be made. On the other hand, with higher sophistication in technology more compact and efficient machinery can perhaps be developed, which will make it technically and economically feasible to move factories from site to site in accordance with the geographical character of the market.

The development of new technologies, such as extensive use of electrically powered equipment, new vibrating techniques, the introduction of fire-retardant plastics, and the use of chemical compounds as additives to other materials, may also assist in producing more complicated and serviceable components at little or no increase in cost. More complex technological innovations are difficult to implement, however; for example, in Czechoslovakia, the prefabrication model BA using prestressed concrete has been abandoned.[62] while the much publicized Russian lightweight Ribbed box system with its special pouring techniques for making thin elements is still in the experimental stage after five years.[63] Revolutionary technological innovations may be longer in achieving success than most enthusiasts have maintained.

The development of computer controls will have far-reaching cost implications for industrialized building. In several highly concentrated industries computer controls have been developed at all stages of production. Resulting economies, such as achieved in the cement industry, have been substantial. Raw materials costs have been reduced, power and fuel utilized more effectively, and the quality of the final product held at exactly the specified level. Danish experience suggests that it may be possible by means of an automated control system in a large prefabrication plant, to produce and handle a large range of components at low cost for substantial production runs.[64]

(3) *Density of the Urban Market*

Because of the large size, heavy weight and low value of most building components, transportation costs act as a greater market constraint in the building industry than in probably any other industry. Experience in West European countries suggests that the maximum market radius for a centrally located plant ranges between 20 and 65 miles. In Denmark, at existing levels of technology, heavy precast systems are not competitive at a distance beyond 50 to 65 miles,[65]

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62 Franek, *op. cit.*, pp. 24–5.

63 Charles C. Zollman, *Study of Convrete Construction in the Soviet Union for Residential and Commercial Buildings, June 1965*, A Report by Zollman as Member of the American Delegation on Concrete Construction (Washington, D.C.), p. 12.

64 Bredsdorff, *op. cit.*, p. 12.

65 Denmark, Ministry of Housing, *The Role of Government and Semi-Official Organizations in the Field of Industrialized Building* (New York, 1967), ST/ECLA/CONF. 27/L.2, p. 13.

while in France the competitive market radius for prefabrication systems is roughly 30 miles.[66] In the United Kingdom, the maximum efficient transportation distance appears to be 20 miles.[67] Increased congestion on European highways will obviously reduce the geographical scope of the market for a prefabrication plant. If water transportation is available, however, the distance may be extended up to as much as 200 miles. The cost of transport per dwelling for a journey of 100 miles in the United Kingdom is reported to be $280 for the Reema system, or about 5 per cent of total costs. Moreover, that system's experience suggests that the transport cost depends less on is capable of making.[68]

As regards the efficient marketing radius of centrally located plants in East European countries, in Czechoslovakia it is 25 miles. The country is supplied by 36 principal factories.[69] Thirty-seven per cent of precast production is transported more than 60 miles, 22 per cent a distance of between 30 and 60 miles, 15 per cent between 12 and 30 miles, and 26 per cent less than 12 miles.[70] Transportation costs in brick-and-cement construction for distances of 30 miles constitute 8.9 per cent of total housing costs, but for completely assembled prefabricated construction they represent 10.7 per cent.[71]

The character and extent of urban settlement is, therefore, a crucial factor in determining the market and production potentials for industrialized building. If the size of the urban market for large-panel concrete systems is large enough, the establishment of a centrally located factory, such as found in the Danish Jespersen and French Balency systems, may be practicable. If, on the other hand, the urban market is not of a sufficient size and duration to justify the erection of a centrally located factory, then industrialized building systems may have to rely on demountable on-site prefabrication plants.

As new and better (and often lighter weight) materials become available and as the demand in affluent societies grows for higher quality, higher value housing, the market possibilities for trade in building components are substantially increased. In many cases, including Austria, Belgium, Denmark, Finland, France, Italy, and Sweden, a steadily expanding trade in construction components is developing among neighboring countries. For example, the Heart Unit, composed of a completely prefabricated bathroom and kitchen unit, produced at Malmo, Sweden, is occasionally shipped as far as 200 miles. In some countries, such as Austria, Finland, France, Italy and Sweden, there is in addition a small overseas demand.[72] In Finland one firm alone has a capacity of 10,000 wood dwelling units per year, of which only about 600 units were produced for the domestic market in 1964.[73]

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[66] Monograph of the National Building Federation of France, International Federation of Building and Public Works, *The Social Aspects of Prefabrication in thte Construction Industry* (Paris, 1967), p. 3.

[67] D. V. Donnison, *op. cit.*, p. 297.

[68] P. A. Stone, *Building Economy: Design, Production and Organization* (London: Pergamon Press, 1966), p. 78.

[69] J. Franek, *op. cit.*, p. 28. Assuming each serves a more or less equal number of people, there would be one factory per 400,000 people.

[70] Monograph of Czechoslovakia, Prague Seminar, Vol. II, p. 303.

[71] V. Cervenka, *op. cit.*, Annex, p. 4.

[72] Fragmentary data concerning international trade in prefabricated components is available in United Nations, Economic Commission for Europe, *Dimensional Coordination in Building: Current Trends in ECE Countries* (Geneva, 1966); see also United Nations Economic Commission for Europe, *Proceedings of the Ad Hoc Meeting on Standardization and Modular Co-ordination in Building* (Geneva, 1959), E/ECE/361, pp. 96–119.

[73] Monograph of Finland, Prague Seminar, Vol. II, p. 369.

A second form of trading relationship is the licensing of prefabrication systems in foreign countries. Systems developed in Denmark, France and Sweden are being applied under license in a number of countries including Austria, Belgium, West Germany, Italy, Spain and the United Kingdom.[74] One Danish firm has licenses in seventeen countries.[75] Still a third type of international trade is the export of complete prefabrication factories. For example, France, Poland, the U.S.S.R. and perhaps other countries have exported such factories.

(4) *Scale of Plant*

One of the recent significant advances in the building industry both in the industrialized and conventional sectors has been an increase in the scale of production. This trend has been reflected in many ways, such as the increase in the number of employees and in the amount of investment per worker of construction firms, the increasing specialization of building materials production, the movement toward greater integration and coordination of management in all the processes involved in construction, the establishment of continuous-process prefabrication plants, and the undertaking of large-scale housing developments with integrated community facilities.

Scale of plant is a crucial factor in reducing unit dwelling costs (Tables 6 and 7). In the Ukrainian Soviet Socialist Republic, doubling the capacity of precast concrete component factories resulted in a 13 per cent reduction in cost, while a five-fold increase yielded a 25 percent reduction. In Czechoslovakia, a 66 per cent increase in door-making capacity reduced costs by 15 per cent, a 150 per cent increase in window-producing capacity yielded a 6 per cent cost saving, whereas a 10-fold increase in concrete floor panel construction capacity achieved a 25 percent cost reduction. Studies of a more limited character from certain West European countries indicate similar trends.[76]

TABLE 6.—EFFECT ON UNIT COSTS OF CHANGES IN CAPACITY OF PRE-CAST CONCRETE COMPONENT FACTORIES IN THE UKRANIAN SSR[1]

Indicators	Annual capacity in cubic meters			
	20,000	40,000	60,000	100,000
Cost of basic equipment	100	147	184.0	204
Number of workers	100	138	181.0	225
Output per worker	100	145	166.0	196
Cost per cubic meter of output	100	87	82.5	75

[1] United Nations, Economic Commission for Europe, "Cost. Repetition, Maintenance: Related Aspects of Building Prices" (Geneva, 1963), p. 32.

[74] Analytical Report by G. Blachere, Prague Seminar, Vol. I, p. 224. See also Appendix.

[75] M. Hartung Nielsen, "Housing—Via Shortage to Exports", *Danish Foreign Office Journal*, December 1964, p. 13.

[76] United Nations, Economic Commission for Europe, *Cost, Repetition, Maintenance: Related Aspects of Building Prices* (Geneva, 1965), pp. 140–151.

TABLE 7.—EFFECT OF SCALE OF PRODUCTION ON UNIT COST OF BUILDING COMPONENTS IN CZECHOSLOVAKIA [1]

Size of plant [2]	Index of average unit costs for—				
	Doors	Windows	Sanitary core: 1 model	Sanitary core: 5 models	Concrete floor panels
10	(3)	(3)	118	145	(3)
50	(3)	106	(3)	(3)	(3)
55	121	(3)	(3)	(3)	(3)
100	100	100	100	113	100
166	85	(3)	(3)	(3)	(3)
200	(3)	(3)	(3)	(3)	90
250	(3)	94	(3)	(3)	(3)
400	(3)	(3)	94	107	(3)
500	(3)	(3)	(3)	(3)	82
1,000	(3)	(3)	(3)	(3)	75
100 corresponds to	[4] 90,000	[5] 120,000	[6] 10,000		[7] 15,000

[1] United Nations, Economic Commission for Europe, "Cost, Repetition, Maintenance: Relafed Aspects of Building Prices" (Geneva, 1963), p. 32.
[2] Measured by index of annual output at full utilization of plant.
[3] Not available.
[4] Doors.
[5] Square meters of windows.
[6] Sanitary cores.
[7] Cubic meters of floor panels.

(5) *Structure of the Industry*

Even though in principle it may be deemed desirable to invest in advanced technologies, there may nevertheless be formidable obstacles in the structure of the industry to the development of an efficient industrialized building system. One requirement for achieving a low cost product with a highly industrialized technology is unity of organizational control over all the relevant processes. Prior to the advent of industrialization, this unity was conspicuously absent in the building industry.

The traditional capriciousness of the market has been a major factor not only in fixing a predominantly small-scale character on the European building industry, but also in leading to a fragmentation of functions—design, building materials and equipment production, and building operations—among separate entities. The test of survival has in fact forced the construction sector to develop an adaptability that is probably unique among major industries. Not only can conventional contractors escape the necessity of making large investments in factories, as do employers in other industries, but in many countries they are able to rent all or most of their on-site equipment. Furthermore, in most European countries the principal contractor, or the supervising engineer or architect as the case may be, is able to call on the managerial and capital resources of many sub-contractors. Consequently, entry into the construction industry has been relatively easy in most countries, at the same time that the mortality rate of firms has been among the highest of all industries.

The crucial point is, however, that while this adaptability has given the industrial structure a certain strength and survival value, it has lead to a fundamental weakness. Because of the industry's amorphous structure, there is insufficient time normally to take full advantage of innovation, development, and management—all of which then tend to play a marginal rather than decisive role in efficiency of operation.[77]

[77] D. Bishop, *The Economics of Industrialised Building* (London: Building Research Station, Ministry of Technology, 1966), reprinted from *Chartered Surveyor,* 1966, Vol. 99, No. 4, p. 197.

Furthermore, experience suggests strongly that good organization and management are key factors in the success of industrialized building. Some contractors have succeeded with systems that have differed but little from systems which other contractors have been most unsuccessful in using.[78] In fact some contractors maintain that the success of industrialized systems is dependent more on organization than on the method of prefabrication.[79]

As indicated in Chapter I, since World War II there has been a significant restructuring of the European building industry, particularly in East European countries. Larger capital investment, larger building enterprises, larger construction projects—all have contributed toward more effective coordination within the construction industry so as to achieve a greater unity of management. In Western Europe, this development is less advanced, although efficient large-scale enterprises are now to be found in most countries.

This restructuring is most readily achieved under closed prefabrication systems, one of the chief features of which is the vertical integration of building functions. East European countries are well advanced in this direction.

Under open systems, where integration is dependent on collaboration of many different firms, successful restructuring of the industry is more difficult. While wide-spread adoption of dimensional coordination, as noted in Chapter III, will promote interchangeability of component parts, various problems such as jointing and the availability of essential component parts may not be satisfactorily handled without concerted attempts, perhaps even under government auspices, to achieve more coordination within the industry.

(6) *Organization of the Work Site*

The ultimate objective of an industrial technology in the building industry is fairly simple to define in the light of experience with highly sophisticated technology in industry generally.[80] The objective is to transfer all possible production from the work site to the factory so as to eliminate most, if not all, processes of shaping, forming, machining, surfacing and other finishing. On-site operations would then consist of mechanically aided transport and positioning of components, and their assembly without need for on-site finishing.

The flow-line method of on-site construction is based on the division of the production process into specific and simple tasks which are carried out by specialized workers. This has been described by the U.S.S.R. as follows:

> "As a result of the large-scale use of completely prefabricated standard dwellings, the most favourable conditions have been created for organising building by the flow-line method. The construction site becomes the assembly shop of the house-building combine. The two operate together as a single continuous production line. Specialised vehicles transport components to the assembly site, working in co-ordinated rhythm with production and assembly. Building production takes on the characteristics of industry to the greatest possible extent."[81]

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[78] P. A. Stone, *op. cit.*, p. 73.
[79] K. M. Wood, "Industrialized Building", *The Builder*, May 24, 1963.
[80] Per Bredsdorff, *op. cit.*, p. 12. This section has drawn heavily on this paper.
[81] National Monograph of the Ukrainian Soviet Socialist Republic, Prague Seminar, Vol. III, p. 649.

In practice, however, certain traditional on-site functions will be likely to remain. Excavation and other foundation work are forming operations that will be difficult to eliminate completely. Furthermore, handling and assembling may be expected to give rise to a certain amount of damage to finished components. According to the experience of the French Estiot system, 30 per cent of the wall panels have casting defects or are damaged in handling.[82] This damage then either requires final on-site refinishing or suggests delaying altogether certain finishing operations until after on-site assembly, so as to avoid expenditures on costly protective measures and repairs.

A systematic application of industrialized building techniques will, therefore, involve a far-reaching change in the composition of the on-site building labor force.[83] But the inevitable decline in the number of traditional building craftsmen has not meant a drastic dilution of the over all skill-mix of the industry. In the first place, industrialization has increased greatly the demand for engineers, technicians, and supervisory workers. In France the proportion of structural engineers and supervisory workers rose from 7.8 per cent of the construction labor force in 1954 to 10.2 per cent in 1962.[84] In Poland it is projected that the proportion of engineers and technicians will increase from 9.5 per cent in 1960 to 14.5 per cent in 1980.[85]

Prefabrication has also increased substantially the number of specialist laborers. While the level of skill is much lower, the higher degree of specialization has in effect resulted in an important up-grading of the unskilled worker. Another important change in labor skills is the growing demand for machine operators. In Sweden the number of tower cranes rose from 50 in 1950 to 1,500 in 1963, yielding a ratio of one crane for every 36 workers. Thus, some skills have profited at the expense of others. In fact a new type of "multi-skill" worker has developed. In the U.S.S.R. it has been found necessary for a worker to learn the basic elements of a second or even a third trade if he is to be capable of replacing other members of his team on the work site.[86]

As observed in Chapter I, the flow-line method of production has been widely adopted in on-site erection, particularly in East European countries. Such a system attempts to establish first, an optimal division of labor among workers within a crew, and second, an optimal division of labor among crews of workers.

In the flow-line method, the size of each crew is determined in such a way that performance time per work station is as nearly as possible the same for all crews. The work is usually planned as follows:

"(a) all the separate tasks, to be given to distinct operative-teams or to different contractors, are listed;

"(b) among the operations listed a key operation is selected, i.e., the work for which a regular recurrence seems to be of primary importance (for example, the pouring of concrete walls and floors into large forms), and the corresponding cycle time is fixed;

"(c) the whole planning of the different operations is then built

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[82] See Appendix, p. 20.

[83] International Labor Office, *Social Aspects of Prefabrication in the Construction Industry* (Geneva, 1968), chapter VII.

[84] National Monograph of France, Prague Seminar, Vol. II, p. 387.

[85] National Monograph of Poland, *ibid.*, Vol. III, p. 535.

[86] N. Pron and M. Drylov, "Osvoenie vtoryh Professij", *Professional 'No-Techniceskfe* (Moscow), Vol. 20, No. 1, January 1963, p. 27.

up around the rhythm calculated, all the other operations being arranged by sizing the teams concerned so as to enable them to follow the same sequence." [87]

Ideally, the size of the structural crew, that is the crew responsible for assembly of load-bearing components, is fixed so that the materials-handling equipment employed for vertical and horizontal transportation and positioning is utilized at near full capacity. Different combinations of equipment and different degrees of its technical sophistication must be considered.

A. Allan Bates suggests that a typical structural crew in the U.S.S.R. is composed as follows: 1 panel assembler (crew chief), 2 panel setters, 1 welder, 1 welder's helper, 1 mason, 1 mason's helper, 1 crane operator, 2 crane slingmen, 2 ground laborers, ½ site superintendent, making a total crew of the equivalent of 12½ persons. A typical U.S.S.R. finishing crew is composed as follows: 1 carpenter (crew chief), 2 carpenter's helpers, 2 plumbers, 1 plumber's helper, 2 electricians, 1 painter (usually a woman), 2 painter's helper, ¼ site superintendent, making a total crew equivalent to 11¼ persons. The normal structural crew in the U.S.S.R. works as a compact, closely scheduled team, while the finishing crew is usually scattered through a series of adjacent apartments at any given time.[88] A typical erection crew on large panel construction in Bulgaria consists of four assemblers, two concrete men, two machine operators, and one welder.[89]

The most efficient number of crews depends on the size and finish of the components. If components are box size, fully finished and equipped, then two crews may be most efficient. In the case of less complex components demanding more specialized assembling operations, the number of crews will be much higher.[90] In normal U.S.S.R. practice, two finishing crews follow up one structural crew, all under the supervision of a single site superintendent, who may be responsible for simultaneous construction of several apartment buildings.[91]

Assuming that the rhythm of work is not fixed by the output of machinery or equipment a major management problem is to establish a flowline that takes into full account the improvement curves of work crews, that is curves which show the rate of production per unit of time. Two phases may be distinguished—first, the operation-learning phase during which workers acquire familiarity with the task and when labor productivity increases rapidly; and second, the routine-acquiring phase during which only gradual improvement of labor productivity is attained through small changes in work methods and organization.[92] Studies show that operational time is always greatly reduced in the early stages of the introduction of the flow-line method.

The problem is then how best to set up work schedules so as to take into account the successive improvement of labor productivity resulting from repetition. Either the number of workers on a given team may be held constant while the time for each unit of work is gradually

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[87] United Nations, Economic Commission for Europe, *Effect of Repetition on Building Operations and Processes on Site* (New York, 1965), p. 114.
[88] A. Allen Bates, *Low-Cost Housing in the Soviet Union*, Typed Memorandum, 1967, pp. 7–8.
[89] B. Obretenov, "Improving the Organization of Assembly of Industrialized House Building", in *Towards Industrialised Building, op. cit.*, p. 290.
[90] Bredsdorff, *op. cit.*, p. 21.
[91] Bates, *op. cit.*, p. 6.
[92] United Nations, Economic Commission for Europe, *Effect of Repetition on Building Operations and Processes On-Site, op. cit.*, p. 10.

decreased, or the time period may be held constant while the number of persons on each team is reduced. While both procedures have been used, the first is generally considered to be superior. A change in membership of the work team breaks the work rhythm and may actually lower productivity. Furthermore, work breaks of any length of time, arising for example from bad weather or delays in delivery of materials, also result in a significant loss of productivity.[93]

The improvement process is dependent on the nature of the operation. In simple operations with a minimum number of instructions, there is a rapid increase in labor productivity and a stable operational level is achieved comparatively quickly. As the complexity of operations assigned to a team increases, the improvement rate is slower. The size of the work team and their experience in working together also affect the rate of improvement. The smaller the team and the longer the time the team has worked together, the more quickly the team will reach a stable work rhythm.[94]

The reduction in building costs attributable to repetition has been considerably greater in industrialized than in traditional construction. A United Kingdom study of the effect of repetition shows a 33 per cent improvement in productivity on industrialized building, compared to an 8 to 12 per cent improvement on traditional construction.[95]

It is generally agreed that the keys to maximum productivity in on-site operation are thorough pre-planning, careful organization, and scrupulous maintenance of continuity of work.[96]

(7) *Working Conditions*

In all European countries, rain is an intermittent obstacle, and in many countries winter is a seasonal deterrent to continuous, efficient production on the site. Consequently, by transferring operations from the building site to the factory, sheltered, organized working conditions have become a major factor in promoting higher productivity.[97] Furthermore, the rapid erection of the building shell and the consequent earlier protection against the weather made possible by industrialized systems have tended to reduce the disruptions in remaining on-site operations that are attributable to the vagaries of weather.

B. COMPARATIVE PERFORMANCE OF EUROPEAN INDUSTRIALIZED AND CONVENTIONAL BUILDING SYSTEMS

The relative economic performance of conventional and industrialized systems can be measured in five different respects: completion time for on-site operations; on-site man-hour requirements; total on-site and off-site man-hour requirements; total building cost per dwelling unit; and general allocation of national manpower resources to the building sector.

(1) *Completion Time for On-Site Operations*

As might be expected, the transfer of functions from the building site to the factory has resulted in significant reductions in the duration

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[93] *Ibid.*, pp. 100–115.
[94] *Ibid.*, p. 11.
[95] *Ibid.*, p. 31.
[96] *Ibid.*, p. 6.
[97] National Monograph of Denmark, Prague Seminar, Vol. II, p. 321. It should be noted that traditional builders in Denmark are erecting tents and other covers over on-site construction, gaining much of the advantage of sheltered, working conditions. This innovation, coupled with other management practices, has sometimes resulted in labor savings as significant as those of industrialized building systems, without plant investment.

of on-site operations. The most drastic have been reported in East European countries. In the U.S.S.R. a large panel flat can be constructed in half as much time as a traditional brick unit[98]; in Bulgaria large panel systems have also reduced building time by almost one-half,[99] while in Czechoslovakia construction time has been cut by practically 75 per cent.[100] Smaller savings in the neighborhood of one-third have been reported in Rumania.[101]

Any important reduction in on-site building time yields certain direct benefits. First, it reduces capital costs during the construction period at the same time that it is shortening the waiting period for the realization of real income or money income from the building in question. Second, cutting the construction time in half or more reduces substantially the financial costs and personal hardships involved in family relocation that may be required by slum clearance programs.

(2) *On-Site Man-Hours*

As operations have been transferred from site to factory, industrialized systems have achieved a substantial reduction in on-site labor requirements (Table 8). In Czechoslovakia and Poland, on-site man-hours have been reduced practically by half. In the United Kingdom, they have been half or less of those in small-scale conventional methods, and similar results have been achieved in Denmark. The on-site man-hour requirements of various methods for a cubic meter of construction in Finland in 1962 were as follows: conventional brick construction—5.8; concrete cast *in situ*—4.5; and prefabrication—3.9.[102] In Hamburg, West Germany, a large panel system required only 50 to 55 per cent of the on-site man-hours used in building comparable masonry construction.[103]

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98 Analytical Report by the U.S.S.R. Delegation, Prague Seminar. Vol. I, p. 239.
99 National Monograph of Bulgaria. *ibid.*, Vol. II, p. 277.
100 V. Cervenka, *The Use of Industrially Made Building Components*, *op. cit.*, p. 2.
101 United Nations, *Industrialization of Building* (New York, 1967), E/C.6/70/Add. 1, Annex I, p. 87.
102 National Monograph of Finland, Prague Seminar, Vol. II, p. 368.
103 National Monograph of the Federal Republic of Germany, *ibid.*, Vol. II, p. 357.

TABLE 8.—VARIOUS TRENDS IN THE REDUCTION OF ONSITE MANPOWER REQUIREMENTS IN HOUSEBUILDING IN SELECTED COUNTRIES

[Man-hours per dwelling unit]

	Conventional construction				
	Small site	Large site	Specialized conventional	Utilizing prefabricated components	Large panel and related systems
1. Czechoslovakia [1]	(2)	[3] 1,130	(2)	(2)	630
2. Denmark [4]		[5] 1,500	(2)	(2)	800
3. France: [6]					
1950		[5] 3,000	(2)	(2)	(2)
1964		[5] 1,500	(2)	(2)	(2)
4. Netherlands [7]	1,100–1,400	700–900	(2)	(2)	(2)
5. Poland [8]	(9)	(2)	(2)	(2)	(10)
(a) Hours of work per cubic meter: [11]					
1961		[5] 7.2			5.4
1965		[5] 6.8			3.2
6. United Kingdom [12]	2,400	1,300–1,800	800–1,300	700	700–1,300
(a) Reema system [13]	(2)	(2)	(2)	(2)	1,090
7. U.S.S.R. [14]	(2)	(2)	(2)	(2)	(15)
8. West Germany: [16]					
1953		[5] [17] 2,235			
1962		[5] [18] 2,080			

[1] V. Cervenka, "The Use of Industrially Made Building Components," Paper for Paris Seminar (HOU/INDUSTRY/B.16, Annex) (Geneva, 1966), p. 2.
[2] Not available.
[3] Bricks and cement block method.
[4] Svend Hogsbro, "The Building Team," Paper for ECLA Seminar ST/ECLA/CONF. 27, Working Paper No. 4 (New York, 1967), p. 2.
[5] Includes both small and large sites.
[6] American Embassy, Paris, Airgram A-1716, March 3, 1966.
[7] Analytical Report of G. Blachere, Prague Seminar, vol. 1, p. 221.
[8] Edward Kuminek, "Changes in the Output of the Building Industry as a Factor in the Development of Home-Building," in A. A. Nevitt, "The Economic Problems of Housing" (London: MacMillan, 1967), p. 233.
[9] Ratio: 100.
[10] Ratio: 52.
[11] Monograph of Poland, Prague Seminar, vol. III, p. 545.
[12] D. Bishop, "The Economies of Industrialised Building," Design Series 54 (London: Building Research Station Ministry of Technology, 1966), p. 201.
[13] R. M. E. Diamant, "Industrialised Building" (London: Iliffe Books, 1964), vol. I, p. 14.
[14] Analytical Report of U.S.S.R. Delegation, Prague Seminar, vol. I, p. 239.
[15] 35–40 percent less than brick building.
[16] Monograph of Federal Republic of Germany, ibid., vol. II, p. 361.
[17] Average size 56 square meters.
[18] Average size 75 square meters.

On the other hand, British experience has also shown that rationalized conventional systems using some prefabricated elements have been able to match industrialized systems' achievement of 700 man-hours per dwelling (Table 8). Similarly, in Denmark rationalized traditional builders have, through better planning and organization and with the advantage of repetitive work, reduced on-site man-hours by 30 to 40 per cent over ordinary conventional methods.[104]

How much further industrialization can reduce on-site labor time remains to be seen. Some suggestion of the ultimate reduction may be indicated by experiments in the U.S.S.R. which show that precast box units finished at the factory can reduce on-site labor requirements to one-third of that now required for large panel systems.[105]

(3) *Total On-Site and Off-Site Man-Hours*

The effects of industrialization on total man-hour requirements differ widely. In Eastern Europe rather spectacular reductions in total labor inputs have been reported. Savings of labor time of 35 to 40 percent have been recorded in the U.S.S.R. on a whole range of

[104] National Monograph of Denmark, Prague Seminar, Vol. II, p. 32.
[105] V. A. Nazarevsky, "Some Economic Problems of Housing in the USSR", in A. A. Nevitt (Ed.), *The Economic Problems of Housing* (London : MacMillan, 1967), p. 238.

large panel buildings utilizing prefabricated reinforced components for the roof, staircases, balconies and other elements.[106] In Czechoslovakia, total average labor requirements for prefabricated housing have been 30 percent below those built by brick and concrete block construction.[107] The Rumanian Government reports that, as compared to residential building utilizing brick and prefabricated flooring, large panel house construction has cut manpower inputs by 30 percent.[108] Large panel housing in Bulgaria has reduced labor costs by 35 percent.[109]

Less information is immediately available regarding experience in Western Europe. In the Netherlands a study has shown that prefabricated systems have reduced on-site labor requirements, mainly of a skilled character, by 10 percent, but roughly 30 percent more labor was required in the factory. Hence, in the aggregate there was no net saving in man-hours required per dwelling unit.[110]

(4) *Total Building Costs*

While the performance of industrialized building systems has shown spectacular results in regard to certain aspects of the building process, the overall savings in money costs per dwelling unit that industrialized systems have registered over conventional systems have been much more modest. This is attributable partly to the fact that certain additional costs are incurred in the shift to an industrial technology.

First, the transportation of large elements from the factory to the site necessitates extra capital and manpower. Moreover, depending on the location of the building site and that of raw materials such as sand, gravel, cement and steel, additional transport may be required. For example, instead of one trip direct from the quarry to the building site in conventional construction, under industrialized construction two trips may be required, one from the quarry to the factory and another from the factory to the building site.

Second, if the technology and the factory assembly line do not permit direct loading from the factory to a means of transport, extra handling costs cannot be avoided. Furthermore, stockpiling of components immediately entails additional capital costs.

Third, prefabricated components, particularly large and heavy elements, are subject to a certain amount of damage in transport, handling and assembly, often requiring expensive skilled labor for repairs.

Fourth, highly finished, high priced, and occasionally fragile components require expensive packaging for adequate protection. For example, the packaging costs for prefabricated door units may amount to as much as one fourth or more of the total price of the door.

Finally, the shift from a handicraft to an industrial technology may require the use of more costly materials. Low dimensional accuracy, arising for example from shrinking and warping, is easily dealt with in traditional construction. In contrast, while most prefabrication systems admit reasonable margins of tolerance, they also demand a higher degree of dimensional accuracy and materials which remain

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[106] United Nations, Reply by the Rapporteur from the U.S.S.R. *Industrialization of Building:* Annex I, Part F (E/C.6/36/Add. 6) (New York, 1965), p. 5.
[107] V. Cervenka : *op. cit.*, Annex, p. 3.
[108] United Nations, Reply by the Rapporteur from Rumania, *Industrialization of Building:* Annex 1, Part E (E/C/6/36/Add. 5) (New York, 1965), p. 8.
[109] National Monograph of Bulgaria, Prague Seminar, Vol. II, p. 277.
[110] Information from personal interview.

free from distortion. Thus, a study in the United Kingdom in the late 1950s found that the cost of prefabricated components was substantially higher than that of the traditional materials they replaced and that savings in on-site labor arising from the prefabrication system were insufficient to offset this cost differential.[111] British experience in this respect does not, however, appear to be typical of other European systems.

It might be expected that during the early stages of industrialization of building, average costs per dwelling unit built with industrialized methods would differ from country to country. While West European experience has shown wide diversity in these costs, they have tended to be much more uniform in Eastern Europe.

In the U.S.S.R., average total costs per dwelling unit constructed by industrial methods are 14 to 15 per cent below those of conventional brick construction,[112] while in Czechoslovakia they are 15 per cent lower.[113] A recent Polish study has revealed some striking conclusions concerning cost differentials in the construction of five-story buildings among four major types of regions.[114] In predominantly industrial areas large panel systems were the most efficient, showing a saving of from 10 to 17 per cent as compared to conventional construction. In large administrative centers with a relatively small industrial labor force, however, such as Warsaw, Krakow, and Wroclaw, large block systems were most economical with savings ranging from 6 to 16 per cent. In provinces characterized by traditions of high standards of workmanship, e.g., Poznan and Gdansk, poured concrete construction requiring large numbers of skilled concrete form workers proved superior, showing savings of 11 to 14 per cent. In predominantly rural areas, traditional construction remained least expensive. With regard to eleven-story buildings, however, while certain regional variations remained, the large panel system showed average nationwide savings of 14 per cent as compared with poured concrete systems.

The general conclusion is therefore that among industrialized methods large panel systems show the greatest uniformity in costs throughout the country. By contrast costs of the large block system varied widely, with the lowest ones occurring in areas having an abundance of craftsmen and professional staff.

Among market economies, experience in some countries has demonstrated a superiority for industrialized systems. In 1967 the cost of a complete dwelling unit built by industrialized methods in Denmark was 15 per cent less than for a traditionally built apartment unit.[115]

In British experience, the height of the building has proved to be an important factor in comparative costs. Industrially built housing is now cheaper than traditional construction for structures over six stories, about the same for structures from three to six stories, but more expensive for structures of one to three stories.[116]

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[111] United Kingdom, Building Research Station, *A Study of Alternative Methods of Construction*, Special Report No. 30 (London: HMSO, 1959), p. 55.

[112] Compare Monograph of the U.S.S.R., Prague Seminar, Vol. III, p. 660 and United Nations, *Industrialization of Building* (E/C.6/70/Add. 1), *op. cit.*, Annex I, p. 118.

[113] V. Cervenka, *op. cit.*, Annex, p. 1.

[114] J. Sanecki, *Ceny budynkow mieszkalnych o roznej technologii wykonania, Biuletyn Instytutu Budownictwa Mieszkaniowego*, Warsaw, July 1966, pp. 7–8.

[115] P. E. Malmstrom and Johs. F. Munch-Petersen, *Philosophy of Design and Adaptation to Production in Industrialized Housing*, paper for ECLA Seminar (ST/ECLA/CONF. 27/1.5), p. 3.

[116] United Kingdom, *Response Paper No. 1*, Paris Seminar, p. 8; D. V. Donnison, *op. cit.*, p. 295.

In West Germany in the early 1960s, total costs of large component prefabrication construction and rationalized conventional buildings were roughly the same.[117]

However, more recent experience in Hamburg has shown that in buildings of up to nine stories industrialized construction costs are five percent below conventional costs, while in much taller buildings the savings may go as high as 12 percent.[118] With respect to the country as a whole, industrialized construction is reported in 1968 as having upwards of a 10 per cent cost advantage over conventional construction.[119]

Experience in other market economy countries does not evidence a clear advantage in favor of industrialized methods. In France, while net savings of 10 percent have been reported in some industrialized housing projects, in general, conventional construction remains competitive.[120] Similarly, both Norwegian and Swedish contractors report that there is no significant difference in cost between the two methods.[121]

After surveying experience with industrialized building a 1967 United Nations study reached the general conclusion that in countries "which have amassed some experience with industrial methods of production and assembly of prefabricated components, the overall cost of prefabricated buildings is lower than that of conventional buildings by about 10 to 15 percent." [122]

It should be pointed out, however, that industrialized systems have been able to obtain other substantial advantages even when they may not have shown a significant cost advantage. Thus, West Germany has emphasized that the main achievements of industrialized buildings have been in "expanding the performance capacity of the building industry regionally, increasing precision of measurements and a more uniform quality of building." [123] Also, the United Kingdom Ministry of Housing and Local Government stresses the value of industrialized systems releasing scarce professional staff to concentrate on improving the quality of community layouts.[124]

(5) *General Allocation of Manpower Resources to the Building Sector*

Practically all European governments have been confronted with critical construction backlogs during the postwar period. While strenuous efforts have been made to expand the output of the conventional construction sector, including in Western Europe the encouragement of the immigration of large numbers of workers from Southern Europe, the desired rate of expansion in construction output has not been generally obtained for several major reasons: the slow rate of growth in on-site technology; the increasing difficulty of recruiting young workers for on-site employment; and objections from building trades unions to lowering apprenticeship requirements and increasing the number of apprentices.

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[117] National Monograph of the Federal Republic of Germany, Prague Seminar, Vol. II, p. 358.

[118] Information received by HUD Mission to Germany, October 1967.

[119] Letter from W. Triebel, Director, Institut fur Bauforschung, Hannover, Germany, February 6, 1968.

[120] National Monograph of France, Prague Seminar, Vol. II, p. 378.

[121] International Federation of Building and Public Works, *op. cit.*, reply of Norwegian Construction Employers Association, p. 1; and reply of the Federation of Swedish Building Employers and the Federation of Swedish Civil Engineering Employers, p. 1.

[122] United Nations, *Industrialization of Building* (E/C.6/70) (New York, 1967), p. 24.

[123] Monograph of Federal Republic of Germany, Prague Seminar, Vol. II, p. 358.

[124] United Kingdom, Ministry of Housing and Local Government, *Industrialised Building* (Circular No. 76/65) (London: HMSO, 1965), p. 2.

One of the most significant achievements of industrialized building systems in European economies has been, therefore, their capacity to circumvent the foregoing barriers to expansion of the conventional building industry.[125] Since industrialized building systems have demonstrated their ability to utilize unskilled and semi-skilled manpower with comparatively limited training, they offer the possibility of substantially increasing national construction output with only modest increase in the total on-site labor force.

C. WEIGHING THE EVIDENCE

Certain specific conclusions concerning the relative performance of industrialized and conventional building systems emerge from the foregoing review of the available statistics—fragmentary, non-comparable, and often contradictory as they are. As building operations are transferred from the work site to the factory and as off-site man-hour and capital requirements are increased thereby, on-site labor input decreases markedly, and the completion time per dwelling unit tends to decline proportionately. In Eastern Europe, large panel systems have shown a strikingly high saving in total manpower required and a smaller, though nevertheless substantial, superiority in total costs as compared to conventional building. In Western Europe on the other hand, it is equally clear that industrialized building has not uniformly demonstrated the same superiority. In some West European countries, under certain conditions total costs of industrialized building have been significantly below those of conventional building, but in other countries no overall cost advantage has been registered over rationalized conventional building.

While the direction of development in Eastern Europe is definitely toward an ever wider application of large element systems, the trend is less clear in Western Europe. The European building industry will certainly continue to be industrialized in the broad sense of the term, but it is not yet certain whether the main emphasis will be on rationalization of conventional construction or on prefabrication.

Can a general conclusion now be drawn from these specific findings? Does European experience as a whole demonstrate conclusively the superiority of industrialized building over rationalized conventional construction? A number of major considerations cast serious doubt on the possibility of arriving at any definitive conclusions at the present stage in the evolution of industrial building technology.

First, while there has now been more than a decade of intensive experimentation with and application of industrialized building systems, it is probably fair to say that the period has been much too short to give a solid basis for determining what the ultimate results will be. Second, with the exception of a few countries, such as Poland in Eastern Europe and possibly Denmark and France in Western Europe, it is highly doubtful that European countries have placed equal emphasis on the development of industrialized and rationalized conventional systems. It would appear that in most West European market economy countries relatively more efforts and resources have been invested in promoting the rationalization of conventional building; whereas in East European planned economies relatively more ef-

[125] P. A. Stone, *op. cit.*, pp. 86–87.

forts and resources have been devoted to promoting fully industrialized building systems. Consequently, the essential conditions for a meaningful comparison between the two types of building systems have not yet obtained in most European countries.

As regards East European experience, quite aside from any allowances that might be made for the "adjustment" of data for political purposes, available cost data may be legitimately questioned in respect to the price placed on capital employed in industrialized building systems. If all capital costs, including interest, are not recognized, the substitution of capital for labor in industrialized building may proceed far beyond the least cost point, without the planning authorities ever becoming aware of it. As a consequence, real production costs may become distorted and comparisons with conventional construction costs may be misleading. Uneconomic allocation of capital in the Soviet Union is strongly suggested by the findings of the United States delegation that studied the U.S.S.R. building industry in 1965.

> "Soviet industrial engineers went all out in the planning of machinery, tools and equipment of all kinds which would be necessary for a speedy and economical flow of raw materials and of products. . . . The degree of mechanization they have now achieved is truly impressive. Perhaps in some plants such automation has been a bit overdone. 'Push button' operations are common rather than unusual, automatic welding machines are to be seen everywhere, tools and jigs of all types and sizes have been developed. . . . The capital investment in each of the plants the delegation visited must have been enormous. Such an investment would be inconceivable and without justification in a free society, where construction is everything but standard. In a society where the individual has the freedom of expression and the developer must satisfy the 'whims' of the buyer, housing developments are as varied as possible, and such extreme mechanization as is found in the USSR would be of no value. From a strictly technical point of view, however, the Soviet achievements in plant machinery are remarkable. Labor forces are continuously being reduced as automation is increased." [126]

On the other hand, even though there may have been a short-run uneconomic substitution of capital for labor in U.S.S.R. prefabrication systems, and a consequent uneconomic discrimination against conventional systems during the period of transition, the net effect has been to accelerate the rate of technological and economic change. By this means it might then be contended that industrialized building technology would come of age much more quickly and the whole society would thereby benefit much sooner.

In East European countries, the large panel component method has begun to realize not only some of the economies of large-scale production but also substantial external economies. Research and development expenditures have been concentrated on one technique, and a greater degree of specialization has been possible in the production of machinery for prefabrication plants. Large vocational training programs for prefabrication workers have been developed. Finally, a large feedback of information concerning experience in production, distribution, transportation, and erection has become available, en-

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[126] Charles C. Zollman, *op. cit.*, pp. 26–27.

abling further improvements to be made in these areas. The East European countries may in fact be on the verge of realizing further large reductions in cost as their technology becomes more sophisticated and as they apply more comprehensively the principles of industrial production to the whole building process.[127]

Similarly, in the market economies, the inconclusive results concerning the application of many prefabricated systems are not necessarily a reliable indication of the systems' future prospects. In some instances, prefabricated components have replaced only certain parts of conventional building, with the result that the number of tasks required to complete the work on the site and the complexity of the process as a whole may actually have increased as compared to conventional building. Such unfavorable results may be expected in the early stages of the development of industrialization, when it is not clearly understood that components must be designed in such a way that substantial advantages are obtained in two different production processes, the production of components in the factory and the assembly without adjustment of components on the construction site.

A large and stable demand is essential for optimal cost performance. Unless some agency comes into the market in some way to guarantee or underwrite long-term demand for the output of a prefabrication factory, it may be difficult—if not impossible—for industrialized systems to become well established. Not only is an untested, highly unstable market an important deterrent to new investment in industrialization, but unstable demand may also be a major factor contributing to the bankruptcy of such investments, once they are made. With the possible exception of Denmark and France, it cannot be said that the necessary conditions for a vigorous development of industrialization have really obtained in Western Europe.

Even though a large and stable market has been guaranteed in some West European countries for a single factory utilizing the large panel system, such an undertaking is still not an adequate test of the full cost-reduction potential of this method. A single plant cannot begin to realize the large external economies achieved in East European economies; moreover, it still has to contend with the costs involved in the various types of resistances to the introduction and application of an industrial technology that are discussed in Chapter VI.

Even assuming that the full development of industrialized building in the free market economies results in greater increases in efficiency, it would be a mistake to assume also that conventional building methods will not experience similar progress. British experience, for example, suggests that:

> "It should be possible to halve the average labor content in traditional local authority housing without using any new components or prefabricated elements. As industrialized techniques develop, they will force traditional methods to become more efficient. The two methods will exist side by side for many years." [128]

Somewhat similar trends are evident in Poland where rationalization of conventional building is being actively promoted along with a rapid expansion of industrialized systems. Traditional building, which constituted over 50 per cent of total Polish urban housing in 1963, is

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[127] V. Cervenka, Paris Seminar, p. 3.
[128] United Kingdom, *Response Paper No. 1*, Paris Seminar, p. 6.

being rationalized by greater on-site mechanization, increased use of prefabricated components, and the introduction of new and more efficient materials.[129]

In the long-run, it is somewhat doubtful whether either industrialized large element or rationalized conventional systems will be able to demonstrate a significant overall cost superiority in the European building industry. Comparative building costs probably can never be completely divorced from the influence of regional and local differences in regard to such factors as building materials, manpower availabilities, management and professional skills, and architectural traditions. Moreover, the system that may ultimately dominate the urban low-cost housing sector may not at all dominate the rural low-cost housing sector or the middle and upper income housing sector. As regards building maintenance and repairs, however, there is little question but that it will remain the almost exclusive province of conventional building systems. In the absence of a strong national policy giving a preferential position to one system over the other, the probabilities are that both industrialized and rationalized conventional systems will continue to develop for a long time to come.

V. The Search for Optimum Operation

Underlying the use of industrialized building systems is the assumption that such systems will lower housing costs below those achievable by conventional systems and thus make a significant contribution to the solution of Europe's housing problems. Naturally, builders employing industrialized methods seek to achieve an optimum level of production. This chapter will review the various contemparary European concepts of "optimum" and the difficulties that have been encountered in realizing it.

A. Definitions of the "Optimum"

Given the framework of the situation in which they do business, practically all building firms aspire to achieve an optimum operation. This is merely another way of stating the basic economic principle that each firm attempts to achieve that combination of its resources yielding lowest costs and thus to maximize its total profit.

In the past when building was exclusively a handicraft operation and when it was customary to build only one house on a single building site, construction operations proceeded more or less on the constant cost principle. That is, the scale of operation played little or no role in fixing costs of a particular house. Each construction site was unique. Design and production planning tended to be individualized.

Even in traditional construction systems there were important opportunities for cost reduction through repetition. Consequently, in the first four decades of this century there were already significant trends toward increasing the scale of building operations in order to obtain economies of repetition. It is only during the post World War II period, however, that the movement to industrialized building has grown to major proportions, both through the rationalization of traditional construction methods and through the development of a new prefabrication industry.

[129] National Monograph of Poland, Prague Seminar, Vol. III, pp. 540–43.

The success of industrialization—as applied to all lines of manufacturing—consists in the fact that unit costs are a function of the scale of production. Up to a certain point called the optimum, the larger the scale of production, the lower is the unit cost. It is for this reason that proponents of prefabrication have for many decades maintained that industrialization of the building industry will solve the problem of large-scale housing for low-income workers.

The concept of the optimum as applied to the building process has been considered from many different frames of reference. These diverse points of view make it exceedingly complex in its application.

In the first place, the concept may be viewed as a project optimum having essentially an on-site orientation: How many dwelling units of a given quality must be constructed in a single housing project in order to insure optimum production? While this approach is a good first step, it is clearly deficient, since in many urban areas available building sites may be well below optimum size. Moreover, it tends to ignore off-site considerations and the possibility that a local housing program may be able to achieve an optimum off-site level of production by undertaking simultaneously operations on many small and medium-sized sites.

A second approach has been to define the optimum scale of production in terms of a single prefabrication plant: At what level of house production of a given quality is the optimum reached? This conception is clearly more useful than the first, since fundamentally industrialization consists in the application of mass production methods, a process best facilitated by transferring functions from the building site to the factory. But this concept is likewise incomplete.

Industrialized building has concentrated principally on prefabrication of components comprising the structural framework, thereby substantially reducing completion time. But establishment of an optimum sized factory for the production of large concrete structural components involves only one important phase of the industrialized building process, since such components constitute only 25 to 30 percent of total building costs. The production of mechanical and utilities equipment and finishing components also needs to be industrialized, and each of these has its own optimum scale of production. Industrialization of mechanical and utilities equipment, which require relatively expensive materials and large amounts of skilled labor, may become as important in cost reduction as industrialization of the structural system, which requires lower cost materials and semi-skilled labor. Thus, while an optimum partial prefabrication system may be more efficient than no prefabrication at all, it is certainly no substitute for an optimum total prefabrication system.

The above considerations have given rise to a third approach looking toward the establishment of an optimum network of prefabrication plants producing not only the basic structural system but also all of the components required for the finished house. This concept is superior to the second concept, since a network of factories yields the most efficient combination of internal economies in house building. It should be observed that optimal efficiency of a particular subsystem may in a narrow sense and in the short-run appear to be incompatible with the overall efficiency of a network of productive facilities devoted to an industrialization of the building process. Moreover, a single network of factories geared to a local five-year housing program, for example in one major metropolitan area or province, is clearly inferior to a series of networks covering all metropolitan areas or provinces in the country for some 20 to 40 years—or until the national housing shortage has been overcome.

The fourth—and most complete—concept of optimum, therefore, envisages a series of optimum networks of factories which will embrace not only the internal, but also the external, economies that can be realized in a comprehensive. long-term national housing program. External economies, as noted in the previous chapter, refer to benefits accruing to an individual firm not as a result of its own efforts but as a consequence of the efforts of other firms in the industry and of other related industries. Such economies may often be realized slowly and indirectly, but their ultimate cumulative impact in reducing housing costs may be substantial.

A complete concept of optimum must make some provision for the indirect social costs of production, since little account is taken of these in normal market processes. Significant differences may exist in the social costs of industrialized and conventional building systems. Thus, no examination of optimum operation by industrialized systems is fully satisfactory without viewing the concept in its largest sense.

B. APPROXIMATIONS TO OPTIMUM LEVELS

The optimum production capacity of a national industrialized building program depends upon a large number of factors. For instance the wide range of possibilities in the realm of concrete technology is indicated by the various lengths of production cycles involved in different methods of casting (Table 9).

TABLE 9.—IMPACT OF PRODUCTION METHOD ON SCALE OF OUTPUT[1]

Method	Length of production cycle	Relative scale of output
1. Site casting	1 week	1
2. Temporary factory	1 day	5
3. Permanent factory:		
(a) Steam curing	8 hours	15
(b) Continuous kiln	4 hours	30
(c) Continuous casting	2.5 hours	48
(d) Pressing	10 minutes	720

[1] D. Bishop, "The Economics of Industrialised Building" (London: Building Research Station, Ministry of Technology, 1966), reprinted from Chartered Surveyor, design series 54, p. 198.

As a general principle the optimum scale of production varies directly with the degree of sophistication in technology. Consequently, with the evolution of building technology there is a tendency toward larger capacity plants. While an analysis of the problem of determining the optimum levels is beyond the scope of the present report, some indication of the probable magnitude of optimum sizes may be given by a review of available European data (Table 10).

In the early 1960s the annual capacity of three typical types of prefabrication factories in the U.S.S.R. were approximately 535, 1070, and 2140 dwelling units, respectively. In the middle 1960s, the plants visited by a United States mission to the U.S.S.R. had a capacity of 5,000 and 6,000 dwelling units respectively. While there may be some error in reporting, according to the Moscow Scientific Research Institute of Standard and Experimental Design there was in 1967 one Moscow prefabrication factory producing 30,000 apartments per year and another producing 15,000 apartments per year.[130]

In Czechoslovakia, prefabrication factories, depending upon the type of production and the degree of mechanization, have a wide range of capacities. Centrally located factories account for 63 percent of total production, with 10 percent being produced in factories of a capacity between 600 and 1,200 dwelling units per year, 44 percent in factories of a capacity between 1,200 and 2,400, and 9 percent in factories with a capacity of between 2,400 and 3,600.[131] With the extension of industrialization to embrace nonresidential, as well as residential, building, it is expected that future capacity of factories will be increased to the equivalent of between 4,800 and 6,000 dwelling units per year.

TABLE 10.—EXISTING AND PROPOSED CAPACITY OF CENTRALLY LOCATED PREFABRICATION PLANTS IN SELECTED COUNTRIES

[Dwelling units annually]

Country	Capacity of existing plants	Proposed capacity
1. Czechoslovakia:[1]		
A. Types (early 1960's):		
1.	600–1,200	(2)
2.	1,200–2,400	(2)
3.	2,400–3,600	(2)
B. Future plans	(2)	4,800–6,000
2 Denmark—Larsen & Neilsen[3]	1,500	(2)
3. France:		
A. Balency system[4]	2,000	(2)
B. Camus system[5]	2,000	(2)
C. Unspecified French study[6]	(2)	1,000
4. Netherlands—BMB system[7]	550	(2)
5. Spain[8]	(2)	4,000–5,000
6. United Kingdom[9]	(2)	2,000
7. U.S.S.R.:		
A. Types (early 1960's):[10]		
1.	535	(2)
2. (external wall panel)	1,070	(2)
3. (main production building)	2,140	(2)
B. Types (middle 1960's):[11]		
1.	5,000	(2)
2.	6,000	(2)
C. Moscow area (1967):[12]		
1. (See text, p. 93)	30,000	(2)
2. (See text, p. 93)	15,000	(2)
8. Battelle study[13]	(2)	[14] 1,000

[1] Monograph of Czechoslovakia, Prague Seminar, vol. II, pp. 302–3.
[2] Not available.
[3] R. M. E. Diamant, "Industrialised Building" (London: Iliffe Books, 1964), vol. I, p. 79.
[4] Ibid., vol. II, p. 23.
[5] Ibid., vol. I, p. 49.
[6] United Nations, "Industrialization of Building," (E/C.6/70/Add.1) (New York, 1967), p. 114.
[7] Diamant, op. cit., vol. I, p. 94.
[8] J. Nadal and F. Aguirre, Prague Seminar, vol. I, p. 215.
[9] D. V. Donnison, "The Government of Housing" (Middlesex: Renguin Books, 1967), p. 298.
[10] U.S.S.R., "Industrialized Techniques in Housing" (Moscow, 1963), pp. 34–5 and annex. In converting the capacity of the 3 typical sized plants from floor space into dwelling units, that is, 35,000 square meters, 70,000 square meters and 140,000 square meters, it has been assumed that a typical Russian dwelling unit had 65 square meters of total floor space.
[11] Charles C. Zollman, op. cit., p. 18.
[12] Ada Louise Huxtable, Soviet Has Mastered Industrialized Technology of Low Cost Mass Building, "New York Times", Oct. 20, 1967, p. 7.
[13] Estimated minimum annual production for economic use of building systems based on European experience. R. B. Guy and Associates, "The State of the Art of Prefabrication in the Construction Industry" (Columbus: Batelle Memorial Institute, 1967), p. 99.
[14] Per year, 5 years.

[130] Quoted in Ada Louise Huxtable. "Soviet Has Mastered Industrialized Technology of Low Cost Mass Building", *New York Times,* October 20, 1967, p. 7.
[131] Monograph of Czechoslovakia, Prague Seminar, Vol. II, pp. 303–304.

In Western Europe, Larsen & Neilsen in Denmark have a plant with a 1,500 dwelling unit capacity. In France, the Balency and Camus systems have plants with an annual capacity of 2,000 units, and French studies are reported to show that centrally produced prefabrication systems are uneconomic below a level of 1,000 dwelling units per year. Two Spanish experts have put the minimum practicable scale of plant at 4,000 to 5,000 dwelling units per year, while a British expert has concluded that in the United Kingdom the minimum size plant producing large concrete components of the type produced on the Continent is around 2,000 dwelling units per year. The smallest centrally located plant appears to be the Dutch BMB with a capacity of 500 (Table 10).

As the density of the urban market decreases and as the transport distance lengthens, a radius is finally reached at which a centrally located plant no longer has a cost advantage over temporary demountable on-site factories or rationalized conventional construction. Thus in Czechoslovakia, which has established a nation-wide network of prefabrication factories, 37 per cent of total industrialized building components are produced in small factories with a capacity of less than 600 units per year.[132] On-site plants with a capacity of 500 and 600 units respectively are also found in East Germany and the U.S.S.R. (Table 11).

TABLE 11.—EXISTING AND PROPOSED CAPACITY OF DEMOUNTABLE PREFABRICATION PLANTS IN SELECTED COUNTRIES

[Dwelling units annually]

Country	Capacity of existing plants	Proposed capacity
1. Czechoslovakia [1]	600	(2)
2. East Germany [3]	500	(2)
3. France:		
A. Balency [4]	400–500	(2)
B. Barets [5]	110	(2)
C. Costamagna [6]	500	(2)
D. Unspecified French study [7]	(2)	250–1,000
4. United Kingdom [8]	150–250	(2)
5. U.S.S.R. [9]	600	(2)

[1] Monograph of Czechoslovakia, Prague seminar, vol. II, p. 303.
[2] Not available.
[3] R. M. E. Diamant, "Industrialised Building" (London: Iliffe Books, 1964), col. II, p. 119.
[4] Ibid., vol. II, p. 22.
[5] Ibid., vol. I, p. 37.
[6] Ibid., vol. II, p. 16.
[7] United Nations, "Industrialization of Building" (E/C.6/70/Add.1) (New York, 1967), p. 114.
[8] D. Bishop, "System Building in Europe," design series 59 (London: Building Research Station, Ministry of Technology, 1966), p. 36.
[9] Diamant, op. cit., vol. II, p. 18.

In Western Europe on-site factories appear to have a wide range of capacities. A United Nations publication reports a French study, without giving the source which concludes that if the market is less than 250 dwelling units per year, the application of prefabrication is not recommended at all. For an annual market of between 250 and 1,000 dwelling units on-site casting is most efficient and above 1,000 units a centrally located factory becomes most advantageous.[133] As

[132] Monograph of Czechoslovakia, Prague Seminar, Vol. II, p. 303.
[133] United Nations, *Industrialization of Building* (New York, 1967) E/C.6/70/Add. 1, p. 114.

regards three French systems, Costamagna has an on-site plant with 500 dwelling units capacity, Barets employs a small 110-unit plant, and Balency has plants with capacities ranging from 400 to 500 units. In the United Kingdom, on-site plants with an annual capacity of 150 to 250 units are normally competitive with rationalized conventional construction (Table 11).

Determining the most efficient size of a single factory producing large panels does not end the search for the optimum. Such a factory is, in effect, only one of several sub-systems that must be coordinated into an optimum network. In Czechoslovakia the following assortment of precast units is utilized:

	Percent
Floor slabs and panels	28.0
Wall and partition panels	20.5
Outside wall panels and block panels	16.5
Roof slabs and panels	6.0
Columns and beams	5.0
Roof trusses	2.0
Stair components	1.7
Bridge structures	1.3
Miscellaneous items and individual products	[1] 19.0

[1] Vaclav Kasalicky, "Production of Industrialized Building Systems" in *Europrefab Conference Papers* (London, 1967), p. 23.

It is apparent therefore that in some urban areas it may be difficult to avoid small quantity production for components which constitute a relatively small per cent of the total building requirements. A Czech housing expert suggests that, while all pre-casting plants may pragmatically have to take on small lots at above optimum cost, overall optimal efficiency requires that mass produced elements constitute at least 70 per cent of total production.[134]

On the other hand, in most urban areas demands for prefabricated components from other types of building will supplement, at least to some extent, those from industrialized residential building. There is, for example, an increasing tendency for the conventional residential construction sector to utilize such components, as well as a steady demand from public works and industrial and commercial construction. Also, demands of the growing rehabilitation and repair market are shifting more and more to prefabricated components. As a result, the total demand for a number of components may be swelled to the point where production in a particular plant can reach the optimum or near optimum level.

C. PROBLEMS IN REALIZING THE OPTIMUM

Even though it may be possible to postulate the approximate dimensions of an optimum network of production facilities, the realization of this optimum in practice, particularly in market economies, faces formidable obstacles.

(1) *Eastern Europe*

One of the great advantages of centrally planned economies in the field of industrialized building is that governments guarantee a market for a given number of dwelling units for a given number of years, not only on a national but also on a local basis. Moreover, in economies that

[134] Vaclav Kasalicky, *op. cit.*, p. 23.

have embarked on a policy of progressive industrialization of the building industry, technology has a built-in growth factor.

As a consequence, economic planners in the building industry can be relatively unfettered in approaching the problem of optimum operation. They can concentrate directly on defining and applying the fundamental technical and economic criteria for achieving the most efficient level of operation. In principle, therefore, East European experience might seem to provide reliable technical and economic guidance for optimum operation. But as observed in the preceding chapter the cost accounting system employed in centrally planned economies, based on the labor theory of value, impairs the usefulness of that experience as an economic guide for optimum operations in market economies.

(2) *Western Europe*

In the absence of long-term government guarantees of one kind or another, industrialized building in free market countries has an even greater vulnerability than conventional building historically has had. The large investment required in prefabrication plant sharply reduces the flexibility of operations that the contractor has traditionally enjoyed in the building industry and jeopardizes the industrialized builder's capacity to survive in an unstable market.

The prefabricator has two general options, neither one of which has proved altogether satisfactory. The first, the conservative investment approach, is to adopt a sub-optimum policy, for example by investment in small scale plant. When plant investments are made only on a small scale, the opportunity of using highly sophisticated technologies is immediately limited, the unit cost is higher, and the potential price appeal to clients is consequently diminished. Thus, in foregoing the opportunity of optimum operation, the firm may from the very beginning be precluded from making a superior showing in comparison with rationalized conventional construction.

Another type of sub-optimum approach has been to confine industrialization to only part of the building process, such as the structural system. In limiting prefabrication, often to that part of the building process which involves a relatively small opportunity for economizing in the use of expensive materials and highly skilled labor, the firm may again be unable to make an impressive showing in competition with conventional systems.

As a matter of fact, in the transistional stage of partial application of industrial methods, total building costs may actually be more than those of conventional systems. The unskillful use of prefabricated components in conventional construction has often only replaced part of the operation, so that the number of the operations, their starting and stopping, and the whole complexity of the process may actually have been increased. If prefabrication is to be successful, therefore, it is necessary to eliminate entire traditional processes, so that there are cost advantages not only of industrial production in the factory but also of assembly of components on-site without adjustment.

The second principal option is to invest in what has been determined to be the optimum size of productive facilities. As long as the enterprise is able to market its output at full capacity, the plant optimum is realized. But should demand decline, this optimum is threatened.

A prefabrication firm confronted with declining demand has the choice of utilizing surplus capacity for stockpiling or of leaving a part of the existing capacity idle. Production for stockpile quickly encounters practical limitations. Since prefabricated concrete components are generally bulky, available storage space is rapidly filled up. At the same time, capital costs involved in carrying a larger inventory mount steadily and at some point become prohibitive. Furthermore, the materials handling costs and the increasing risks of damage to components also increase. Two essential stages in an efficient technology are to be able to transfer prefabricated products from the factory directly onto a means of transport and transfer components from a means of transport directly into their ultimate positions on the site.[135] Intermediate storage reduces some of the cost advantages of industrialization.

On the other hand, high overhead costs associated with idle capacity rather quickly cancel out cost advantages that industrialized systems might have over conventional methods.

In France, heavy prefabrication systems are reported to have an annual capacity of around 60,000 dwelling units but a demand of less than 40,000; in Germany they have a capacity of about 30,000 and a demand of some 20,000; while in the United Kingdom the capacity is reported to be 40,000 compared to a demand of roughly 20,000.[136]

It is clear, therefore, that practical realization of an optimum operation—or even a sub-optimum operation which may still be substantially below the costs of conventional construction—is more difficult to achieve in building than in probably any other major industry. In the automobile industry with which building has frequently been compared, it is not possible for traditional handicraft methods to co-exist with mass production systems, except in the high-priced, custom market. The market is so large, the technology so sophisticated, the capital requirements so high, and mass production so efficient, that low capital-intensive methods just cannot compete, even though the overhead costs of idle capacity or of stockpiling automobiles may become significant.

In the building industry, however, it has been possible for traditional construction systems to exist side by side with industrialized systems, and not only in the high-price, custom market. Because of its locational aspect, the geographical extent of the building market is circumscribed. As observed in the preceding chapter, to cope with such a limited market, which is in addition the most unstable market among all major industries,[137] building has been forced to develop a highly amorphous and dispersed structure with a great capacity for adaptability.

The more sophisticated the technology and the higher the capital requirements, however, the less viable are prefabrication firms in competing with conventional construction systems. Often, even though a low capital-intensive technology in the building industry cannot undersell a high capital-intensive technology, it may actually have a superior survival value because of the nature of the market.

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[135] Vaclav Kasalicky, *op. cit.*, p. 23.
[136] R. B. Guy and Associates, *op. cit.*, p. 59.
[137] International Labour Office, *Practical Measures for the Regularization of Employment in the Construction Industry* (Geneva, 1964), Chapter I.

Only by changing the traditional nature of the building market, therefore, is it possible for an industrial technology to prosper. In place of instability there must be continuity; in place of sub-optimum scale there must be optimum operations; in place of a single optimum firm there must be an optimum network of facilities applying an industrial technology. So crucial is the factor of stability, that the Battelle Memorial Institute probably rightly concludes that continuity is even more important than volume in assuring the success of prefabrication.[138] It is unlikely that the full optimum can ever be achieved unless the social interest is taken explicitly into account through some form of long-term public intervention in the building market.

These considerations are of little practical consequence for middle and high income group housing. High prices for custom built housing are not a fundamental deterrent to new construction. But for low income group housing, which in various European countries constitutes from one third to two thirds of the total housing market, these considerations do become vital.

VI. Political Considerations

As observed in the preceding chapter, the key to testing the full potential of industrialized building is the creation of a large and stable market. To supply this market, a number of governments, particularly those with centrally planned economies, have launched comprehensive national housing programs. This chapter will first review the broad outlines of these national programs and second, examine the resistances that similar programs have encountered in free market countries.

A. GOVERNMENT ACTION TO CREATE A GUARANTEED LONG-TERM HOUSING MARKET

The most important pioneer in developing a guaranteed housing market has been, of course, the U.S.S.R. After a long development period following the end of the war, in 1959 the Soviet government announced its seven year program for the construction of 650 to 660 million square meters of housing, or about 15 million dwelling units, during the period 1959–1965. Other East European countries have had similar programs as a part of their general economic planning.

In Hungary, three types of economic plans may be distinguished. A 20-year program for 1961–1980 has been drawn up for the building industry based on the growth envisaged in the other sectors of the national economy and on the expected improvements in the social and cultural life of the people. Within this program a five-year plan then formulates targets on the basis of priorities in the national economic plan and of resources which will be available for further expansion. Special attention is given to co-ordinating the manufacture of prefabricated components with on-site construction programs. Finally, detailed annual building plans are prepared. It is through these annual plans that the economic planning agency, the ultimate client of the building industry, ensures effective co-ordination of the activities of all members of the "construction team".[139]

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[138] R. B. Guy and Associates, *op. cit.*, p. 60.

[139] National Monograph of Hungary, Prague Seminar, Vol. II, pp. 406–8, also comments of J. Bogusz, *ibid.*, Vol. I, pp. 161–3.

Among free market countries, the French Government embarked on one of the most successful postwar prefabrication programs. In 1953 a long-term "industrialized sector" housing program was adopted, providing for 25,000 additional dwelling units to be constructed by a score of different industrial process.[140] With this initial government support, a number of prefabrication systems became established during the years between 1956 and 1963, but have been unable to make much further progress without greater public support. Thus, even though roughly 100,000 houses were constructed in 1965 with various prefabricated components, the prefabricated concrete panel systems accounted for only eight percent of total house construction [141] (Table 1).

In 1966, the Danish Government embarked on a long-term program involving the annual construction of 7,000 dwellings utilizing industrial techniques. These dwellings constituted 18 percent of total construction, or about 30 percent of annual house building for rental markets. This policy envisaged a five-year rolling program revised annually. When a project is placed in the program, it is guaranteed that a starting permit will be issued at an agreed date within the coming five years. To be eligible for this government program, projects must be based on advanced, industrialized methods, but no restrictions are imposed on the type of system, choice of materials, etc.[142]

Still another approach to developing a large and stable market has been followed in the United Kingdom, where special efforts have been made to promote the continued development of a wide range of industrialized systems that are currently in use. Since 1964, the National Building Agency has attempted to persuade the nearly 1,400 local authorities to form ordering consortia in letting contracts for public housing. By July 1966, 400 local authorities had banded together to achieve large-scale ordering and some basic standardization of building dimensions and components.[143]

B. LONG-TERM PHYSICAL PLANNING

To obtain the full benefits of industrialized building systems, it is essential that housing be conceived and built as a part of an integrated community. Not only does such an approach yield higher productivity in enlarging the scope for industrialized building, but it also promotes greater efficiency in the community that eventually emerges.

One of the distinctive features of the U.S.S.R. housing program is that it is carried out in conjunction with the building of schools, shops, cultural and other community facilities. An overall coordination of construction activity with the national investment program is in fact achieved through central economic planning. While in practice considerable sectors of private and cooperative housing have remained in the U.S.S.R., their importance seems to have declined. In principle the Soviet government is apparently committed to creating an industrial, urban society, primarily housed in multi-family, multi-story

140 National Monograph of France, *ibid.*, Vol. II, pp. 378–9.

141 United Nations, *Annual Bulletin of Housing and Building Statistics for Europe* (New York, 1966), p. 51.

Airgram A–1716, March 3, 1966, from Embassy Paris states that principal large-panel French systems accounted for only 15,000 units in 1965 or less than 4 percent of the total.

142 Denmark, Ministry of Housing, *op. cit.*, pp. 6–7.

143 *Statist*, "Backing the Systems to Beat the Housing Problem", June 29, 1966, p. 308.

dwellings constructed mainly of precast components. Approaching the housing problem in this manner, the government has been able to maximize building economies not only by expanding existing towns and cities but also by creating new towns.

Among West European economies, the principle of advance planning of the physical environment through town and regional planning is generally accepted. France has reached the most advanced stage in regional planning in its fifth Plan, whereby the government has attempted to achieve a close integration of regional and inter-sectoral planning within the national plan. In most West European countries, governments have also embarked on regional programs to develop growth centers in depressed areas.[144] Nevertheless, the implementation of physical planning principles has often fallen short of expectations. Partly this arises from lack of a basic legislative authority as well as a shortage of professional planning personnel, but mainly it is attributable to failure to commit sufficient financial resources for the necessary planning preparations.[145] As a consequence, therefore, it has not yet been possible in Western Europe to realize the full building economies that can be achieved through integrated long-term physical planning at the local, regional and national levels.

C. RESISTANCE TO INDUSTRIALIZED BUILDING SYSTEMS

Among centrally planned economies there was probably little opposition within the building industry to the adoption and widespread application of industrialized methods. In fact, on the return of peace after World War II the resources of the building industry were so badly depleted, and so great an expansion was needed to meet postwar requirements, that reorganization of the industry along new lines seems to have been carried out without resistance.

In market economies, however, resistance to the introduction of industrialized building methods has developed on several fronts. Some architects have resisted the introduction of standardized industrialized building. In France, for example, professional architectural associations have strongly opposed nation-wide competitions which tended to promote the establishment of teams of architects and contractors for designing prefabricated housing.[146]

In many countries a certain amount of opposition to industrialized methods, particularly prefabrication, was initially demonstrated by the traditional skilled construction trade unions. In the United Kingdom in fact, the opposition at one time took the form of strikes and boycotts against builders handling prefabricated components.[147]

Conventional builders' responses to industrialized building systems have varied widely. Their initial reaction has tended to be hostile, but, as observed in the preceding chapter, they have generally responded to competition from industrialized systems by improving and rationalizing their conventional methods.

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[144] L. H. Klassen, *Area Economic and Social Redevelopment* (Paris: Organisation for Economic Cooperation and Development, 1965); L. H. Klassen, *Methods of Selecting Industries for Depressed Areas* (Paris: Organization for Economic Cooperation and Development, 1967).

[145] E. Jay Howenstine, *Compensatory Employment Programmes, An International Comparison of Their Role in Economic Stabilization and Growth* (Paris: Organisation for Economic Cooperation and Development, 1968), Chapter XV.

[146] National Monograph of France, Prague Seminar, Vol. II, pp. 381–83.

[147] R. B. White, *Prefabrication: A History of its Development in Great Britain* (London: Ministry of Technology, Building Research Station, H.M.S.O., 1965), pp. 108–149.

Mortgage banks and insurance companies have also tended to block the expansion of industrialized housing. For example, in France, even when new prefabricated materials were officially approved by the Government, they were still viewed with suspicion by insurance companies that had to cover the ten year liability of builders.[148]

Many of the resisting groups in the building industry have been directly or indirectly responsible for the retention of outdated building codes, which have often been a brake on the development of industrialized housing. Local building codes are frequently written in terms of specifications rather than performance, thereby excluding the introduction of new prefabricated materials. In Austria prefabrication has encountered difficulties from the fact that provincial building regulations, of which there are fifteen, permit the use of prefabrication only under certain conditions.[149] Building codes in France have been less of a problem since the substitution in 1955 of a national building code for various sets of local regulations.[150]

In conclusion, while political problems have been troublesome in some market economy countries, they have not been severe enough to prevent the introduction of industrialized building systems. Indeed, as these systems become more widespread, the political problems appear to diminish.

VII. Social Considerations

Whether or not the consumer has a choice as regards the nature, type and location of his housing, all accommodation—at least in theory—is designed to service best the ultimate user. In examining the role of social considerations in determining choices among European building systems, it is useful to examine four major factors: the existing housing stock; the cultural heritage; user requirements; and consumer choice.

A. THE ROLE OF THE EXISTING HOUSING STOCK

In the early postwar period, most European governments were confronted with exceedingly critical housing shortages as a result of war damages and a low rate of construction both during the war and in the pre-war depression period. As a result, housing standards in new construction were reduced to a bare minimum. Standardization was acceptable for new construction if it promoted greater productivity; the principal objective was simply rapid production of additional space. In a country confronted with serious overcrowding, the doubling of the quantity of space per person naturally has a much higher social value, as compared with qualitative improvement in the same space per person, than it does in a country not confronted with such overcrowding. In this situation, industrialized housing emerged as one of the most promising means of alleviating the housing shortage.

In the U.S.S.R., large panel construction gradually assumed ascendancy in the building industry, and it has grown steadily in importance in other East European countries as well. With so great a backlog of housing demand, overcoming the quantitative shortage took precedence over qualitative improvement. By the middle 1960s, however, as the

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[148] National Monograph of France, Prague Seminar, Vol. II, p. 380.
[149] National Monograph of Austria, Prague Seminar, Vol. II, p. 261.
[150] National Monograph of France, *ibid.*, p. 382.

pressure of physical overcrowding diminished, a greater concern for user requirements and for qualitative improvements became manifest.

In West European countries as well, strict limitations were imposed on standards during the early postwar period, as efforts were concentrated on overcoming quantitative deficiencies. While large panel construction was developing slowly and in comparatively few places, various forms and degrees of mechanization and rationalization were being widely introduced into conventional construction. By the late 1950s, however, emphasis in most market economies had begun to shift to qualitative improvements in new construction.

It is clear that as critical space shortages disappear, increasing importance will be attached to qualitative improvement in housing accommodation, and there will be greater pressure for diversity in choice of accommodation.

B. THE CULTURAL HERITAGE

A great challenge for industrialization of building has been achieving harmony with the European cultural heritage. Major elements that have influenced the European attitude and practice with regard to industrialized building systems are the following: an appreciation for quality in architecture; a respect for the human scale; an attachment to open space and nature; and a feeling of community.

One of the characteristics of traditional European building is its high quality—not only in the material sense but also in esthetic appearance. In practically all European cities there are houses and other private and public buildings many hundreds of years old—partly because masonry bears age well. In many towns, even beautiful old wood houses still exist in a good state of repair. In modern times in both Eastern and Western Europe, university faculties in architecture, planning and engineering have maintained a continuity in this building tradition. They have been distinguished by the achievement of a balance between scientific excellence and the practical building arts. At the same time the long-standing popular respect for professional quality has created a receptive climate for good design. On the whole professional and administrative staff responsible for design and approval of housing projects have been able to work together in a creative atmosphere.

Second, most European cities were designed long before the advent of machines and motor vehicles. The treasured part of these cities is the "old town", typically with winding cobblestone streets, gabled tile roofs, and distinguished wrought iron fittings. Designed for the pedestrian, the cities have retained their human scale. Industrialized housing, however, has yet to strike a balance between retaining a human scale and the need to accommodate itself to modern urban requirements.

Third, although European urban dwellers are long accustomed to city life, they nevertheless retain a great respect for open spaces, trees, flowers, and greenery. Living in concentrated masonry structures has heightened the populace's appreciation of and their need for contact with nature, both within and outside of the urban environment. By comparison, recently created cities, spawned in a highly materialistic, industrialized milieu, often contain a certain barrenness.

Within the European cultural background there is also a strong sense of community, born of centuries of experience in common defense against fire, invader, and flood. Cooperation has become an established element in the European way of life.

It is readily apparent that much of the animus and discipline of industrial technology diverges from the spirit and mentality of European tradition. It is not surprising, therefore, that as observed in Chapter III the early products of many industrialized building systems did not blend well with the urban environment. Monotony and bleakness were much in evidence. It is only in more recent years that, in response to social demands rooted in this cultural heritage, architects have succeeded in harmonizing with traditional values the forms created by the new technology of industrialized building.

C. USER REQUIREMENTS

In Europe housing policies and the structure of the building industry have been such that the ultimate consumer, particularly among low income groups, has played a comparatively small role in determining the kind of housing that is available to him. Urban housing has been mainly multi-family masonry construction. It has been rented, not owner-occupied. In the past 50 years there has been an increasingly large social housing sector, which public authorities have owned and rented at subsidized levels. Except in housing for upper and high middle income groups, there has been until recently little systematic effort to determine and build according to consumer preferences.

In East European countries there has been an increasing awareness of user requirements. Czechoslovakia has taken the lead in this respect,[151] followed in particular by Hungary and Poland. The Research Institute for Building and Architecture in Czechoslovakia has undertaken a broad program of social as well as technical research on user requirements, utilizing all types of analytical methods, including computer techniques.[152] As a part of the Czechoslovakian program, in 1962 a nation-wide discussion was initiated with a series of model exhibitions in the ten largest towns. Some 425,000 people saw the exhibitions; 34,000 persons filled out questionnaires regarding the advantages and drawbacks of the various models; and 14,000 persons offered suggestions for improved housing design and arrangements. The purpose of this Czechoslovakian program is to develop a scientific basis for introducing eventually a greater flexibility into the design of industrialized housing, and thus to overcome the insufficient attention that has been paid to tenant requirements.

In Western Europe research on the social aspects of user requirements has lagged somewhat behind technical research. There is, however, a general recognition of the need to introduce greater flexibility into the design of industrialized housing, and a number of studies are now underway in various countries. The Swedish Institute of Building Research has offered its services to the International Council for Building Research, Studies and Documentation (CIB) in coordinating international research relating to sociological aspects of housing design.[153]

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[151] Jiri Musil, "The Sociological Approach to Planning Workers' Housing; the Experience of Czechoslovakia, *International Labor Review*, December 1962, pp. 548–549.
[152] V. Cervenka, *op. cit.*, p. 6.
[153] United Nations, Economic and Social Council, Committee on Housing, Building and Planning, *Report of Fifth Session* (E/C.6/85, Supp. No. 7) (New York, 1968), p. 28.

It is clear that a great deal of work remains to be done on determining user requirements.

D. THE ROLE OF CONSUMER CHOICE

Postwar awareness on the part of the common man that the process of national economic growth can mean forever higher disposable income is beginning to have a far-reaching impact on the housing market. In the face of absolute space shortage, the occupant with only meager accommodation tends to count himself fortunate. As that situation eases, the occupant demands more, yet nevertheless is satisfied with relatively modest accommodation. But, as the occupant's income rises, he demands higher standards of housing and more attractive surroundings in his physical environment.

In East European economies, it will take some time before the consumer will be able to express his choice directly in the housing market. Not only is there a critical shortage of space to overcome, but also the central planning apparatus tends to obstruct expression of consumer choice. Nevertheless, as observed in the case of Czechoslovakia, housing policy has already shown a responsiveness to the view that consumer preferences should be considered in determining housing design.

By contrast, in Western Europe expressions of consumer choice have been a major factor holding back the development of prefabrication. In part consumer resistance has been a reaction to early prefabricated structures that were bleak and unimaginative in design. In other cases, such as Austria [154] and Finland [155] resistance has arisen from prejudices against standardization and a preference for individualism in one's own home.

While the promises for significant technical breakthroughs in prefabrication remain bright, thus far performance has fallen considerably short of expectations. Partial prefabrication (prefabrication of components such as doors or windows) has grown steadily in importance; in fact it has been increasingly utilized by rationalized conventional construction. But with few exceptions, total prefabrication systems have prospered and expanded only where they have had some form of assistance, guarantee, or underwriting by a public or cooperative body. Given a choice, therefore, consumers as a whole have not opted for total prefabricated systems. Dwelling units built by many such systems have cost more and have been of lower quality than structures built by rationalized conventional methods. Moreover, the cost advantages that some prefabrication systems have been able to achieve have tended to be offset by a lack of individuality.

The question of consumer choice goes to the heart of one of the central problems of industrialized building, the difference of approach of the designer and the manufacturer.[156] The construction designer has two main tasks. First, he must determine user requirements for the end product, such as requirements for space, circulation, loading, heating, lighting, ventilation—in fact all the physical and psychological conditions which a building has to satisfy in itself and in relation to the climate in which it is built. Second, he must enhance the

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[154] National Monograph of Austria, Prague Seminar, Vol. II, p. 260.
[155] National Monograph of Finland, *ibid.*, p. 374.
[156] R. Walters, *op. cit.*, pp. 3–4; V. Cervenka, *op. cit.*, pp. 4–5.

lives of those who will live and work in and around the structure; in other words, he must create good architecture. The work of the designer should reflect the fact that the activities, needs, and tastes of people are constantly changing. The prefabrication manufacturer, on the other hand, has quite a different approach. For him, efficiency in production is all-important; this requires standardization and mass production of whatever type of prefabrication system is decided upon. By these means he can achieve automation in the production process and obtain the best quality consistent with commitment of a minimum of resources.

A great deal of attention has been given to the problem of harmonizing the differing approaches of producer and consumer, of striking a good balance between flexibility and standardization in design. It may well be that automation and computer control can provide a low-cost reconciliation of these two requirements.

VIII. Conclusions

Taking account of the shortcomings of available data described in the Introduction, the major findings of the study are as follows:

1. At this stage in the evolution of housing policy and practice, large-scale application of industrialized building systems fundamentally is not limited by technological, design or cost factors, but only by institutional constraints.

2. East European countries report that large panel prefabricated building systems enjoy a cost superiority of some 15 per cent over conventional construction in such countries. These industrialized systems occupy a predominant position in the housing market of Czechoslovakia, East Germany and the U.S.S.R. In all of Eastern Europe, the share of industrialized building in national housing production is increasing at a significant rate.

3. In Western Europe industrialized systems have demonstrated cost superiority over conventional building in some countries, notably Denmark and West Germany, approximately equal costs in other countries, and even in certain instances cost inferiority to rationalized conventional methods. In no West European country does industrialized building occupy a predominate position in national housing production, though its share of the market is steadily increasing in most countries.

4. No overall generalization can be made concerning the relative efficiency in Europe between industrialized and rationalized conventional building systems. In Eastern Europe the neglect of capital costs in accounting systems limits the usefulness of cost data for comparison with free market economies. In Western Europe industrialized systems have not yet been developed on a scale and with a continuity that will permit an adequate test of their cost reduction potential. Moreover, since rationalized conventional systems have probably been developed more intensively in Western Europe, they would be expected to be relatively more competitive with industrialized systems there than in Eastern Europe.

5. Under certain circumstances, European experience does justify conclusions with respect to current relative efficiencies of the two

building methods. For low-cost housing in economically developed urban areas with trained industrial and professional manpower and an adequate supply of available capital, industrialized building is in general relatively more efficient, providing it is able to obtain the requisite scale and continuity of production. For rural housing, middle and upper-income group urban housing, and maintenance, repair and renovation of the existing housing stock, rationalized conventional building is in general relatively more efficient. In the absence of a strong national policy giving a preferential position to one method, the probabilities are that both industrialized and rationalized conventional systems will continue to develop competitively for the foreseeable future.

6. The possible development of compact, efficient on-site prefabrication plants may significantly affect the relative efficiency of industrialized building and extend its market beyond highly concentrated urban areas.

7. Industrialized building has demonstrated other advantages—including quality control, reductions in on-site labor requirements and completion time, and circumvention of the recruitment and training difficulties that many European countries have encountered in expanding their on-site construction labor force.

8. In addition to immediate direct economies from mass production, continuous large-scale industrialized building introduces the possibility of obtaining substantial indirect, long-run external economies. Such external economies arise from concentration of research and development expenditures, specialization in factories producing prefabrication machinery, establishment of vocational training programs in prefabrication skills, and more effective use of information feedback from experence in production, distribution, transportation and erection.

9. In its developmental phase, the design of European industrialized building systems has been deficient in two principal respects: excessive standardization to achieve lowest unit cost and largest total output, particularly in Eastern Europe, resulting in a tendency to neglect consumer preferences; and in some systems, particularly in France, engineer domination of the architect with respect to project design. More recently, industrialized systems have achieved a higher quality both in building design and in integrating housing with the existing environment.

10. Efficient use of industrial technology requires substantial changes in the traditional relationships among designers, building components producers and contractors so as to achieve unified managerial coordination of the building process.

11. Efforts to protect traditional building methods have not substantially impeded development of industrialized building systems, except to the extent that they have been expressed in the maintenance of scientifically lagging building codes.

12. Industrialization is significantly changing the skill-mix of the building labor force by eliminating many of the traditional on-site craft skills; by increasing demands for engineers, technicians, and supervisory staff; and by creating new demands for multi-skilled workers, machine operators, and assemblers.

13. The development of sophisticated manufacturing technologies and the growing international agreement on dimensional coordination based on the ten centimeter module have greatly increased the practicability of developing supranational open industrialized building systems and of expanding international trade in building components.

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The following are the chief sources of information on European industrialized building and are those on which the present study has been based. A brief comment is provided on the contents and usefulness of each.

1. D. Bishop, *The Economics of Industrialised Building*, Design Series No. 54, Building Research Station, Garston, England, 1966, 11 pp.

This paper presents basic cost data and information on building technology as it relates to experience with industrialized building in the United Kingdom.

2. D. Bishop, *Systems Building in Europe*, Design Series No. 59, Building Research Station, Garston, England, 1966, 4 pp.

This article is a summary of Mr. Bishop's impressions of the building industry in Sweden, France, and the U.S.S.R. His critical analysis of the factors operating behind the building scene that affect building are enlightening.

3. R. M. E. Diamant, *Industrialised Building*, Iliffe Books Ltd., London, 1964, 1965, Volumes I & II, 206 & 214 pp., illustrated.

These two volumes are a collection of three to five page summaries of the major European building systems that originally appeared in the "Architect and Building News" magazine. The source material for the articles is probably manufacturers' literature and interviews with knowledgeable persons. In some instances figures used in the text appear to contradict one another. Despite this shortcoming the description of the systems and liberal use of photographs present a useful picture of the European building scene.

4. D. V. Donnison, *The Government of Housing*, Penguin Books Ltd., Middlesex, England, 1967, 391 pp.

Many tables and explanation of the European housing situation make this book invaluable in understanding the social, economic and political aspects of the question. Donnison argues that overcrowding and squalid surroundings are as bad as hunger, illness and unemployment and must be dealt with by all sectors of the economy.

5. Jiri Franek: *Housing in Czechoslovakia*, Research Institute for Building and Architecture, Prague, 1967, 61 pp.

This booklet contains a brief description of various aspects of Czech industrialized building methods, including architectural designs, pictures of finished dwellings and some tabular material.

6. R. B. Guy and Associates, *The State of the Art of Prefabrication in the Construction Industry*, Columbus, Ohio, Battelle Memorial Institute, 1967, 236 pp.

The Report prepared for the Building and Construction Trades Department of the AFL–CIO covers experience in both Europe and the United States. Special attention is given to the probable constraints on future growth of prefabrication and its impact on the various building trades.

7. International Council for Building, Research, Studies and Documentation—CIB, *Innovation in Building*, Elsevier Publishing Co., New York, 1962, 232 pp., illustrated.

The second CIB Congress proceedings approach industrialization of building by examining factors that lead to innovation in the building industry. This text presents excellent background material for understanding the how and why of industrialized building. Especially relevant are the discussions on how new developments arise, interplay between builder and user, and a review of construction trends around the world.

8. International Council for Building Research, Studies and Documentation—CIB, *Towards Industrialised Building*, Elsevier Publishing Co., New York, 1966, 491 pp., illustrated.

This collection of the third CIB Congress Conference papers gives the reader a clear picture of the degree of sophistication of industrialized building research as practiced throughout Europe. Eastern Europe is concerned with production and optimization of plant facility use with emphasis on developing mathematical models to determine optimization of various practices. Western Europe on the other hand concentrates more usually on planning activities. Some of the major topics discussed in these papers are the changing structure of the building industry, the integration of design and production, planning of operations and functional requirements.

9. International Federation of Building and Public Works, *Social Aspects of Prefabrication in the Construction Industry*, Paris, 1967, thirteen separate country monographs.

This volume contains answers from national employers' associations in all West European countries to a questionnaire regarding labor-management practices, with a view to developing an "employer point of view" for the discussions to take place at the 8th Session of the ILO Building, Civil Engineering and Public Works Committee in September 1968.

10. International Labor Office, *The Social Aspects of Prefabrication in the Construction Industry*, Geneva, 1968.

This report prepared for the 8th Session of the ILO Building, Civil Engineering and Public Works Committee to be held in September 1968, deals primarily with labor aspects of prefabrication in both the developing and highly developed countries.

11. P. E. Malmstrom and J. F. Munch-Petersen, *Philosophy of Design and Adaptation to Production in Industrialized Housing*. United Nations Seminar on Prefabrication of Houses for Latin America, Copenhagen, 1967, United Nations, New York, 1967, 19 pp.

This paper is a useful summary of factors to be considered when changing the locale of a prefabricated housing system.

12. A. A. Nevitt (Ed.), *The Economic Problems of Housing*, Macmillan, St. Martin's Press, New York, 1967, 329 pp.

This volume contains essays presented to a meeting of the International Economic Association. Of particular interest are: "The Political Economy of Housing" by D. V. Donnison; "Changes in the Output of the Building Industry as a Factor in the Developing of Home Building" by E. Kuminek; and "Some Economic Problems of Housing in the U.S.S.R." by V. A. Nazarevsky.

13. Organisation for European Economic Co-operation, *Modular Co-ordination in Building*, Paris, 1956, 168 pp.

This study reviews the progress made on establishing modular coordination in design, manufacture of building materials, and building in European countries.

14. Organisation for European Economic Co-operation, *Prefabricated Building: A Survey of Some European Systems*, Paris, 1958, 122 pp.

This brochure gives illustrations and descriptions of the major European prefabrication systems.

15. P. A. Stone, *Building Economy: Design, Production and Organisation*, London, Pergamon Press, 1966, 249 pp.

This is a basic text on industrialization as it relates to the British economy. The author concludes that rationalization of the building industry can be achieved by both evolution of traditional practice and revolution through exploration of new materials and methods such as are found in industrialized building systems. With either method, organization and planning are most important.

16. U.S.S.R., *Industrialized Techniques in Housing*, *Moscow*, 1963, 85 pp.

This booklet contains a description, mainly technical, of industrialized building methods, with pictures of plants, panel making machinery and housing units.

17. United Nations, *Industrialization of Building*, E/C.6/70 and E/C.6/70/ADD. 1, United Nations, New York, 1967 (two volumes).

These two volumes were prepared for the Committee on Housing, Building, and Planning of the Economic and Social Council covering mainly the problem of industrialization in developing countries. The Appendix contains a number of national monographs on the subject.

18. United Nations, *Modular Co-ordination in Building*, United Nations, New York, 1966, 67 pp.

This document describes the status of modular co-ordination efforts around the world. It argues that such rationalization is one of the most important requirements of the industrialized method of building.

19. United Nations, Economic Commission for Europe, *Annual Bulletin of Housing and Building Statistics for Europe 1966*, United Nations, New York, 1967, 136 pp.

This is the basic statistical text on building as collected by the United Nations Committee on Housing, Building, and Planning.

20. United Nations, Economic Commission for Europe, *Cost, Repetition, Maintenance: Related Aspects of Building Prices*, ST/ECE/HOU/7, United Nations, New York, 1963, 165 pp.

This report contains numerous charts, graphs and tables concerning optimum size and production runs for prefabrication plants in Sweden and Czechoslovakia. Also, the economic significance of maintenance and the problems of durability are discussed.

21. United Nations, Economic Commission for Europe, *Effect of Repetition on Building Operations and the Processes on Site*, ST/ECE/HOU/14, United Nations, New York, 1965, 150 pp.

This study undertakes to examine in by means of mathematical formulations and the graphical development of statistical data the effects of repetition on building. A useful discussion of the flow line management method is included.

22. United Nations, Economic Commission for Europe, *Proceedings of the Seminar on Changes in the Structure of the Building Industry Necessary to Improve its Efficiency and Increase its Output*, Prague, Czechoslovakia, April 1964, Volumes I–III, ST/ECE/HOU13, United Nations, New York, 1965, 713 pp.

The first volume contains the conference proceedings. Volumes II & III national monographs from 20 European countries plus the United States and Israel. The national monographs prepared by Rapporteurs for the Rapporteurs for the country which they describe and relatively uncritical. Volume I reports conference discussion of such issues as the structure and development of the building industry, product and production processes, problems of continuity of demand and production, and trends and future prospects of the building industry .These three volumes constitute the best single source available.

23. United Nations, Economic Commission for Europe, *Second ECE Seminar on the Building Industry*, Paris, April–May 1967, HOU/BUILD/27, with 4 addenda.

The basic paper contains essential information on the Seminar; Add. 1 and Add. 2. contain Conclusions and Recommendations by the Seminar; Add. 3. contains 4 excellent basic papers setting forth the issues; while Add. 4 contains a summary of the discussion in the Seminar. A number of unpublished papers were prepared and circulated in response to the papers contained in Add. 3.

24. Charles C. Zollman, *Study of Concrete Construction in the Soviet Union for Residential and Commercial Buildings*, Report of American Delegation on Concrete Construction, Washington, D.C., 1965, offset, 99 p.

This is a report of a eight man team which travelled 12,000 miles in the U.S.S.R. studying Soviet concrete construction. While its emphasis is primarily on the technological and production side, it touches upon economic, social, political and design aspects as well.

INDUSTRIALIZATION OF HOUSING: TODAY'S POTENTIAL

by

MARION SCHLEFER*

I. FRAMEWORK

In recent years the housing industry has been producing nearly one-and-a-half million non-farm dwelling units per year. Estimates by Senator Abraham Ribicoff call for a production of two million units per year to meet immediate needs; the AFL–CIO calls for two-and-a-half million units. In 1960, nearly one-fifth of all housing units were classified by the Bureau of the Census as either dilapidated or in need of immediate repair. If needs for replacement for dilapidated and run down housing are considered, the need for new construction is estimated to be as high as three million per year.[1]

Expressed in another way, the problem is apparent in the gap between the need for decent housing on the part of low-income persons and the inability of the industry to produce dwelling units at minimum standards which come within the range of effective demand by the low-income group. In other words, as presently organized using conventional technology, the industry has proved unable to supply housing to low-income without subsidy.

Furthermore, when low-cost housing is supplied through subsidy programs, the effort to hold down cost usually results in a dwelling unit which has no chance to be upgraded or altered. For this reason as income rises, the tenant looks for new housing in other areas, thus denying the community his leadership ability and tending to maintain the neighborhood as an exclusively low-income area.

The amount of reduction in the cost of housing to the consumer which can be achieved by industrialization is limited by the proportion of total cost attributable to construction.[2] A significant amount of total cost to the consumer is attributable to the costs of financing (interest, title, transfer costs, and taxes) and to the cost of land. Of the total amount attributable to construction the National Association of Home Builders estimate that 70–75 percent is in materials and 25–30 percent in labor. Others consider that the proportion of labor is higher.

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[1] Hooper, William L. Office of Science and Technology, Executive Office of the President. Innovation in Housing: Will Pipedreams Become Practical Reality? (Address) September 9, 1967, p. 3.

[2] The term industrialization includes mass production either off-site or on-site of whole units or standardized component parts ranging from simple window frames to complete structural systems.

One important fact to bear in mind, however, is that these costs to the consumer are not independent of each other. For instance, if the cost of construction can be reduced, both interest charges and taxes come down proportionately. If the construction period can be reduced or construction costs carried in part by the factory, then the period of interim financing can be reduced. In this case the fabricator rather than the consumer is carrying this cost, which will in turn be charged to the consumer in higher prices or may be offset by technological advances. Furthermore, the cost of land directly affects the possibility of producing housing to meet the low- and moderate-income markets. Urban renewal write-downs and local tax abatement are often essential to the effective operation of moderate-income programs at today's urban land prices. In addition, the size of the market directly affects the price of industrialized housing. In short, it is legitimate to isolate the cost of construction for analysis of the benefits of industrialization, if it is understood that the various costs are not independent and that industrialization might well transform all aspects of the industry.

II. What Might Be Accomplished With Industrialization

Gunnar Myrdal has pointed out that the industry divides easily into two parts, namely, "the manufacturing of building materials and components, on the one hand, and their assembly on the building site, on the other." [3] In recent years the building industry within the United States has been prefabricating parts of buildings, windows, roof trusses, siding with prefinished coats and so forth. However, the emphasis in improvements in home construction has been on on-site assembly. Our system excels in the rationalization of the process of site assembly. The coordination between the arrival of materials and the programmed use of construction teams is the traditional strength of our construction industry. There have been certain exceptions, most notably the mobile home industry which represents complete prefabrication. Last year the mobile home industry statistics claimed that mobile homes accounted for 20 percent of homes sold. Neither prefabrication of parts nor even prefabrication of complete units necessarily involves the use of new materials nor the application of a systems approach to building.

A year ago the Journal of Housing took a dim view of the potentialities of industrialization. ". . . the conclusion still seems unavoidable that pre-fab construction techniques, as we know them today, can have only negligible impact on the critical and large-scale American problem of how to provide, in quantity, housing that meets defensible modern standards at costs within the reach of low-income families." [4] Today, the editors of this Journal take a more optimistic stand. Several new approaches to industrialization of construction show promise and account for their more optimistic view. Some schemes use the mobile home unit as a basic component to be stacked; others emphasize the prefabrication of boxes which utilize materials and technologies new to the housing industry; still others apply systems planning to the housing industry defining goals, and working out coordinated subsystem components which will then be organized according to the demands of the particular situation for assembly on site.

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[3] Myrdal, Gunnar. In Proceedings of the Third CIB Congress, Towards Industrialized Building. Copenhagen. 1965.
[4] *Journal of Housing*, No. 8, September 1966. p. 435.

MOBILE HOME INDUSTRY

Mobile units which are not permanently affixed to the ground and carry license plates do not come under the usual building and housing codes. HUD considers that the mobile home industry has potential as a producer of low-cost housing and is sponsoring on an experimental basis several different mobile home projects which will become part of the real estate. Specifically, HUD is working with Magnolia Mobile Homes Sales Corporation, on projects of stacked units for town houses. The first project at Vicksburg, Mississippi, uses two mobile units stacked to make one dwelling unit. Altogether there will be 28 dwelling units. The cost of these units is expected to be about $10 per square foot including land or $7.50 on foundation exclusive of land.[5] This compares with a square foot estimate for a District of Columbia Public Housing Project about to go out to bids of $9.15 per square foot. Cheap conventional construction would come in under this figure but such cost comparisons do not take into account quality comparison, nor do they indicate what costs might be achieved with volume production of mobile units.

The plan at Vicksburg and at Amherst, Massachusetts, where the next Magnolia project will be built, is to evolve a way of putting units together which would work for dense housing in the city and at the same time to display no trace of their mobile origin. The Amherst project will consist of 104 dwelling units. Each of these projects will be insured under Section 221(d)(3) and Section 233 of the Federal Housing Authority insurance program. Section 233 exempts projects from the usual minimum FHA standards for experimental work with new materials and methods. Square foot cost, however, is not expected to be reduced below conventional building costs on these two demonstrations.

HUD is also sponsoring a mobile home industry Low-Income Housing Demonstration at Reston, Virginia. An initial grant of $200,000 for a 50-unit pilot program will be expanded to 200 units. The project may be insured under FHA Mortgage Insurance under Section 233, pursuant to 221(d)(3). However, Reston Experimental Housing expects to be able to reach the level of income equivalent to 221(d)(3) in Washington, D.C. without a 221(d)(3) subsidy. It has been determined that the units they need can be built in a mobile plant at a cost of between $5 and $6 per square foot or an on-site cost of approximately $7.50 without land. Because of the community amenities and master plan which Reston offers, its land prices are relatively high. However, the land use plan offers the advantage that these units will be in groups in close proximity to single family houses and multi-family buildings for higher income groups.

The mobile home industry depends on mass production and neither of the experimental mobile home projects described is able to offer even a sizeable market, thus they can test methods of design but cannot test true cost reduction. To produce the Reston units certain retooling of the factory will be necessary which requires a capital expense for relatively few units. The Reston units will be substantially three bedroom units although partitions for children's bedrooms do not reach the ceiling in order to bring extra light and air into the play-

[5] Hooper, *op. cit.*, p. 5.

room beyond. Each will include two mobile units but differ in floor area according to their placement in the three story structure. They will vary from 880 square feet for third floor units to 1008 square feet for the ground floor and second floor units.

The Architectural Forum reports that architect Paul Rudolph, of Yale University, has proposed schemes for a "vertical core with mobile-home boxes 'plugged-in'".[6] These boxes might be suspended from an overhead truss or slipped into a structural grid of steel or concrete. A similar scheme is proposed by Seaside, California in its model cities application. This scheme was developed by the Los Angeles architectural firm of John F. O'Grady and Walter K. Zell. These architects suggest that such a core structure could be placed on an air-rights platform and needs little land base.

The mobile home industry has been slow to respond to suggestions for new experiments because it is prospering as is. However, Boise Cascade, a lumber company, owner of Kingsbury Homes, a successful company selling pre-fab homes of conventional design has recently decided to acquire a mobile home company.[7]

BOXES AND THE HABITAT CONCEPT

Conrad Engineers, a New York firm which developed the core for "Instant Rehabilitation", the 5th Street Project in New York City, has made a study of technologies applicable to construction and already in use in other manufacturing processes. Conrad Engineers has developed a light weight concrete box based on an expansive concrete which prestresses its steel reinforcing shell as it dries. Prestressing in three dimensions allows Conrad Engineers to construct a light weight box of only 20 tons as opposed to Habitat's 90 tons. Such a system allows very thin strong walls (2″ thick except for those between units which are 8″). The objection has been raised that boxes strong enough to withstand lifting and trucking to the site are then unnecessarily strong for building construction which does not require such strength in place. However, it is the opinion of Conrad Engineers that box structural techniques are not now being applied but could be applied in such a way that full strength can be used by grouping loads which are transferred from one unit to another, each unit helping to hold up the whole.

Conrad Engineers is currently building a six story conventionally stacked building for moderate income housing to be financed under FHA Section 233. This building is located in Richmond, California and will total 24 dwelling units of two boxes each. To meet code regulations in Richmond it was necessary to strengthen the structure at each corner with a column.

Habitat '67 presents an innovative assembly of box units in such a way that the architect becomes involved in creating a total living environment giving each unit a sense of place or identity within a community of dwellings. Moshe Safdie, the architect, worked out coordinated systems for automobile and pedestrian traffic, indoor and outdoor space, privacy and communal amenity. Although he presented an in-

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[6] Architectural Forum, May 1967 ; page 44.

[7] Further information is available from: Mr. John Odegaarde, Kingsbury Homes, 5096 Peach Tree Road, Chamblee, Georgia.

spiring notion for the construction of housing at high density with high amenity, he did not work with advanced technology. The weight of the concrete boxes necessitated exceedingly expensive cranes for lifting the units into place and resulted in an average cost of $100,000 per unit.

There is now a proposal under study by HUD for a Low-Income Demonstration Grant which would combine the light weight strong box developed by Conrad Engineers with the advanced design of Moshe Safdie for an American Habitat '68. The Architectural Forum for October 1967, suggests that this structure is under consideration for the National Training School Site in northeast Washington, D.C. The Forum sums up box building in these words: "In short, the technical means exist—and have existed for some time—to make the Habitat concept economical as well as beautiful. All that is necessary is to go outside the narrow confines of the traditional building industry, and to use resources in other, possibly more advanced fields of manufacturing." [8]

COMPONENT SYSTEMS

Realizing that the value/weight relationship is usually too low to transport large boxes long distances, others have proposed schemes which seek to workout component systems by systematic social and structual analysis to be assembled at the site.

Neal Mitchell Associates of Cambridge, Massachusetts,[9] has worked out a unique approach to component building based on the experience of various members of this group in South America. Mitchell Associates studied the squatter settlement to see what could be learned from such a completely flexible system where even demolition and reconstruction is rapidly accomplished. In collaboration with his associate Ian Donald Terner,[10] Neal Mitchell evaluated the priorities of the urban in-migrant. They found that the priorities of the migrant vary with his fortunes. The newly arrived migrant values *location* most highly; the squatter places emphasis on *security* in land tenure; and as his status becomes more secure, the *amenity* of his house becomes dominant and he places a value commitment in the structure itself.[11]

In order to meet these varying priorities, Mitchell Associates developed a system which emphasized flexibility through upgradability and expandability and was sensitive to cultural and physical environment providing for the use of indigenous materials in combination with the structural system. "The project started as a systems based analysis of the failure to provide adequate housing in the currently underdeveloped world. The strategy was to bring the latest in science and technology to bear in the controlled manufacturing of a structural system, yielding an inexpensive, durable and foolproof product that could be erected quickly and easily in the field by totally untrained people without construction equipment." [12]

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[8] Architectural Forum, May 1967, *op. cit.*

[9] See appendix I.

[10] Neal B. Mitchell, Jr. *and* Ian Donald Terner. Squatter Housing: Criteria for Development, Directions for Policy, 1967.

[11] Most publically sponsored programs are aimed at that segment of the population for whom amenity is dominant. In the United States, there are many persons who never have a chance to be accepted by Public Housing because their incomes are too low or their social behavior not acceptable. Nor is provision made for consciously putting aside housing amenity in an effort to combine resources in an income-producing project at the temporary expense of housing. Further, public housing is inflexible at the upper end of the scale because it provides no means of upgrading housing or retaining the tenant with the rising income.

[12] Appendix I.

Sixteen footings are dug in a grid pattern either by hand or with a drilling rig mounted on a tractor (the only step requiring trained labor). Digging of footings can be accomplished without disturbing the earth's surface by stripping of topsoil or vegetation. The system consists of four precast, lightweight, cellular, reinforced concrete components: columns, cantilever frame beams, tie beams, and a roof/floor slab system which are erected on the concrete footings to form the structural bays. If a single bay dwelling is constructed, the family may continue to farm or garden without injuring the remaining 12 footings which serve as incentive and reminder that the house can be expanded. Materials for expansion may be stockpiled in the neighborhood. Such a dwelling constructed in South America would cost between $200 and $400 and is strong enough to rise to three stories or to expand horizontally in the direction of the existing footings. Wall panels are available in a variety of materials or indigenous materials may be used. Utility cores, electrical and mechanical systems are also available. Expandability allows not only for enlargement of the dwelling but for addition of a shop or a second unit for temporary housing of a relative or for rental housing to augment income.

Mitchell Associates have revised the system to meet U.S. tastes and standards while retaining the original emphasis on flexibility and interchangeability of parts. On April 29, 1967, the Archdiocese of Detroit received a HUD 207 Low-Income Demonstration Grant of $203,000 to cover research costs for applying the Mitchell system to a moderate income project in Detroit. The actual cost of research to Mitchell has been closer to $300,000. The project will include 17 units, 13 in a complex and 4 individual homes and is expected to cost between $8 and $12 a square foot. The square foot cost goal is $7.00 but this goal could be achieved only through volume production. Like the original system, this system consists of light weight sub-systems of columns and beams into which various panels can be fitted. It is simple to construct with no part weighing more than 150 pounds and can be built with self help. Upon completion, the project will be transferred to the FHA Section 233 insuring program and eventually to Section 221(d)(3) when (and if) provision for home ownership in multiple units is passed. Home ownership is particularly important for the Mitchell systems because of the provision for future expandability.

Mitchell Associates' system now comprises about 15 or 20 sub-systems in addition to the four original systems. These additional sub-systems include plumbing, electrical, interior panel development, etc. Some of the sub-systems are applicable to existing housing as well as to new housing. Parts are interchangeable so that the house can be rehabilitated simply by easy replacement of subsystems. Emphasis was put on the development of existing technologies which have not been used in building, for example, a chemically treated light weight cement and plastic pipe. Sub-systems were kept in small units to facilitate construction and replacement. Mitchell Associates have experienced difficulty in interesting manufacturers in making the necessary investment to design sub-systems. This is in part attributable to lack of a guaranteed volume market. The panel sub-system, for example, was sent to several hundred companies of whom only seven responded and only one to the point. Many manufacturers are interested primarily in a market for their own products and would like to market an aluminum house, a steel house, an electric heating and appliance house, chemical house, etc.

Mitchell Associates demonstrates the monthly costs of housing with a 30-year mortgage at 6 percent with a 40-year mortgage at 3 percent, in a chart (Appendix I). As part of the usual cost of housing, Mitchell proposes the establishment of a reserve contingency fund which would serve as an insurance against inability to keep up mortgage payments or tax payments during short periods of up to three months.

The Washington area will have a chance to see the Mitchell self-help system tested in Toby Town, Maryland where the Toby Town Redevelopment Corporation, a non-profit group established by the County Government to guide the community's renewal, has approved the construction of 27 units to house 93 residents. The housing will probably be built under a "Turnkey" provision by the Redevelopment Corporation using residents as workers who will be paid in "sweat equity" toward the purchase of their homes. The Montgomery County Council has agreed to make exceptions to various parts of the zoning, subdivision, road and building code ordinances.

TECHCRETE

The Techcrete component system builds with large scale components of precast concrete. Techcrete has completed a moderate income housing project in the Roxbury Section of Boston, financed under FHA Mortgage Insurance under section 221(d)(3).

Components are trucked to the site and assembled by crane. Developed by Carl Koch of MIT, this system of heavier and larger components also emphasizes flexibility in multi-family construction. It avoids restrictions on planning exterior treatment. Units can be stacked to any number of stories up to 32 or use horizontally in a number of forms for row houses or walkups.

The system consists of 3 bearing wall panels erected first which support a 32 foot pretensioned precast plank, 40 inches in width. Floors are "clamped" to walls by post tensioned steel rods. The remaining wall area can be enclosed with nonload bearing materials. The objective of the Techcrete system is to bridge the gap between a "over generalized" American construction industry and the "over specific" European system. The editors of the Architectural Record define Koch's system as, "A design method to lower first and continuing cost and increase quality: a flexible design method to permit the widest possible range of uses and appearance to meet variations in site, density, local preference, a process which offers the greatest possible opportunity for speeding up and simplifying the process of building from first realization of need to occupancy (a large factor in reducing cost)."[13]

The System relies on interchangeable parts with a wide variety of component choices. It becomes the function of the architect to coordinate the building process to make a whole of disparate pieces contributed by architect, developer, manufacturer and building authority.

Square foot costs were approximately $12 to $14, too high to produce moderate income housing without subsidy.

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[13] Finally: a low-cost component system for housing that really works. *Architectural Record,* March 1967, pp. 187–195.

The Techcrete Foundation has been established to carry on studies to produce improvement in design, construction and erection of their components, to program development of new components, to work with labor unions and government officials on code provisions, and to help to provide a market for The Techcrete System by providing information to sponsors and architects, and finally to provide a source of R. & D. for the housing industry in the area of component construction.

"NOVOA SYSTEM" PRECAST CONCRETE HOUSES

This project insured under FHA Mortgage Insurance under Section 233, Experimental Housing, pursuant to Section 203 was constructed in Puerto Rico. Like the Mitchell System it can be assembled by unskilled labor using relatively light-weight components (250 pounds, instead of 150 pounds maximum weight of individual components). A prefabrication plant was located at the site to produce concrete H columns and panels. It is classified as experimental because the characteristics of the panels do not meet the American Concrete Institute Code. A modular house was produced which can be easily expanded and which was made to sell for between $14,000 and $16,000. The panels are dropped into the H columns. The floor is tile and the roof poured concrete with no further finish. These houses are reported to be aesthetically and functionally successful.

SCHOOL CONSTRUCTION SYSTEMS DEVELOPMENT (SCSD)

One of the most interesting of the recent approaches to construction has been privately subsidized by the Ford Foundation's Educational Facilities Laboratory. The SCSD under Ezra Ehrenkrantz, a project manager, who has had architectural experience in England and in this country, has developed a school construction system relevant to this study for its systems approach to a particular construction problem.

A task force of educators and designers was set up to analyze educational needs and requirements which were converted into performance specifications against which a number of manufacturers were invited to prepare proposals for a prototype design. Bidding was done by a team of manufacturers for a compatible combination of systems. The sub-systems which accounted for about 50 percent of the total cost were structural steel, ceiling and lighting, air-conditioning, interior partitions, cabinets and lockers. It was specified that the manufacturer would be fully responsible for development through production, installation and maintenance.

All of this systems analysis and bidding preceded design of a particular building by a particular architect. The objective has been to achieve a greater flexibility in two ways; namely, greater freedom of architectural design within the system and the achievement of rapid change of interior architecture and interchangeability of parts. Such flexibility is particularly important for schools where teaching methods are rapidly changing. Specifically, this would mean that the size of classrooms and the arrangement of partitions can be inexpensively and rapidly altered and lighting and air conditioning systems can be immediately rearranged by shifting ceiling panels to meet the new situation. Exterior panels were omitted from the system; this has enabled individual architects to express differences in facade treatment as well as structural form. What really has been done is to give the architects, "a catalogue of new, ingenious, and economical components, all of which are designed from the outset to fit together." [14]

SCSD would not have been able to achieve support of manufacturers in the form of the capital investment necessary to offer innovative component sub-systems without a guaranteed market. This was achieved with the participation of a group of California school districts which got together to work out a market large enough to justify expenditure by the manufacturer. Costs on the one school completed were about 10 cents per square foot higher than a comparable conventional school but many amenities were included which were not possible under conventional construction.

It is worth noting that several manufacturing companies who developed systems which were not chosen by SCSD were, nevertheless, able to use the systems they had developed in the formation of new companies, e.g., Compatible Design Systems. This development is right in line with the ultimate objective of SCSD namely, "to bring about a situation in which any individual school project may obtain genuinely competitive bidding of system against system without the necessarily clumsy administrative arrangements required by the original development program." [15]

SCSD holds forth the real possibility of interchangeability of parts. Would not the home, school, or any building benefit from change as needs change within it? Perhaps, certain subsystems should even become personal property rather than real estate. For SCSD, at least, the educational test will determine the space utilization rather than vice versa.

Mr. William K. Wittausch [16] makes a similar point. He postulates that the house should be thought of as three elements: environment, enclosure, and equipment, or, in other words, the site, the shell, and the core components. These elements vary in durability and if taken as separate aspects of a house (which are easily replaceable) may be easily exchanged for rapid rehabilitation. "It is in the replacement aspect of housing that the introduction of new concepts can help the housing industry. The industry could begin to design such new housing that incorporates easily maintainable and interchangeable features."

Mr. John Eberhard of the National Bureau of Standards describes SCSD as an outstanding example of a new organization which has created an aggregate market for market of new systems. "The genius of the SCSD system is that it solved an old problem in a new and more systematic way." [17]

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[14] Educational Facilities Laboratories. SCSD: The Project and the Schools, May 1967.
[15] *Op. cit.*, page 31.
[16] Wittausch, William K. Housing as a consumer product: an emerging new industry, 1967.
[17] Eberhard, John P. Technology for the city. Science and technology, September 1966.

HOUSING BY CORPORATIONS

Many corporations including International Telephone and Telegraph, which has bought out Levitt and Sons, Reynolds Metals Company, General Electric, and Westinghouse, have done a good deal of talking about producing particular housing models which will incorporate a new market for their particular products. At this time, invasion of the construction industry by corporations has not materialized. Such a possibility exists as a potential and is felt by the housing industry as a threat.

Futuristic suggestions have been made for disposable housing and for construction by a process called "filament winding" which has been used for fabricating nose cones for space vehicles.[18]

A far cry from such advanced technological innovation as has been just suggested, a system has been devised by Mr. Edward T. Dicker called the Stack-Sack International which has reduced square foot cost to $5.50 including central heating and air conditioning—exclusive of land cost.[19]

FOREIGN EXPERIENCE

Although many precast systems are used in Eastern Europe and in Israel, the effects of scale are most notable in Russia where prefabrication has become routine. However, its experience is not generally applicable here. "The high rise apartments built for Russian middle class families would not meet the space, design, or construction quality demands of the average American, but, available evidence indicates that construction costs, calculated by using equivalent U.S. wage rates and material prices, are well below any existing or anticipated U.S. experience and may be as low as four or five thousand dollars per unit." [20]

Paul I. Niebanck, Department of City and Regional Planning, University of Pennsylvania, Philadelphia, recently reviewed a book by Marian Bowley on the British Housing Industry.[21] Miss Bowley states that, "American readers may find comfort in the fact that certain experiments in the building industry here (in the U.S.) have had their counterparts in England. For example, it has been the British experiences that prefabrication is hardly a panacea for the problem-laden industry. So-called "non-traditional" homes, of prefabricated components or new materials, have resulted both in savings and unanticipated costs. Most of the bright new ideas have withered on the vine because of cost factors, insufficient scale of operation, and negative consumer response among others; and the ideas that did catch hold were rarely genuine innovations." She adds that, "Hopes for the cost reduction, greater production, more consumer choice and other goals all seem to rest largely on the form of organization and management of the industry, rather than on marginal reforms or greater direct participation of the government."

Mr. Guy G. Rothenstein of Associated System Planners and Designers (ASPAD) takes a much more optimistic view of the progress

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[18] See appendix II, Journal of Housing, September 1967.
[19] See appendix III.
[20] Hooper, William L. *op. cit.*, page 9.
[21] Bowley, Marian. The British building industry: four studies in response and resistence to change. New York, Cambridge University Press, 1966; reviewed by the Journal of the American Institute of Planners, January 1967, p. 61.

and applicability of European precast systems to the United States. Mr. Rothenstein states, that, "in France today, 60% of all multi-family housing is system built by more than 200 plants with a production capacity of 500 dwellings per day." [22]

Mr. Rothenstein defines system building in an industrialized society as "the complete integration of all sub-systems (structural, mechanical, walls etc.), assemblies, components and parts into *one overall system* making full use of industrialized production, transportation and assembly." He adds that, "The basic elements of industrialization are MECHANIZATION and the PROGRAMMING of the process of building." Systems can be of two types, "open" or "closed". "Open" systems, which Mr. Rothenstein says are widely used in Eastern Europe, are based on modular standardization of plants all over the country. These components are catalogued and stocked and architects can pick compatible parts. The "closed" systems used in Western Europe depend on contractor-owned tooling permitting industrialized design within one system.

ASPAD has two systems which are currently available in the United States—the Sentra System and the Balency System.[23] Rothenstein believes that these systems have potential for the United States to improve quality, speed construction, and lower cost. Mr. Rothenstein estimates that under his system total labor cost is reduced by 20 to 30 percent assuming labor as 50 percent of total construction cost.[24] He also estimates that there would be a material cost savings.

He further suggests that portable factories could be set up in model cities neighborhoods thus fulfilling the social objective of employment as well as providing housing.

Mr. Rothenstein discusses the need for an assured market and suggests that the system building plan, including plant operation, should be under the jurisdiction of a general contractor to assure integration of the complete process.[25]

Precast housing systems, such as those just discussed, are inflexible and do not allow for changes in interior architecture or variability of size. Built on a large scale, costs could be reduced. Such systems might be used in the interim which will be needed to bring technological sophistication to the point where industrialized housing of a more flexible kind, similar to the SDSC approach, might be available. Such an interval has been variously estimated as between four and at least ten years. European design tends to be more standardized than design in this country. "No real industrialization is possible without standardization and—in the building industry—no standardization is possible without systematic dimensional coordination." [26] It seems unrealistic to think that we will have countrywide dimensional coordination or even code coordination in a country where the housing industry

[22] See appendix IV.
[23] See appendix IV.
[24] The National Association of Home Builders estimates that labor is 25 percent of construction cost.
[25] Further information can be obtained from: (1) Mr. Toni Potter of Taylor-Woodrow-Blitman, Inc., 101 Park Ave., N.Y.—The English parent company Taylor-Woodrow has extensive experience in system building; (2) Mr. George Santry, Schokbeton Products Corporation, 35 Mason Street, Greenwich, Connecticut. The Engineering New Record is preparing an article about Thamesmead, England, a community for 60,000, entirely built by industrialized construction methods.
[26] United Nations. Modular co-ordination in building Asia, Europe and the Americas (ST/SOA/62). New York, 1966, p. 1.

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is traditionally localized, small scale, and competitive and where climatic conditions vary so greatly. An "open" system might bring about a situation in which the architect no longer laments the lack of components but the restricted choice of dimensions.[27]

III. The Construction Industry and Research

The organization of the construction industry is such that most research currently being undertaken is undertaken on the part of an individual manufacturer in the area, for example, chemicals or plastics, and is listed as research in that particular area rather than in construction. For this reason, it is impossible to judge the total amount of research that is currently being undertaken that affects housing. However, we do know that there are few persons or organizations undertaking research or development projects which concern the whole process of construction.

The National Home Builders Research Foundation in Rockville, Maryland, established by the National Association of Home Builders, has been engaged in various phases of research for some time. Dr. Ralph J. Johnson, its Staff Vice President, stresses that there have been many innovations and new materials put into use in the housing industry in recent years. He believes that many prefabrication ideas fail simply because they can't compete from a cost point of view. Innovation, he believes, will bring very modest cost reductions. He further states that construction time on conventional building has been reduced to 30 days and that prefabrication as currently practiced (roof trusses, prehung doors, etc.) characterizes the entire process. Furthermore, he points out that volume buying doesn't reduce costs significantly. He claims that most builders of 50 dwelling units and up a year can buy materials at almost the same price as those who build 1,000 houses. (Levitt & Sons builds about 1,200 houses a year in their metropolitan Washington development.) The Foundation conducts research in three areas: (1) the design and development of experimental homes and systems, (2) laboratory studies to lower engineering cost of materials and components, and (3) industrial engineer to increase productivity of labor and to use materials more efficiently.

The Building Research Advisory Board, with headquarters in Washington, will do research for government on contract—but has no testing laboratory. It also represents the building industry. It points out that the genius of the American system has been on-site organization. For years BRAB has been trying to get the Federal government to direct the Federal Building agencies—Corps of Engineers, Veterans Administration, Bureau of Reclamation, National Aeronautics and Space Administration, Public Buildings Service and others to set aside at least .5 percent of their budget for research and development. BRAB has recently created a Building Industries and Manufacturers Research Council. It also sponsors a Federal Construction Council which includes the Bureau of Standards. However, it operates on a budget of only $117,000 a year.

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[27] See Oddie, Guy. The future—can we face it? The architectural implications of industrialized building. Architectural Review (London), November 1966, p. 323. For additional information on European housing see 1) United Nations, New York. Modular Coordination in building Asia, Europe and the Americas; 2) International Council for Building Research, Studies and Documentation. Towards Industrialized Building. Proceedings of the third CIR Congress, Copenhagen, 1965, New York Elsevier Publishing Co., 1966.

BRAB questions the existence of a market for industrialized housing in this country at this time. This, it is thought, is the real problem which industrialization faces. It also believes that contractors and manufacturers will hold their R & D at a minimum so long as the national government uses the housing industry as a fiscal tool for achieving a monetary objective. A high interest rate and slow building discourages the manufacturer from long term research. It is concerned about the antitrust attitude which frowns on combinations of small industries but allows diversification of production within large corporations such as the aerospace industry. Mr. Robert Dillon, of BRAB, suggests the following as major areas of construction which need further research: power distribution (limits flexibility of the dwelling unit), waste disposal (certain companies are studying cyclical systems which would allow reuse or conversion into fuels of wastes), and foundations (to find ways of keeping them from being so deeply rooted in the ground and inflexible). Mr. Dillon also emphasized the need for destructive testing. The Ford Foundation funded a New York test in which one steel, one concrete and one composite building were dedestroyed to determine strength and resistence. General Motors does this sort of testing on automobiles all the time but it is most difficult to finance within the construction industry.

The Building Research Institute is an independent organization with headquarters in Washington, D.C. They publish the *Building Science Directory* and a bi-monthly journal, *Building Research.* They also hold conferences to further research in building science.

Outside the construction industry itself, private research is producing many products which have already found some degree of acceptance within the construction industry or which hold potential for the future. Recently, the Antitrust and Monopoly Subcommittee of the Committee on the Judiciary held hearings on new technologies and industrial concentration. Dr. Stephen W. Tsai of Washington University, St. Louis, described how the use of lumber can be made more efficient when a glass-epoxy composite is bonded to the wood. "The stiffness of a wood beam can be increased by 700 percent of thin layers of glass composite with a thickness only 10% of the depth of the beam are added to its top and bottom. If carbon composites are used to reinforce the beam, instead of glass composites, the composite beam will be stiffer by 1,900 percent, nearly a 20 fold increase. A (nominal) 2×4 beam reinforced with carbon composites is almost as stiff as a (nominal) 2×12. * * * The use of composites with lumber has the added advantage of preserving the wood, and maintaining structural integrity. The number of sizes of lumber can also be reduced. Instead of having many sizes, one can, in principle, reduce construction lumber for homes to one nominal size, say 2×4. Not only can the use of lumber be extended, it also makes the framing of homes considerably easier." [28]

During the same hearings, Mr. Alvin M. Marks, President of Marks Polarized Corporation described an aerosol heat-electric power generator which "(to somewhat simplify) converts heat directly to electricity. It makes use of the forces of nature by 'bottling a thunderstorm' in that, like lightning, it draws electricity from minute droplets

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[28] Tsai, Stephen W. High performance composites. Presented at Hearings on new technologies and concentration. Senate Antitrust and Monopoly Subcommittee, Committee on the Judiciary. Washington, D.C., September 20, 1967.

of water."[29] Mr. Marks also describes the electro-optic window and wall panel (VARAD). This is a panel which changes its light transmission and reflection characteristics under electrical control. It can be controlled manually or "by sunlight using a photoelectric cell and an electric circuit."[30] Mr. Marks stated in his introductory remarks that, "Although these developments are different inventions, they are closely related in their technical and economic implications. They will provide solutions to urgent needs for low cost, decentralized production of electricity, cleaner air, control of light and heat, and decreased fuel and electric power consumption in buildings. A healthier, more comfortable environment, at lower cost, will result. The development of a small electric power generator, requiring little capital investment, would decentralize the production of electric power, and will have a tremendous economic impact on the United States, and on the newly developing nations of the world."[31] Such technologies are currently available, but Mr. Marks believes that they languish from lack of support. "These new technologies could provide solutions to many of our critical problems and provide a better life for all."[32]

Mr. Robert S. Morrison, President of the Molded Fiber Glass Companies, Ashtabula, Ohio, described fiber glass panels which have been used in England for multi-story buildings for the Greater London Council. He believes that such a system could be used in this country but states that, "it is unlikely that any private contractor would take on the costs of tooling to make these panels, the engineering of the building and its other special components, and the erection of large buildings for low cost apartments."[33]

Testimony was also given by representatives from the Prestressed Concrete Institute and the Society of the Plastics Industry which discuss the further applications of these materials to the building industry. Considerable progress has already been made in the use of these two materials.[34]

The National Bureau of Standards Building Research Division develops knowledge and tests methods for writing of standards, works with FHA on minimum standards and has moved, in the last three years, in the direction of building components testing. It is concerned with the following major facets of building science and technology: internal environment systems; strength and safety in structures; weathering of building systems and sub-systems; exploratory research; consultative and advisory services; operation of standard reference laboratories; retrieval and dissemination of technical information; and building codes and standards. This makes the Bureau of Standards one of the few organizations to consider the whole process of construction. However, even here there is no assurance that research will be carried on within context of social goals.

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[29] Marks, Alvin M. Economic implications of charged aerosol and dipole technology; presented at Hearings on new technologies and concentration, Senate Antitrust and Monopoly Subcommittee, Committee on the Judiciary, October 3, 1967.

[30] *Ibid.*

[31] *Ibid.*

[32] *Ibid.*

[33] Morrison, Robert S. Effect of fiber glass reinforced plastic on the creation of new business enterprises, etc.; presented at Hearings on new technologies and concentration, Senate Antitrust and Monopoly Subcommittee, Committee on the Judiciary; Washington, D.C., Fall 1967.

[34] For example, see Conrad Engineers and Mitchell Associates.

It is left to the Department of Housing and Urban Development to carry on research on innovation in construction as a part of its broader view of urban problems. Sections 110 and 111 of the Housing Act of 1966 have been consolidated into the newly formed Office of Urban Technology and Research which brings together grants under Section 701(b) (Urban Planning Research and Development), Section 314 (Demonstration Grant Program for Urban Renewal Areas), and Section 207 (Low-Income Demonstration Program). This office is headed by Thomas F. Rogers, a former Deputy Director of Defense Research and Engineering in the Department of Defense. Mr. Rogers will work closely with the FHA which administers the Section 233 insuring program for experimental housing. The President requested $20 million for this office for fiscal 1968. The House and the Senate agreed on $10 million.

Through the direct role which the government plays in housing—the real estate it owns, the housing it builds for military personnel built on bases which are exempt from local codes, the mortgages it insures, the direct housing programs it administers, the influence it exerts over metropolitan planning, and the taxing power controls, it is possible for the Federal Government to exert great influence on building practices.

Mr. William L. Hooper, Office of Science and Technology, Executive Office of the President, emphasizes the importance of applying techniques developed in the Department of Defense in procurement and use of advanced systems. "New procurement concepts could be applied to either military housing or public housing. These might include:

—large scale procurement, with a single bid covering all housing units to be built in a given geographic area;
—multi-year procurement or an option to purchase additional units at specified prices in subsequent years;
—selection of contractor on a cost effectiveness basis, not simply on low bid grounds;
—assignment of detailed design responsibility to the housing system contractor and the substitution of performance requirements and good engineering judgement for detailed construction specifications;
—introduction of maintenance cost considerations into design and construction by incorporating life-cycle procurement." [35]

Mr. Hooper also points out that tax policy and regulations have a direct impact on construction and housing. Policy on the Federal, State and local level should be examined.

Finally, the work of special commissions and committees to examine various aspects of the urban problem should furnish insight on aspects of industrialization of housing. The President's Committee on Urban Housing, chaired by Edgar F. Kaiser has established a series of task forces to study the existing housing programs, problems in finance, problems in manpower, housing goals, research and development, and new program proposals that would involve private industry in housing construction. The National Commission on Urban Problems, chaired by former Senator Paul H. Douglas, is looking at the overall urban problem with special emphasis on a comprehensive study of

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[35] Hooper, William L., *op. cit.*, page 10.

housing and building codes, zoning, tax policies and development standards required under Section 301(a) of the Housing and Urban Development Act of 1965.

Urban America pulls together many diverse aspects of research and policy determination for metropolitan America. Established under a grant from the Taconic Foundation in February 1965, it merged the goals of Mr. Stephen R. Currier with the goals of the American Planning and Civic Association. In December 1965, Urban America merged with Action Council for Better Cities. It now operates in five areas of activity: an Urban Design Center (which publishes the Architectural Forum) a Business and Development Center to involve the private sector in urban development, an Urban Policy Center, a Nonprofit Housing Center and an Urban Information Center (which publishes *City*).

IV. Obstacles Facing Industrialization of Housing

Foremost among the obstacles to industrialization would appear to be the lack of markets sufficient to justify entrance or capital cost. A lack of general acknowledgment of the importance of comprehensive research is also a major obstacle. There are many other short term problems such as building codes, zoning regulations, local union work rules, building inspection practice, and tax structures. Many of these difficulties are local in nature. Given an effective market and needed transitional programs such as adequate retraining for workers displaced by technological progress, it can be assumed that a point would be reached were traditional restrictions would crumble.

Mr. John P. Eberhard suggests the need for creating market opportunities to justify the entrance price. Such markets might be achieved, he notes, in three ways: by building new towns (such as Reston or Columbia), by the creation of new organizations "which have as their purpose the aggregation of the requirements of a large group of customers into a significant market opportunity (School Construction Systems Development) . . . (or the) use (of) government to provide a focus and financial support for getting at programs for rebuilding existing cities or supporting new ones." [36]

The question arises as to how large the market must be to justify the entrance price. Several authorities place the figure as high as 50,000 dwelling units a year. It seems most likely that the Federal government, rather than the local governments, must facilitate the organization of larger guaranteed markets. However, direct government subsidy or entry into the housing market, even in the form of research, raises some problems. If, for instance, the government were to hold a patent on a particular component system, the entrepreneur knows that there is no restriction on the use of this component system and this will limit the profit potential. Various ways out of this dilemma have been suggested. For example, an approach similar to the approach used in the manufacture of weapons can be used. In this situation the government develops performance standards and offers a guaranteed market by bid to the contractor who meets the specifications. Such a system might be applied to government building. The Communications Satellite comsat model has also been sug-

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[36] Eberhard, John P., *op. cit.*

gested for the formation of a non-profit organization to stand between the government and private industry. Such a nonprofit corporation might be formed to coordinate the industry. On a small scale, such a corporate conglomerate has been formed in Pittsburgh including a number of large companies to provide seed money for rehabilitation of housing. The Kaiser Committee will probably consider such new approaches to government and industry.

The relationship between government and private enterprise is further complicated by the fact that any subsidy for technological innovation to achieve low-cost housing would also build middle-income housing which would threaten existing housing markets.

An approach such as that of the Rent Supplements Program is particularly good because it does not interfere with the operation of market factors nor does it distort or hide the true cost of building.

The organization of the building industry itself could prove to be an obstacle if the power structure as evidenced in the competitive building industry and the land ownership patterns with associated banking and real estate interests do not encourage large scale development. Manufacturers can also slow down the process of industrialization. Rigidity in channels of marketing and investment in distribution and sales systems at times makes it difficult to get the manufacturer to bid on a new product.

The leadership of the AFL–CIO is sympathetic to new building systems. They realize that in the long-run innovations may create more jobs and transfer some jobs to a full year as opposed to a good weather schedule. However, in the short-run, there are problems with job preservation disputes between on-site workers and off-site workers. The *National Woodwork Manufacturers Association* v. *National Labor Relations Board*, 35 U.S.L. Week 4349 (U.S. April 17, 1967) is such a case. In this case, the literal reading of the statute would have prevented the union from negotiating with the contractors to prohibit the purchase of prehung doors from another company. However, in a five to four decision the Supreme Court decided that it was not the intention of the statute to void work preservation agreements but to void secondary boycotts in which the union had no direct economic interest. The National Association of Home Builders and other groups are drawing up a bill to clarify the point. It is their contention that there is a point beyond which you cannot go in negotiating work preservation clauses without acting contrary to public policy. Mr. John J. Riley, labor lawyer at the NHB, believes that except for this decision there are no real legal obstacles to industrialization. There are, however, local code problems and local union agreements which must be negotiated.

The "Instant Rehabilitation" 5th Street project in New York City presents an example of the difficulties which can be caused by code and union regulations. In this project, the FHA wanted to use a single gas stack for a six story building, a procedure which the American Gas Association had adopted as adequate but was prevented from doing so by the code which required six stacks for a six story building. Further, one core system developed for the "Instant Rehabilitation" project could not be used because the unions would not allow a pre-fab part brought into the city. Problems were also encountered in requirements for particular plumbing fixtures and materials. If emphasis is placed on true performance standard codes, many of the code problems will be avoided. This rehabilitation project is generally considered to have been a cost failure, largely because it was a research project; it cannot therefore be judged on the same basis as a volume production project.

A further obstacle to the industrialization of housing is the cost of money and the fluctuating interest rate. Industry representatives believe that the building industry is used by the Federal government to regulate the economy.

From the point of view of the consumer, a high interest rate substantially increases the cost of housing. Various processes associated with transfer of title and title insurance also are cumbersome and expensive. If the policy of the Federal government is to encourage home ownership, then encouragement should be given to allowing mortgage payments in lieu of rent allowance in welfare allotments. The Mitchell Associates propose a cost of home ownership insurance fund to insure against short periods of inability to pay mortgage payments or taxes.

An all-risk insurance arrangement might be explored to encourage low-income housing construction within certain designated areas in this country.

V. Conclusion

Knowledge of technological innovation and technologies in use in other fields but relevant and applicable to the construction industry show exciting potential. However, the technological sophistication of the industry is not such that much of this new technology can be used widely or immediately. This lack of technological sophistication starts with a lack of good designers and architects who understand component systems and extends to the consumer who believes that standardization necessarily eliminates variation.

The greatest obstacle to production of industrialized housing for the mass of people who lack housing appears to be the gap which exists between what the low-income person can buy and what low-cost systems can produce at present volumes of production. This gap cannot be closed until a large guaranteed market becomes available of sufficient size so that the enormous design and tooling or capital costs can be justified by the entrepreneur.

The Eastern European systems are generally rigid and have lower quality and space standards than those to which we adhere. This is true to a lesser degree also of Western European systems. Were such systems developed to our standards, or were we to change our standards, they would still not have the design or social flexibility which we look for. Such systems do not ordinarily provide a sense of place nor allow for any interior architectural variation, future additions or changes. Nor does such a system allow for individual architectural expression. Most important, such a system does not allow for varying social goals which should be incorporated into performance requirements at the outset.

The more successful American approaches have applied a systems analysis working out program objectives and setting requirements for component sub-systems which lend themselves to standardization without limiting architectural expression or future flexibility or interchangeability of parts. The systems approach sees the dwelling not as a single unit with a given life but as a combination of systems, for instance, site, shell and core. This approach allows long-term maintenance responsibility, and interchangeability which allows new divisions between rental and private property and new concepts of responsibility by the manufacturer for his product.

The job to be done requires that the need for housing for low-income persons be translated into an effective market organized on such a scale that necessary research and capital expenditure will be justified from a business point of view.

(Appendixes follow:)

APPENDIX I

MITCHELL FRAMING SYSTEM: NEAL MITCHELL ASSOCIATES, INCORPORATED*

RESEARCH, DESIGN, DEVELOPMENT, CONSULTING

Neal Mitchell Associates, Incorporated, has developed a prefabricated system of light-weight structural components that can be rapidly erected into the frame of a single or multi-story building. The system is based on four factory-produced components: a column, a cantilever beam, a tie beam, and a slab. All are made from precast, reinforced cellular concrete. The components can be erected at a building site by people who have no prior construction experience. No construction machinery is required since all components weigh less than 150 pounds and can thus be set in place by two men. The system is designed so that a one-room building can be expanded incrementally into a multi-bay four-story structure. It is therefore possible to construct a wide range of building types—from small homes to apartments, offices and stores.

Since the structural integrity of the system is consolidated in the frame, the architectural treatment of the exterior walls and interior partitions can be sensitively adapted to local climatic and environmental conditions, as well as to cost. This permits the use of a non-bearing wall material that functions merely as a climatic barrier, and provides the required privacy and security. Within the modular dimensions set by the framing system, the wall can be also mass-produced under plant conditions, and then attached to the frame at the job site. The walls may be used as a skin that completely masks the frame; or as infill, utilizing the precast concrete frame as a visual and architectural asset.

The Mitchell Framing System reduces the cost of housing construction without sacrificing any of the attributes of conventional construction. This is possible because building components are mass-produced from low-cost raw materials, and the frame is easily erected at the job site with a minimum of labor and time and equipment. In addition, the frame allows designers and builders to choose any locally-available and culturally appropriate material for low-cost walls, without regard to structural and load-bearing properties.

Architectural plans and studies have confirmed that the system's modular structural frame can be used to build a $300 single-cell dwelling in impoverished areas of developing countries, or four-story luxury apartments in the United States.

Under study at present are prefabricated kitchen and bathroom packages, and a study by Lennox Industries of a series of custom developed heating/air conditioning units. Also under development are a series of prefabricated modular wall panels utilizing a wide range of materials and finishes.

In summary, the project started as a systems-based analysis of the failure to provide adequate housing in the currently underdeveloped world. The strategy was to bring the latest in science and technology

*Cambridge, Massachusetts.

to bear in the controlled manufacturing of a structural system, yielding an inexpensive, durable and foolproof product that could be erected quickly and easily in the field by totally untrained people without any construction equipment. Interest centered on developing a light-weight fireproof system, so safe as to withstand heavy wind and seismic loads. The goal was a self-help "expandable" house that had provisions for future expansion and could grow with the needs and financial resources of the occupant.

While this, and more, has been achieved in the underdeveloped context, the system and component products developed have already demonstrated that they are strongly competitive in the domestic market, particularly where erection speed and low-cost are essential.

MONTHLY COSTS OF HOMEOWNERSHIP

Unit	Mortgage payment (principal plus interest)	Taxes on house and land	Operating expenses (utilities and heat)[1]	Maintenance costs[1]	Management fee (at 3 percent of mortgage)	Reserve contingency fund	Insurance	Total monthly cost[2]
(A) 3-BRdet[3]	$39.60	$14.60	$25.00	$7.50	$1.19	$1	$5	$93.89
(B) 4-BRdup	42.92	21.11	30.00	7.50	1.29	1	5	108.82
(C) 5-BRdup	50.65	24.57	35.00	8.50	1.52	1	5	126.24
(D) 5-BRdup	49.55	24.09	35.00	8.50	1.49	1	5	124.63
(E) 1-BRtwn	17.95	9.95	20.00	6.50	.54	1	5	60.94
(F) 3-BRtwn	38.25	19.02	30.00	7.50	1.15	1	5	101.92
(G) 5-BRtwn	50.65	24.57	35.00	8.50	1.52	1	5	126.24
(H) 1-BRtwn	17.95	9.95	20.00	6.50	.54	1	5	60.94
(I) 3-BRdup	39.63	19.64	30.00	7.50	1.19	1	5	103.96
(J) 4-BRdup	42.43	20.90	30.00	7.50	1.27	1	5	108.10
(K) 4-BRdet[3]	59.94	21.11	30.00	8.50	1.80	1	5	127.35
(L) 1-BRapt	12.89	7.68	20.00	6.50	.39	1	5	53.46
(M) 3-BRapt	27.55	14.24	20.00	6.50	.82	1	5	75.11
(N) 2-BRapt	25.13	13.16	20.00	6.50	.75	1	5	71.54
(O) 2-BRapt	25.13	13.16	20.00	6.50	.75	1	5	71.54
(P) 2-BRapt	25.13	13.16	20.00	6.50	.75	1	5	71.54
(Q) 2-BRapt	25.13	13.16	20.00	6.50	.75	1	5	71.54
Total	590.48	284.07	440.00	123.50	17.71	17	85	1,557.76
Average	34.73	16.71	25.88	7.27	1.04	1	5	91.63
Percentage	38	18	29	8	1	1	5	100

[1] Prorated (roughly) according to type and size of unit.
[2] A single additional payment must be made for closing costs when house is bought (equals approximately $300 for a $10,000 house).
[3] Units (A) and (K) are detached houses with mortgages for 30 years at 6 percent; all other houses have 40-year, 3-percent mortgages.

Note: BRdet, bedroom detached; BRdup, bedroom duplex; BRtwn, bedroom townhouse; BRapt, bedroom apartment.

APPENDIX II

INDUSTRIALIZED HOUSING: HAVE WE OVERLOOKED TRUE VALUE?*

A year ago, an editorial in the Journal said that "the conclusion still seems unavoidable that pre-fab construction techniques, as we know them today, can have only negligible impact on the critical and large-scale American problem of how to provide, in quantity, housing that meets defensible modern standards—at costs within reach of low-income families" (see No. 8 1966 *Journal*, page 435).

Although it is still true that no one has yet found a "system" or industrialized approach that can significantly reduce the cost of housing below that built with conventional methods, it is probably a mistake to judge the effectiveness of any new technological innovation strictly in terms of cost reduction. As Under Secretary Robert C. Wood of the Department of Housing and Urban Development says in one of the following articles ". . . any pure cost-benefit approach to urban programs will be doomed by its inevitable inconsistency." In terms of the larger urban values that Dr. Wood refers to, industrialized housing appears to have a great deal to offer. For example, if we are soon going to have a serious shortage of decent urban housing, then an industrialized or systems approach to building can be extremely useful in giving us housing more quickly—if not more cheaply—than conventional methods. And, if it is true that we are facing a serious shortage of labor skills, then any system than can "simplify" the skills that go into building a house is going to be extremely useful.

We should also think in terms of political and social changes and where new building technology will fit into this new framework.

Thus, we as a nation, must accept as inevitable the fact that any kind of decent housing for low-income groups will require some kind of subsidy. A systems approach to satisfying low-income need can yield good quality housing, quickly and efficiently, but not cheaply.

REALIZING THE PROMISE OF INDUSTRIALIZED HOUSING**

—why has it been so difficult to apply principles of mass production to building?

**By GUNNAR MYRDAL, Professor of Economics, Institute for International Economics Studies, Stockholm, Sweden. The following article is excerpted from a paper which Dr. Myrdal presented at the Third Congress of the International Council for Building Research, Studies and Documentation (CIB) in 1965 at Copenhagen, Denmark. The paper forms part of the complete proceedings of the Third CIB Congress "Towards Industrialized Building," which has been published on behalf of CIB by the Elsevier Publishing Company, Amsterdam.

Why has it been—and why is it still—so difficult to apply principles of industrial production to building? Mass production—to be economic and thus able to match the resources available to the majority of the consumers—calls for the adoption of certain principles that have so far been rather neglected in many countries.

*Excerpt from *Journal of Housing*, No. 8, September 1967 (reprinted with permission).

First, of all, continuity of operation is required if the building industry is to amortize any great increase in capital investment. The industry cannot be expected to take the risk of employing highly capital-intensive methods of production as long as governments keep using housing construction as a regulator of the national economy. This point has been made before but is worth repeating. There are few sectors of the economy less suited for economic balancing than housing production—unless, happily, if it is lifted to industrialized building. If construction activity has to be used for economic balancing purposes —which may occasionally be necessary, though less so with wiser economic policies applied by the governments—the projects for periodic retrenchment should be searched for in other sectors than housing: in urban renewal projects, public works, and other demands of a once-for-all type. The most important incentive towards industrialized building would be a guarantee on the part of the government that mass construction of residential buildings will not be interferred with but everything done in order to make possible a steady, rising level of housing construction.

Standardization: Starting Point

But continuity of demand is not enough to ensure the adoption of industrialized methods of production. Variations in the *composition* of demand must also be decreased as far as possible in order to make standardization possible. Buildings are complex products. They have to satisfy different needs; they must be adapted to differences in outside conditions (climate, ground conditions, earthquake hazards, etc.). And tastes are different. But this does not justify *unlimited* variations of the product, and in particular not of its components. Indeed more discipline is necessary on this point; no other mass industry has developed without standardization of the products.

Investigations into the composition of actual output of the building industry have revealed tremendous variations of the building product. And most of these variations could not at all be motivated by differences in functional requirements or preferences of the consumers. On the contrary, the requirements—in particular in residential construction—have been found to vary rather little and the tastes to be conventional and traditional.

The samples made of produced houses, show a number of *almost* identical types of product: millions of almost identical living rooms, bedrooms, kitchens, bathrooms, etc., are produced. But the small variations in measurements and arrangement prevent effectively the adoption of industrial methods of mass production. And all these differences are not—in the majority of cases—specifically asked for by the actual consumers but are prescribed by the impulses of designers, investors, or client organizations.

Market research, which forms an important and integral part of any industrial production, has so far been more or less neglected in building production. Too little effort has so far been devoted to the task of finding out, in a scientific way, which are the preferences of the consumers and which variations in design could be justified from the functional point of view.

MASS PRODUCTION—OF WHAT?

As in other branches of industry, a distinction should be made between the products suitable for mass production under industrialized conditions and intended for the great majority of consumers, on the one hand, and the comparatively very limited amount of tailor-made handicraft work for those who can afford to pay for it, on the other. This distinction is not very clear in building today. In fact, it seems to me that the building industry today is often trying to mass produce tailor-made products—but without first taking measurements for size and form. It is clear that such a confusing situation cannot be very advantageous either for the industry or the consumer. * * *

There are, no doubt, some very specific characteristics of building production that are not common to any other industry. The first fact that strikes an outsider is the division of the production process into two fairly distinct stages, namely, the manufacturing of building materials and components, on the one hand, and their assembly on the building site, on the other. In fact, two industries—or even many more, if one separates all the different branches of industry delivering all kinds of materials and equipment necessary to make up a building—are involved in the production process leading to the end products: homes. As a matter of fact, today the greater part of actual production in the more developed countries takes place outside the building industry proper. The work on the building site no longer contributes so much to the production of the building but rather constitutes a service of assembling parts and components, which thus become a finished building. This is clearly illustrated by the fact that today normally 50 to 60 percent of the production value of a building—in some cases up to 70 percent or more—represents outlays for building materials, components, and equipment delivered to the building site by other industries.

There are natural reasons for this division of the building production process. As a rule, the building is too heavy and bulky to be completed in a factory; moreover, the low value/weight ratio of the finished building economically prevents transporting it over too long distances. Apart from exceptional cases, the constituent parts of the buildings are therefore manufactured and transported to the site separately.

PROFIT MOTIVE

There is, of course, great danger involved in breaking up the production process into too many independent units. Bearing in mind that the building industry is internationally not very competitive, such a proliferation of the production process could lead to a *laissez-faire* policy, implying that nobody cares about the quality and price of the end product, while everyone concentrates on making his own little part of the production process most effective and profitable. The natural consequence is that the different manufacturers of building materials and components, the suppliers of equipment, and the building contractors all tend to accept prevailing preconditions for their activity, diverting most of their interest to maximizing their own profit within this given framework. The gap between demand and supply in an internationally non-competitive industry means also that the contractors regularly operate in a sellers' market, which implies that he has less incentive to rationalize his production in order to cut his costs.

The split pattern of the production process is further aggravated by the division of responsibilities for the final building between the client, the designer, the quantity surveyor, and other specialized experts taking part in the projecting of various aspects of the buildings. Each participant in this collective work may do his best—seen from his own narrow angle—but without caring much about what lies outside his own profession. There is apparently a risk that not enough efforts and thought are given to planning the end-product, taken as a whole, and to the maximum efficiency of the overall production process.

Despite these disadvantages, however, I believe we should be very hesitant to abandon the organization and division of work traditionally applied in building production. Naturally, it is much easier to solve problems of coordination, management, and control if we integrate within one single enterprise all the different stages of the production process. And this solution has indeed been tried, if I am correctly informed. But isn't that, so to say, to "throw out the baby with the bath water"? Doesn't the original division of work provide the *best* possibilities of specialization and hence standardization and mass production, not of identical buildings, but of identical components, which can be combined into a great variety of buildings and thus satisfy a whole range of functional and aesthetic requirements?

But specialization calls for coordination. Indeed, to obtain real economic gain, a specialized production process, divided into a large number of independent sub-processes, calls for *more* special efforts for coordination than a process integrated within the framework of one single organization or company. There is otherwise an obvious risk for "suboptimization."

In industrial production, *best* partial solutions must give way to the best *total* solution that can be economically realized and thus come within the reach of the majority of the consumers. Decisions on quality, appearance, price, and other basic characteristics of the building should not be decided upon separately and independently by all the different participants taking part in the production process, but by a strong directing enterprise, directly responsible to the consumers for the end result. I may illustrate this by a comparison with the automobile industry, which is really highly industrialized. Which car manufacturer would stand the competition for a long time if he let the motor specialist decide upon the design of the motor, the structural engineer on the chassis, the designer on the appearance, and the equipment specialists on the layout and fittings? The result might be a wonderful car, but it would be impossible to sell at a price the customer would pay.

Another important function that must not be forgotten in a highly specialized production process is research and development. I am not thinking of specialized research into new building materials, better technologies, mechaniation, and other important but restricted aspects of building production. This kind of research and development will undoubtedly be taken care of by the different specialists and building materials manufacturers taking part in the building production process. I am thinking of *interdisciplinary* research, with the aid of finding the best compromise solutions of the final building in terms of functional, technical, economic, aesthetic, sociological, and other requirements. And I am not thinking merely of interdisciplinary research into the building itself only, but into the environment of the building as well.

In other branches of the economy, we confidently leave most of the problems of organization, coordination, research, and development to private enterprise as guided by the market. The competition between different production enterprises, each integrating within one single body all the different stages of production—from market research through research and development and finally to production and sale—ensures that good products at reasonable prices are offered to the consumer.

In building production, however, the specific nature of the product, which in turn calls for a split pattern of production, combined with the lack of international competition and, to a certain extent, inelastic demand and a permanent sellers' market, limit our possibilities of just leaving the whole problem of building production to the forces of the market. Comparisons with other industries in this respect are misleading. Nevertheless, those responsible for building production have certainly much to learn from other branches of the economy in terms of planning, organization, cost and quality control, and management. The fact that the building production process is divided into a number of sub-processes should not make us forget the main function of the producer of the final product: the leadership.

Who provides the leadership may be of less importance. In the case of detached single-family houses, where production is designed to satisfy the demand of the individual consumers, the main coordinating responsibility may stay with the building contractor. This system has proved efficient, in particular in countries with highly competitive economies and where building firms may operate rather freely and independently of restrictions, as in the United States.

As to buiding for collective demand, the natural coordinator is the group of clients or the investor. In this case there is no direct contact between the individual consumer and the producer of the building. This is a danger, of course, but should, at the same time provide unusually good opportunities for a rational industrialized production. But have these opportunities been utilized so far? Have the investors and the client organization fully appreciated their responsibilities as representatives of the ultimate consumers? Have the technical possibilities for mass production been exploited?

The answer is both yes and no. In the socialist countries of Eastern Europe, standardization of measurements and qualities of building components, functional units, and of whole buildings, has, in individual cases, gone very far and methods of mass production have been adopted, with substantial savings as a result. Some experts argue—and this is in fact beginning to be recognized in these countries as well—that standardization has in some cases even been driven too far, so that functional requirements and the characteristics of the products do not harmonize. It has also led to monotony in architecture. A more flexible approach is now searched for in these countries.

On the other hand, in the market economies of Western Europe—and the United States—comparatively little has so far been done to restrict the number of product types and thus make way for industrialization. In all countries it is now becoming realized that radical measures must be taken to speed up production. This, and the different experiences that have been recorded up till now, would seem to suggest that there is considerable scope for international collaboration between all countries in this field. . . .

CONCLUSION

I have spoken very little about specific technical means and industrial methods of building production as such. This is not only because I feel incompetent to talk about these matters; it is also because I believe—indeed I am convinced—that some of the major obstacles on the road towards industrialized building are not of a technical but rather economic, organizational, and political character.

SOME NEW APPROACHES TO INDUSTRIALIZED BUILDING*

a new surge of interest by homebuilders, large corporations, and government, coupled with some far-out research ideas, mark current efforts to develop a technological answer to housing problems

Since the *Journal of Housing* last featured the subject of industrialized housing (see No. 8 1966 *Journal*, page 435), signs have begun to appear indicating some—if only slight—movement towards solutions to the problems mentioned by Gunnar Myrdal in the preceding article. The two groups most capable of overcoming the economic and organizational hurdles—big business and government—are showing an increasing interest in developing "systems" approaches to home building. Furthermore, a growing research effort sparked, in part, by the aerospace industry, may bring the kind of technological breakthrough that could conceivably change the financial and political patterns that have traditionally regulated the home building industry.

In the meantime, the building industry, which has been accused of complacency and even of obstructing the development of innovative approaches to home building, has been reassessing its role in the urban housing market, where the need for innovation appears most critical.

In a speech before one segment of the building industry—the Mobile Home Manufacturers Association—William L. Hooper, a technical assistant to President Johnson's adviser on science and technology, warned the industry to pay more attention to innovation if it wanted to remain in the urban housing market. "Innovation in housing will come by one of three routes," he said. "Either the traditional housing industry will meet the challenge . . . or the second possibility is the mobile home sectionalized housing industry will apply its talents to manufacture of fixed-site urban housing, or the third possibility is that firms not now in the housing field, and perhaps not now in existence, will be attracted into the field to exploit the housing market which is not now being satisfied."

This last possibility Mr. Hooper characterized as "innovation by invasion"; he warned his audience that "if you don't want a huge ur-

**Journal of Housing*, No. 8, September 1967 (reprinted with permission).

ban housing market to be suddenly usurped by outsiders from who knows—the auto industry, the aerospace industry * * * you had better find ways to demonstrate what you can do in manufactured townhouses, high-rise sectionalized buildings, all of the rest."

NAHB Builds a Prototype

The challenge to the traditional housing industry has already been recognized—if only in a limited way—by the National Association of Home Builders, which acts as a spokesman for most of the nation's home builders. Rather than seeking an organizational change in an industry characterized by relatively small firms, the association, through its subsidiary—the NAHB Research Foundation—is trying to develop an innovative systems approach that can be used by almost any size builder to tap the urban housing market.

On August 2, NAHB signed a contract with the Redevelopment Land Agency of Washington, D.C. to construct six experimental townhouses, as pictured on page 432, on an urban renewal site almost within the shadow of the Capitol. The project, which is under joint sponsorship with the Portland Cement Association, will feature the use of pre-stressed lightweight aggregate concrete panels. A local Washington builder will put up the six moderately priced structures using a system developed by William J. Mouton of New Orleans, who has been hired as consulting engineer for the project. Ranging in interior size from 1300 to 1700 square feet and in price to accommodate sale to families within the moderate-income limits defined by Section 221(d)(3) of the National Housing Act, the six townhouses are to serve, hopefully, as a prototype for inner city building.

The Mouton system was chosen for several reasons but primarily because it seems well suited to the present capabilities of most home building firms. "Our primary objective," says Leon Weiner, NAHB president, "is to develop a building system * * * that will enable home builders to contribute to housing lower-income families in the urban redevelopment market."

The panels used in the Mouton system are all 6 inches thick but can be molded in lengths of up to 20 feet—as against a maximum of only 6 feet in some of the European pre-cast systems. They can be used for both exterior and interior walls, as well as for roofing. In addition, they can be pre-stressed and molded on-site and, because they are relatively light, they require no special equipment such as heavy lift cranes or travel lifts to put them in place. The designer estimates that the cost of equipment for using his system represents about one one-hundredth of the capital investment involved in building with such systems as the Balency system or the cellular system used in the construction of Habitat 67 (see No. 8 1966 Journal, page 439).

The Mouton system being used by NAHB is said to have certain other advantages that may be even more important than low capital costs. In most pre-cast systems, joining has to be done by welding, requiring close tolerances and skilled craftsmanship. Mouton, however, has perfected a method of "keying" his panels so that they dovetail; dowels and grout are used for sealing the joints. The panels, themselves, have been tested in NAHB's research foundation laboratory at Rockville, Maryland and been found to have exceptional heat, sound, weather, and fire resistant qualities. The experimental townhouses, therefore, will require no insulation and no roof topping, representing a savings in time, as well as money.

As efficient as the Mouton system appears to be, it is not expected to save a significant amount of money in terms of the full purchase price of a home; it does not affect the cost of site acquisition, financing, and equipping a house with plumbing, electrical, and heating fixtures—or about 75 percent of the total price of acquiring a home. It does offer, nevertheless, a possible solution to two critical problems in urban home building—the skilled labor shortage and the slowness of present construction methods. By eliminating several steps in the construction process and simplifying others, it requires less than half the skilled laborers used in traditional building methods; the use of pre-cast panels and the elimination of interior finishing means a savings in construction time. Mr. Mouton says that a Louisiana builder who used his system was able to finish a three-story office building in less than three months.

"We're not sure that pre-cast panels are the answer, but we want to test them," says NAHB President Weiner. "Our urban housing needs are too urgent for us to continue building at the pace we have been."

Mobile Home Developments

The closest thing this country probably has to on industrialized home building is the mobile home industry. A synthesis of the automobile and the fixed-site dwelling, the mobile home accounts for one of every five new homes sold today, according to industry spokesmen. Its relatively low cost, short-term financing, and light upkeep make the mobile home popular with moderate- to low-income families, especially retired persons who no longer want to be burdened with the maintenance of a fixed-site home. But its relatively small size—even the largest custom built ones don't exceed two bedrooms—limits its potential for the family of two or more children. Zoning ordinances and scarcity of cheap land also make it difficult to establish low-density "trailer parks" or mobile home sites in the central city.

Like the rest of the home building industry, mobile home production is characterized by a number of relatively small, low capital enterprises competing in a rapidly growing market. Despite their current prosperity, a number of mobile home manufacturers are beginning to realize that their future prosperity is not so much out of the highway but in the big, tough urban housing program.

A number of plans are coming out of the industry and from other sources for using the techniques of mobile home manufacture in fixed-site, high-density development. Most of these plans revolve around the concept of the "vertical trailer park" or stacking of units.

The City of Seaside, California, in its model cities application, proposes to test the feasibility of a system for stacking mobile home-type units that has been developed by the Los Angeles architectural firm of John F. O'Grady and Walter K. Zell. In the O'Grady-Zell system, mobile home units without their rolling undercarriage would be literally plugged into a core (see photo). The core, itself, could be located on low-cost or no-cost land (utilizing air rights over public highways). Combined with the mass production savings of the units, such siting, according to Seaside renewal officials, "could furnish attractive standard housing at rentals and purchase costs substantially below the current market."

Magnolia Mobile Homes Sales Corporation, a division of Gurdon Industries, is actually testing the feasibility of stacking factory assembled units in a 221(d)(3) low-income housing project under construction near the Magnolia factory at Vicksburg, Mississippi. Magnolia Homes offers the mobile home industry what HUD officials believe is the best opportunity yet to show what it can do to produce good quality low-cost housing.

The Vicksburg project, which is being sponsored by the Dabney Foundation, will produce 28 two-story townhouses. Each townhouse is composed of a first-floor unit consisting of a living room, dining room, kitchen, and stairway to the upper unit or module. The upper unit contains bedrooms and a bathroom. Both units are manufactured in the factory and hauled to the site. Because each unit has its own structural integrity, the only on-site preparation required is the laying of a foundation on which to set the ground floor unit.

"We are purposely not complicating the project for this demonstration," says David Wolff, director of operations. "We are interested, however, in something like the O'Grady-Zell system for future demonstration purposes." He points out that, with 20 plants located in various sections of the country, Magnolia could supply factory-produced units for any project or demonstration in practically any major metropolitan area in the country. "We regard ourselves essentially as a parts supplier," he says.

Finally, Mr. Wolff foresees a great savings in time, as well as costs, is using mobile home manufacturing techniques for building in-place housing. "It never rains, sleets, or snows in our factories," he notes.

Innovation by Invasion

There are many persons, including Gunnar Myrdal who believe the home building industry, as presently constituted, is incapable of either developing or utilizing any significant innovation. A truly industrialized housing approach, they argue, requires the kind of corporation that not only can afford to risk experimentation but also can afford to experiment on a large scale. The home building industry, they note, is still characterized by a predominance of relatively small, underfinanced firms that seldom operate outside their home base area. A workable systems approach, they say, will not come from any of the firms presently in the business but from one or more of the nation's giant industrial corporations.

Although the "innovation by invasion" route referred to earlier in this article does not appear imminent, there are signs of a growing big business interest in home building. Many of the corporations showing this interest are already indirectly involved in home building as major suppliers of materials; others have had no previous connection with home building.

One of the latter firms is International Telephone and Telegraph Corp. This July, ITT announced the purchase of Levitt & Sons, one of the few home building firms that operates on a national scale and has operations abroad. Although ITT announced that Levitt & Sons would operate an an "autonomous" subsidiary under the continued direction of its founder, William J. Levitt, the merger still has the potential to produce a new concept in housing.

For one thing, the marriage of ITT and Levitt was not one of necessity but of desire; despite a tight money market, Levitt's profits increased by 23 percent last year. The reason for the merger, according to Levitt, was to acquire the financial muscle needed to speed up its plans for *developing and creating cities.*

On its part, ITT looks upon its acquisition of the firm that pioneered in large-scale home building as providing an "ideal vehicle" for participating "in the revolution in housing which will take place in the next decade." Neither ITT nor Levitt has specified what form they expect this revolution to take but one can assume that it will heavily involve some kind or kinds of systems approach.

Perhaps more significant than the ITT-Levitt merger have been announcements by the nation's two largest manufacturers of electrical equipment that they were exploring a systems approach to the planning and building of new towns. The General Electric Company announced its intention more than a year ago (see No. 8 1966 Journal, p. 443) but has yet to release any details of its plans. Meanwhile Westinghouse Electric Corporation has stolen a march on its rival not only by announcing its intentions to establish "an urban laboratory" to test new building systems but also by acquiring a site and builder to develop its plans.

Westinghouse will develop its experimental city on a 10,400-acre site northwest of Fort Lauderdale, Florida in the planned city of Coral Springs. It acquired the site when it purchased Coral Ridge Properties, one of the largest of a burgeoning number of Florida-based development companies. The entire project will be under the direction of Westinghouse Vice-President E. H. Seim, who foresees the emergence of a new kind of developer, one "whose plans and foresight will affect thousands of acres of land and hundreds of thousands of people." In order to encourage and reach these large developers, Westinghouse has set up a corps of construction representatives to offer its entire product line to developers and a back-up crew of city planners, systems engineers, and market planners.

"While we believe there are existing prospects for the new cities being built from scratch on the undeveloped countryside, we believe there is equal challenge and promise in rebuilding the great old American cities," says Mr. Seim. Who the new giant developers will be or where they will come from he does not say but the guess is that among them will be corporations such as GE, Westinghouse, ITT, or their subsidiaries.

Another guess is at the kind of systems they will develop. It is obvious that a producer of some basic building material would try to utilize his own product as much as possible in any system he introduced. For example, Reynolds Metals Company is introducing a so-called "City Shape/21" system for expanding the central core of cities over waterways (see illustration) that will require large quantities of aluminum and other lightweight materials.

Actually, City Shape/21 goes beyond housing. Its designer, Chicago architect Stanley Tigerman, says he is trying to introduce a "unique third dimension to the conventional flat grids of existing cities." He seems to be following Buckminster Fuller when he talks of providing in his system a "total environment," including residential, commercial, industrial, and transportation functions. The entire complex would rest on pontoons and could more than double the size of a downtown area such as Chicago's Loop.

Reynolds itself does not seem to be interested in building City Shape/21 but is apparently looking for an existing developer to tackle such a project. It offers a possible solution not merely to the problem of home building systems but to the problem of what is regarded as probably the most complicated system of all—the city.

GOVERNMENT ENCOURAGEMENT

Unlike what has happened in some European countries, the government in this country has, until recently, offered little encouragement to industrialized housing. A new attitude seems to be emerging in the Department of Housing and Urban Development. An indication of this new attitude was the creation within HUD of a new office of urban technology and the appointment of former Pentagon analyst Thomas F. Rogers as director of the new office (see No. 4 JOURNAL, page 195). The new office is expected to work closely with its Federal Housing Administration co-partner in HUD, and with private interests, to encourage the development of workable systems approaches.

What is seen as another hopeful sign is the new emphasis on building systems in HUD's Section 207 and 314 demonstration grant programs and in FHA's Section 233 experimental housing insurance program.

The change in the Section 233 program has been little publicized—as has the whole 233 program. The reason may be that Section 233 is not an insurance program, as such. It does, however, make it possible for builders to test new materials or techniques by waiving the minimum property standards on the "experimental" portion of a project that would otherwise be eligible for mortgage insurance under any of FHA's mortgage programs. Thus, for example, the sponsor of a 221 (d)(3) low-income housing project could, because of Section 233, specify use of experimental materials or construction techniques not presently authorized by FHA minimum property standards—if the use of such materials or techniques promised to lower building or maintenance costs or provide certain other benefits. If the "experiment" should prove successful, in the opinion of FHA, the new product or technique would then become acceptable in any FHA-insured construction.

The purpose of Section 233, obviously, is to encourage innovation in home building. Until now, the emphasis in the program has been on new product development, such as plastic pipe and foam and paper sandwich lathing, rather than on systems development. Even this modest application of the law, however, has been considered disappointing in that Section 233 has failed to produce any great time or cost saving innovations.

James R. Simpson, director of building technology in the new office of urban research, explains why the 233 program, which he once headed, has not been very successful: "Manufacturers don't want a product they are trying to market to be labelled 'experimental'," he says. "They want their potential customer to believe that any product they have for sale has already been proven."

The new emphasis in Section 233, according to Mr. Simpson, will be on a total systems approach to housing innovation. For example, the vertical stacking of mobile homes in Vicksburg, Mississippi's 221(d)

(3) project mentioned earlier is one of seven experimental systems projects being insured by FHA. All of these projects have Section 233 waivers. HUD hopes to encourage the use of still more systems approaches through the 207 and 314 programs and through its own urban research and technology program, once it is funded (see No. 4 Journal, page 194).

Two Categories of Systems

All of the building systems receiving government encouragement in one form or another fall into two fairly distinct categories: (a) prefabricated boxes, or parts of boxes, which can serve as a single-family home or be stacked for multi-family housing and (b) prefabricated pieces and parts that can be arranged in various ways. The vertical trailer park is an example of what can be done with the first type of system; the Mouton system, as described on page 431, encompasses the pieces-and-parts concept. Each system is recognized to have its advantages: the box system is more complete, since each box can be a finished living unit; the pieces-and-parts approach is more flexible, permitting the builder to arrange the same components in an endless variety of shapes and sizes.

Perhaps the outstanding example of what can be done with a box system in Montreal's Habitat 67 (see No. 8 1966 Journal, page 444). Because of the imaginative stacking of the units and the use of enclosed walkways at the different levels, Habitat is able to combine the amenities of the single-family home in the suburbs with the practicality of the in-town apartment.

In constructing Habitat, however, its architect, Moshe Safdie, ran into engineering problems that he never fully solved. The major problem involved bringing the units to the site and putting them into place. Because the average unit weighs some 90 tons, Safdie had to erect a factory as close to the building site as possible. He also had to employ specially designed lift trucks and cranes to move the units from the factory and put them in place. All of this required a heavy capital investment, resulting in an average cost of $100,000 per apartment unit. Even if he had been able to do a much bigger project, Safdie admits that he could not have reduced the cost per unit below $40,000.

Nevertheless, officials in the office of urban technology have been impressed with Habitat. And they also believe they have found an answer to Safdie's weight problem in an Oakland, California project that is being insured under the FHA Section 233 program. In Oakland, a six-story, low-income apartment building is being erected using a box system developed by CONRAD Engineers, the same firm that worked out the system used in New York City's "instant rehab" project (see No. 4 Journal, page 214). Called UNIMENT, the system involves the vertical stacking of boxes, or volume modules, prefabricated out of chemically pre-stressed concrete, a material never before used in building construction but becoming increasingly common in highway construction.

Because chemically pre-stressed concrete has exceptional strength characteristics, a load-bearing wall built of this material can be relatively thin and lightweight. For example, UNIMENT modules have load-bearing surfaces only 2 inches thick (as against 6 inches or more in other pre-cast concrete construction) and weigh only 20 tons (as against 90 tons for a comparable sized Habitat unit). The UNIMENT modules can thus be transported to the building site on regular flat bed trucks and lifted into place with conventional equipment.

In the Oakland project, the UNIMENT modules are being arranged side-by-side, one atop the other, resulting in a finished product that resembles any conventional apartment building: seen as an unfortunate contrast with Habitat. The esthetic potential appear to have been neglected almost entirely.

In order to exploit more fully the potential of both Habitat and UNIMENT, HUDs office of urban technology has been trying to arrange a meeting between Safdie and Edward K. Rice, the engineer who developed UNIMENT, to discuss a future project that would utilize the architectural brillance of the former with the engineering sophistication of the latter. What HUD hopes will emerge is a system for building low-cost, functional, and esthetically exciting housing.

In the meantime, HUD is not neglecting the potential of the pieces-and-parts approach. A recent $203,000 Section 207 low-income housing demonstration grant to the Catholic Archdiocese of Detroit (see No. 5 JOURNAL, page 277) will test the cost reduction potential of a components system developed by Mitchell Associates of Cambridge, Massachusetts. Already successfully demonstrated in South America, the Mitchell system is designed for, among other things, maximum use of self-help in home building.

The system utilizes a set of lightweight, fireproof structural components made of precast, reinforced cellular concrete that can be rapidly erected as the load-bearing frame of a single- or multi-story building. No component weighs more than 150 pounds and the structure can be erected by as few as two people with no prior construction experience and with no construction machinery, according to the designers. A one-room or single-cell structure can be put up for as little as $400. It could later be expanded inexpensively by adding components.

The greatest potential in the Mitchell system, however, is seen to lie in its flexibility. It incorporates much of the same concept that goes into the production of automobiles; that is, a basic frame or chassis to which the manufacturer can add on any number of accessories depending upon the financial capability of his intended customers or the use to which they intend to put the vehicle. These accessories can either be attached during the original construction or added at some later date. In addition, the Mitchell system incorporates the idea of interchangeable parts; in case of damage or excessive wear due to age or climatic conditions, the owner merely removes one of the components and replaces it with a matching one.

Because the architectural integrity of the Mitchell system is incorporated in the frame, it permits the use of any nonbearing wall material for insulation and privacy. Within the modular dimensions set by the framing system, this in-fill material can also be mass produced and installed at the job site.

In choosing accessories, the Mitchell firm is going even one step further than many prefabricators. For example, it has developed a one-pipe, polyvinyl chloride bathroom package that can be easily installed. Other accessories may include such luxury features as air conditioning and built-in hi fi. Even the outer walls may be covered with a new "skin" to add a richer or more decorative appearance.

The designers of the Mitchell system, then, are thinking not merely of the immediate housing need of the low-income person but anticipating his long-range need. As his income rises, he can add on to his existing house the features he would want, rather than having to seek these features in another, more costly home. In this sense the housing prefabricator has gone beyond the automobile industry by eliminating the need to "trade up" to a more expensive model in keeping with the customer's rising status.

Far-Out Ideas

What appear to be exciting potentialities of current building systems are criticized as not carrying the idea of industrialization far enough, in the opinion of some thinkers. In fact, these critics say, none of these systems even begins to utilize the technology already developed in such frontier fields as the aerospace and computer industries.

Professor C. Theodore Larson of the University of Michigan's architectural research laboratory is one such critic. The basic flaw that Professor Larson sees in most of the current efforts to develop a widely applicable systems approach is the designers' adherence to the idea of building *permanent* structures. Permanence, he feels, puts even the most innovative building systems closer to the pyramids, technologically, than they are to a modern vehicle.

What Professor Larson and some of his colleagues are working toward can most accurately be called a *disposable* house. The cost of their ideal structural system would be so low that, rather than trying to maintain the house, the owner would simply replace it when it began to deteriorate. Carried a step further, a section of a city, or the entire city itself, could be made of disposable buildings that could be replaced before they wore out. A disposable city is seen as a futuristic solution to the slum prevention problem—and to a host of other urban ills.

Professor Larson's primary concern, however, is not with slum prevention; it is with utilizing technological advances. "Why should buildings have fixed life spans," he asks, "when modern technology is going to make them obsolete within a few years?" Expecting buildings to last 40 years or more, he says, only hampers the incentive for technological progress.

A conversion from permanent to disposable housing is seen as bringing many beneficial social and economic effects. For example, it would free housing from the restraints of long-term mortgage financing, enabling many low-income families to purchase housing much as they can purchase consumer items on short-term credit. Indeed, housing, itself, would become a consumer rather than investment item. Disposable housing is seen, also, as a probable encouragement to more flexible and rational land uses by replacing current purchase arrangements with short-term leasing. In this sense, a piece of land could be freed from its current use every five years or so for some different, perhaps more rational use.

This kind of thinking apparently seems too futuristic to have any application to today's housing needs. Nevertheless, prototypes of disposable houses have already been developed. All of them have certain common characteristics: they are constructed of extremely lightweight, inexpensive materials; they can be constructed quickly, often in a matter of hours, with a minimal labor force; and, of course, they are cheap to produce. However, none yet goes beyond the building of an outer core or shell. They are all what space scientists would call "first generation" buildings.

The use of various foam plastics, which have a density of less than two pounds per cubic foot, has produced several buildings at the University of Michigan architectural research laboratory. In one experiment, two men were able to erect a 45-foot diameter dome, complete with window and door openings, in only 12 hours. The experiment was carried on in collaboration with Dow Chemical Company, using the company's polystyrene foam boards and "spiral generation" process. As explained by Professor S. C. Paraskevopoulos, the process involves the use of a specially designed machine, which bends, places, and fastens together the 4-inch thick plastic foam boards in a predetermined shape, layer upon layer, into a rising structure spiral. In erecting the dome, the two workmen had to dig a shallow trench corresponding to the diameter of the dome. They then inserted 2 x 4-inch wood blocks to serve as supports for a base ring. A starter strip of polystyrene foam was attached to the ring and the spiral generation process was begun. The completed dome was then lowered into the trench, which was backfilled with earth. Openings were marked, cut, and reinforced around the edges with fiberglass tape and epoxy resin. A cement floor slab was poured and its edge anchored to the dome. The surface was then coated with a mixture of latex paint and vermiculite (to protect it from the sun's ultraviolet rays, which will cause polystyrene to deteriorate rapidly). Partitions were installed in the openings and a flexible polyethelene gasket used to create the joints between the dome and the glass fenestration.

This particular dome was designed to last for up to three years, or even longer if a new mixture of latex and vermiculite were applied. Although Dow Chemical does not plan to produce any more domes for the time being, the original one is still in use as a temporary clubhouse for a local country club.

The University of Michigan architectural research laboratory has another "first generation" building, which demonstrates a process that Professor Larson thinks has "tremendous potential." The process is "filament winding," which has been used successfully in fabricating nose cones for space vehicles. Developed by Hercules Powder Company, a DuPont subsidiary, it involves spinning a hollow shell out of fiberglass and resin. The advantage of using fiberglass is that it has the strength of some steels combined with the lightness of some plastics. The machine used to do the spinning can be hooked to a computer, which, in turn, can be programmed to produce a structure of any shape. The computer can also be programmed to leave space for window and door openings.

The building that demonstrates this process has rectangular dimensions of 8 feet by 12 feet by 20 feet. It cost only $1000 to build but another $500 was needed to ship it to Ann Arbor, Michigan from the Hercules plant in New Jersey. The research laboratory is now working on a "mobile factory," which would eliminate the cost of shipping finished shells in quantity.

It may be decades, of course, before a synthesis occurs between the aerospace industries and the homebuilding industry but the ideas emanating from the architectural research laboratory at Ann Arbor and from other research programs give an indication of the potential of such a merger.

APPENDIX III

DICKER STACK-SACK INTERNATIONAL SYSTEM

In response to an inquiry concerning the Dicker Stack-Sack International, the following information was received from Dennis E. Dicker, Executive-Assistant, as to what might be accomplished using the Dicker Stack-Sack International system, please be informed that using this system this house can be built for less than $5.50 per square foot which includes *centrally heating* and *air conditioning.*

As to the economical and technological obstacles that prevent or limit the use of my system please be advised that presently we encounter no obstacles.

To explain the system to you the following methodology and technology is used: Burlap sacks six (6) inches in diameter and twenty-four (24) to twenty-seven (27) inches in length are filled with a dry mix consisting of sand, gravel, and cement. The quantities used are commonly known as a five (5) sack mix. A foundation is poured ten (10) inches wide and reinforced with four (4) half (½) inch rods. The foundation is poured to ground level, and then three-eighths (⅜) inch reinforcing rods are placed in the concrete foundation protruding upward. These rods are spaced on twelve (12) inch centers. The sacks are then placed on the foundation and are pierced by the rods in the foundation thus tying the bottom coarse of sacks to the foundation. As the sacks are laid in place they are wetted with water coarse by coarse. Also as the sacks are laid on the foundation they create a form for the slab, thus doing away with any type of conventional forming. Each sack is pierced with two (2) three-eighths (⅜) inch reinforcing rods seven (7) inches long that in effect tie each sack to the sacks above and below giving a complete network of steel reinforcing through all the sacks. After the wall is in place a "tack-coat," which is pumped on consisting of four (4) parts sand and one (1) part cement is applied insuring further stability and bonding. After the "tack-coat" is applied a "finish coat" consisting of the same materials as in the "tack-coat," is applied to an average thickness of one (1) inch interior and exterior. The finish can be either smooth or rough, the smooth being more costly than the rough finish.

The house which we have built in the rear of my office, 2600 Fairmount, is available to be seen at any time your office desires.

Presently Mr. Shupee, who is the head of the architectural department at the University of Texas at Arlington, Texas, is doing both engineering and architectural studies for the Dicker Stack-Sack International method which in turn will give me all of the necessary testing data.

APPENDIX IV

Paper on European System Building Presented by Guy G. Rothenstein of ASPAD, Inc. at the Interagency Discussion on Advanced Housing Held March 21, 1967, at the Executive Office of the President—Office of Science and Technology, Washington, D.C.

I welcome the opportunity to discuss my favorite subject "System, or industrialized building".

ASPAD stands for: Associated System Planners and Designers. We are an independent professional organization, or group practice of planners, designers, architects, structural engineers and mechanical engineers, specializing in the new field of system building. We treat all these disciplines on an equal level—not subordinated one to any other.

Our Philosophy: We are very research and development minded like any organization working in a new field—but we stress the point, that system building is fully developed in Europe, with actually 20 years of practical experience, which certainly is enough time to perfect systems and take out unavoidable "bugs".

The extent of use of system building in Europe, specially in housing is considerable: in France today, 60% of all multi-family housing is system built by more than 200 plants with a production capacity of over 500 dwellings per day.

In England 25% of all multi-family housing was system built in 1966. The figure for 1967 is expected to be 40%. Russia, which started only in 1956, is building presently 85% of its housing by industrialized methods. The city of Moscow alone is assembling 300 apartments per day, while New York City's projected building rate for all multi-family housing for 1967 is less than 80 units per day.

The housing requirements of Western Europe are very much similar to those of the U.S. and the new technology developed there since 1947 at tremendous cost, is to a large extent applicable to our problems, permitting to save years of research and experimentation and millions of dollars in cost.

Definition: System building in an industrialized society is the complete integration of all sub systems (structural, mechanical, walls, etc.), assemblies, components and parts into *one overall system* making full use of industrialized production, transportation and assembly.

The term "building system" is presently greatly misused for improvements of building materials, combinations of materials or structural concepts which, at best, might classify as "sub systems".

There is also confusion about what "industrialization" is—it is often confounded with technology or prefabrication—neither "per se" mean industrialization. Prefabrication is often a first step towards industrialization but not always, as for instance, the precasting of architectural concrete in the U.S., which is strictly a "craft".

The basic elements of industrialization are *Mechanization* and complete *Programming* of the process of building. This is rarely understood by our "craft oriented" building industry. Here is an example of what programming means in a European building system using *multifunctional* precast concrete panels: exterior wall panel no. 218 which includes windows, insulation, finishes and electric work is programmed to be produced during the 3rd daily cycle of casting machine no. V on a given day. 10 days later at 10:15 a.m. this panel is programmed to be loaded into the second rack of trailer "F", to be transported to site crane no. 4. This crane, as part of it's daily program of 80 lifts, is scheduled to lift panel #218 in it's position in the building at 11:24 a.m.

In general terms, this program was conceived during the design phase of the project and it is carried out with a maximum variation of plus or minus 10%, which means that projects of many hundreds of apartments are completed on schedule or within the estimated budget cost with very minor variations.

Materials: System building is possible with practically all basic building materials. In Europe concrete is the most widely used and at present the technology of its use is the most advanced. The reasons for this are that concrete is readily available everywhere. It is relatively inexpensive, has good structural qualities, is fire and sound resistant and can be easily molded into multifunctional assemblies incorporating windows, doors, insulation, finishes, electrical and mechanical work.

Types of Concrete Systems: There are "open" and "closed" systems. Open systems widely used in Eastern Europe are based on modular standardized assemblies produced by different plants all over the country. These are catalogued and stocked and architects are directed to use these for certain types of buildings. This approach hardly fits in our concept of building.

However, the "closed" systems used in Western Europe are predicated on contractor owned tooling permitting industrialized production of architect "custom" designed buildings.

These systems use off-site production, on-site production, or combinations of these. There are systems using large panels (length and height of a room), small panels like our office partition panels, and "box" systems such as "Habitat 67" in Montreal.

Types of Housing Which Can Be Built by Concrete Systems:

Anything from one family houses to 30 story apartment houses. Our cost studies indicate that it is most advantageous to be used for medium and high rise apartment buildings from 3 to 25 stories. It can be used for low income, middle income and luxury housing, housing for the elderly, college housing and nursing homes and other health facilities.

I shall now show two films on systems which are well representative of the many systems used in Europe today. These were selected because my firm and myself investigated these carefully in our consultant capacity and we are in a good position to report on these systems and answer questions which you may have.

(1) The Sectra system, available in the U.S. through Schokbeton Products Corporation, is a system of on-site, cast-in-place reinforced concrete, using industrialized methods. Structural and electric sub systems are fully integrated—other sub systems are highly compatible. Tooling design for U.S. use is presently being developed.

(2) The Balency system is available in the U.S. through Balency-MBM Associated. It is a combination of highly mechanized factory production of loadbearing exterior and interior multifunctional wall

panels with industrially site cast floor slabs. All sub systems are fully integrated.

The high degree of mechanization permits the use of unskilled labor organized in crews, repeating the same task several times each day. Several plants for the U.S. are in an early planning stage.

These films make building look very easy. What we have seen is nothing experimental. It is happening just a few hours from here all over Europe day in, day out at the rate of thousands of dwellings per day.

It happens in countries with which we have friendly relations and active exchanges of technical information in many areas other than building.

POTENTIAL FOR U.S. HOUSING: System building has 3 basic advantages: *quality—speed—cost.*

(1) *Quality.*—The machine sets the standards of workmanship at a much higher level than those of craft production. On projects with economical limitations there is a much greater architectural and design freedom than in conventionally built housing. It should be understood that the discipline of system building affects the method of construction but not necessarily the visual aspect of a building. There is great freedom in choice of form, module, proportion, texture and color and no need for standardization of these.

(2) *Speed of Construction.*—Spectacular cases of performance are on record: In France a fireproof 5 story, 40 family apartment house was assembled in 9 working days after completion of the foundations and tenant occupied another 15 days later.

This is something which should make the proponents of "instant rehabilitation" jealous. The average time of completion for large projects is 6 to 8 months which is about half the time of corresponding U.S. developments.

(3) *Cost.*—The general rule of industry applies: The greater the mechanization, the lower the cost. Savings are three fold:

1. *Initial Cost.*—Site labor is often reduced by 50%, total labor by 20% to 35%. Man hour averages per 1000 sq. ft. of dwelling are in Europe 900–1100. U.S. averages 1200 to 1600 man hours. Since labor cost is about half of total cost, the potential of labor savings amount to at least 10% of project cost. There is also a potential of material cost savings of possibly 5% of project cost, by using a single material "concrete" for structure, walls and partitions. It is cheaper to buy a single raw material and convert it in a factory without waste into a finished product, than our combination of a multitude of materials such as brick, block, gypsum products, etc., which have to be fitted on the job with great waste.

2. *Savings Through Shorter Construction Time.*—It is estimated that the combined savings of interest, tax, overhead, capital turnover and earlier occupancy, amount to 1% to 1½% of project cost per month saved. 6 months of time saved may mean 6% to 9% of project cost.

3. *Savings in Maintenance.*—Performance records show definite savings over conventional plaster finished buildings.

The total savings over the life of a building, while difficult to compute, are very substantial and should amount to more than 20% of project cost. This may well be the answer to the so far unsolved project cost. This may well be the answer to the so far unsolved problem of keeping rents down in low and middle income housing.

Relation to Model Cities Program: Besides the physical and direct economical aspects of system building, there is a broader economic aspect in regard to the Demonstration Cities Program: Portable "house factories" may be located in project areas and give area residents new job opportunities. Since a high proportion of unskilled labor can be used in the factory and on the building site and no physical strength is required for this work, this will stimulate employment for the young, elderly and even physically handicapped workers. On-job training is easy and system building continues year round. Permanent plants located in industrially zoned areas can contribute to the sound development of the entire city and the spectacular speed of building with community participation may become a great moral factor.

What are the Constraints? Everybody worries immediately about "*labor*" and "*codes*." The films presented here were viewed by President Haggerty of The Building and Construction Trades Department of AF of L–CIO and he expressed the opinion that the use of these systems can certainly be negotiated with the union locals.

The general advantages of system building for labor are year round employment, easier work, safer working conditions, shorter training periods, better opportunities for young and elderly workers. Contractors opinions on labor reaction vary greatly, depending on the locality and the type of system considered. Generally, large well established firms with good labor relations, think that European system building, with certain modifications, is well usable here.

In respect to *codes*, there are no structural problems for systems using reinforced concrete. AC1 section 318–63 is applicable. Since "closed" system buildings are always individually designed, local code requirements for mechanical sub systems can be easily followed.

The biggest obstacle to introduce system building in the U.S. is the *financing* of the plant equipment. U.S. building is so fragmented through sub contracting practices, that even the biggest firms are small when it comes to invest in tooling for industrialized production. This situation is well highlighted by the fact that in our urban renewal or new town projects millions are spent for "land" and not a dime on industrial tooling for building. Things are different in Europe. In larger developments the first thing done to produce housing is the planning of a "house" factory. The Greater London Council has been planning a 60,000 inhabitants new community, Woolwhich-Erith (now called "Thamesmead") for several years. Based on successful previous experience, it was decided that this project should be industrially built. Bids were taken from 3 systems builders for 4,000 dwellings, including an on site production plant with a yearly capacity of 1500 dwellings. The contract was awarded to the Balency system licensee for about $26,800,000 plus a variable fee of about 2%. At completion of this first contract new bids for operating the plant and building additional units will be taken.

If we want to get industrialized building started here we have to face the basic truth that *industrialized building is not possible without industrial tooling*. Same as it is impossible to produce an automobile body economically without a stamping press—it is impossible to produce a concrete building panel economically without a casting machine. Too much time and money is spent on attempts to bypass this truth—ingenuity and technology are wasted by government, and private industry to save pennies where proper tooling would save dollars.

Today, the building industry is in respect to tooling for industrialized building, in the same position as the aircraft industry in respect to tooling for the supersonic airliner. Both need government help to get started and will then become self supporting. U.S. industry is always quick to follow the path of success.

WHAT IS THEN THE BEST APPROACH? There appear to be two possibilities:

(1) The method used by the Greater London Council, to get a single contract big enough to include full amortization of the tooling.

(2) To make the investment a partial risk by creating a sizeable guaranteed market, provide loan assistance for tooling and use a cost plus contract for the site labor of the first contract only, to avoid that the contractor may bid a higher price than for conventional work.

It is also important that system building, including the plant operation, be in the hands of a general contractor or builder developer to assure complete integration of programming, planning, design, engineering and execution. Subcontracting as practiced at present in the precast concrete industry, is not workable for system building.

WHAT RESEARCH AND DEVELOPMENT IS REQUIRED FOR THIS PROGRAM? Not very much. One essential project is a study on the integration of mechanical sub systems using standard U.S. approved components and parts. Major savings are reported from Europe by integrating structural and mechanical sub systems—as much as 50% on electrical contracts and 20% to 25% on heating and plumbing contracts. While structural savings alone are considerable, we should also take advantage of these major mechanical savings.

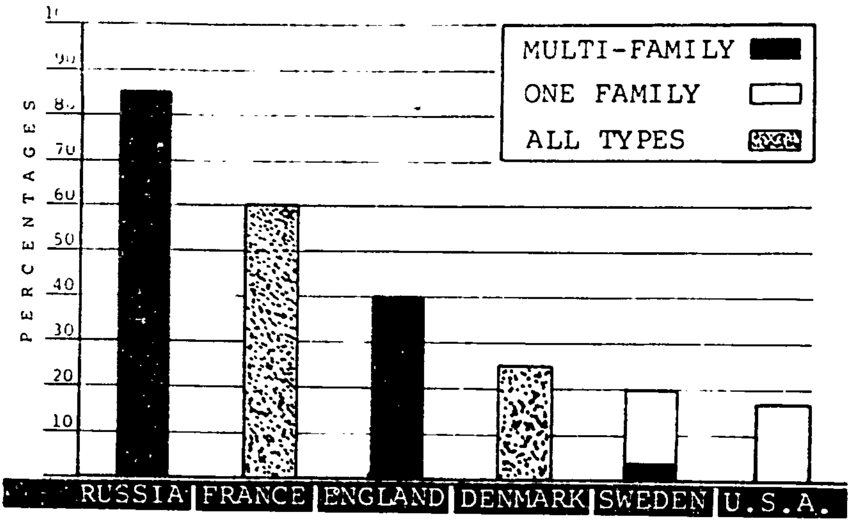
Another project which is important and for which we have submitted an application for a technical studies program grant to F.H.A., concerns system building and its relation to F.H.A. Minimum Property Standards. Technical and procedural revisions and additions will be necessary to permit the use of system building for F.H.A. mortgage insured projects.

A similar study should be made concerning the standards of Housing Assistance projects.

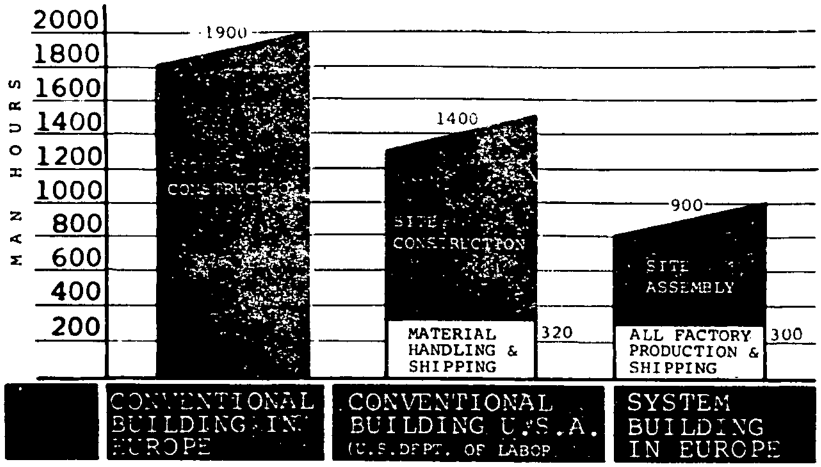
A third study project which we would like to suggest concerns the feasibility of locating industrialized housing plants in model city areas to create employment opportunity for local residents. This study should cover the physical, social and economic aspects, and can be oriented toward general needs or specific city programs.

We stand to gain a lot by adapting proven European building systems to U.S. housing construction.

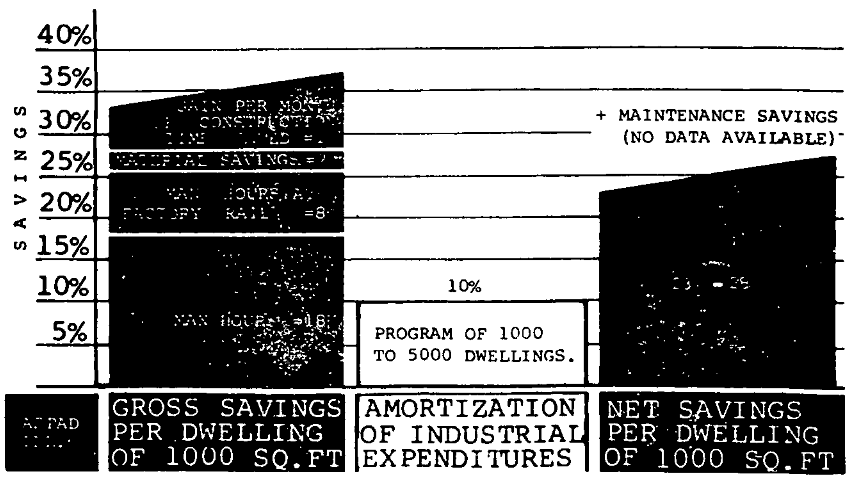
1967 ESTIMATED PERCENTAGES OF DEGREE OF INDUSTRIALIZATION OF HOUSING CONSTRUCTION.



MAN HOURS OF ALL TRADES PER 1000 SQ. FT. OF HIGHRISE HOUSING — AS PAD ILL. 5



APPROXIMATION OF POSSIBLE SAVINGS IN U.S. HOUSING CONSTRUCTION THROUGH SYSTEM BUILDING



COMMENTS ON CHART ILLUSTRATIONS BY MR. ROTHENSTEIN

III.4: 18% of U.S. housing represent mostly prefab. homes, using rationalized, rather than industrial methods.

III.5: Of particular significance is the fact that material handling and shipping of conventionally built U.S. housing requires more time than the factory production and shipping to the site of a complete dwelling in European system building.

III.6: Figures of potential labor and material savings are based on European man hour and material requirements figured at average U.S. cost.

The potential initial savings of 23% and 28% represent savings of square foot cost for fireproof multifamily housing of possibly $2.00 in low cost areas and $4.00 in high cost areas.

FINAL REPORT ON THE STATE OF THE ART OF PRE-FABRICATION IN THE CONSTRUCTION INDUSTRY

TO

THE BUILDING AND CONSTRUCTION TRADES DEPARTMENT, AFL-CIO, FROM BATTELLE MEMORIAL INSTITUTE: COLUMBUS LABORATORIES*

INTRODUCTION

In October, 1966, the Construction Economics Research Group of Battelle Memorial Institute was asked by the Building and Construction Trades Department of the AFL-CIO to undertake a research program on "The State of the Art of Prefabrication in the Construction Industry". This study was concerned primarily with estimating the amount of construction that may be transferred from the job site to the factory or otherwise changed in character as a result of prefabrication. An analysis was made, representing Battelle's best effort within the constraint of time and cost, of the residential, nonresidential, and nonbuilding segments of the construction industry in the United States. An additional cursory investigation was given to estimating the effects of other technical innovations (not necessarily related to prefabrication) that will require a reallocation of manpower and skills at the job site.

The intent of this study was to provide the Building and Construction Trades Department with a long-range planning tool to aid in future decisions related to (1) skill requirements, (2) manpower requirements, and (3) new training programs.

Battelle's findings and conclusions were presented orally on September 21, 1967, to the Executive Council of the Building and Construction Trades Department. This report confirms that presentation and summarizes Battelle's work in fulfillment of the research agreement.

SUMMARY

Prefabrication was first introduced into this country in 1624 when the English brought a panelized wooden house to Cape Ann. Although the word "prefabrication" has been used frequently since then, there is little agreement as to its meaning. Much of this confusion exists because prefabrication is a generic term used to describe a manufacturing process through which a building, structure, house, shell, component, or piece is produced. The process includes certain integral operations, such as precutting, preassembly, and prefininshing, and all companies that participate in this process—regardless of their degree of involvement—can be called prefabricators.

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*Sept. 29, 1967: by R. B. Guy; L. H. Parmelee; R. W. Trestrail; S. E Goldstone; J. E. Burch.

Thousands of companies are involved in prefabrication in the United States. These include mobile-home manufacturers, sectionalized-home manufacturers, home manufacturers, traditional builders using some preassembled components, on-site fabricators, component manufacturers, and building-material suppliers. Most of these companies either make or use preassembled components—except the mobile-home manufacturers, who produce totally prefabricated units, and the building-material suppliers who market precut pieces.

Currently, most of the buildings in the United States that are being assembled on site from factory-made components are in the low-rise category. They include single-family dwelling units, town houses, garden-type apartments, dormitories, nursing homes, branch banks, office buildings, and industrial buildings.

In most instances, the end result of prefabrication of low-rise buildings is the rapid erection of the basic shell of the structure, which accounts for only about 30 percent of the total cost of the structure.

In the high-rise building sector, prefabrication is capable of playing a much greater role during the building process than most people in this country realize. For instance, using existing technology and products, a building can be erected entirely from preassembled components. After the shell is erected, various components and subsystems also can be used to virtually finish the interior space.

Prefabrication is making significant inroads in Europe through industrialized building methods. These methods are responsible for about 25 percent of all construction currently put into place, but the Europeans are very confident of a rapid increase in industrialized building during the next decade.

To achieve industrialization of building, the Europeans have developed building systems which lend themselves to mechanization and automation. A frequently used definition for a building system is "The application of modern management techniques to coordinate design, manufacturing, site operations, and overall financial and managerial administration into a disciplined method of building." These systems may be either "open" or "closed", and are initiated by any of four types of organizations: (1) contractors, (2) engineers, (3) clients, and (4) manufacturers.

There are currently hundreds of building systems available throughout Europe. Most of them use heavy, precast concrete components and are designed primarily for the construction of high-rise, high-density housing. The components can be produced in either a large central manufacturing facility or an on-site plant. The central manufacturing facility is by far the most popular.

A number of factors appear to be required for the success of a European "systems sponsor". These include (1) strong internal business organizations, (2) large volume (a thousand units per year), (3) concentration of volume (within a 25-mile radius), (4) continuity of production (3 to 5 years), and (5) strong, active government support. The last factor is achieved readily in most of Europe, since the public housing sector of the market usually exceeds 50 percent.

Some changes will occur in the United States during the next decade in the field of prefabrication. The magnitude and extent of these changes will be influenced greatly by (1) the construction environment, (2) technological advances in construction methods, equipment, materials, and design, and (3) various constraining factors.

A projection of the U.S. "construction environment" in 1975 indicates that wages, land prices, and construction activity are all expected to increase at a fairly rapid rate, which should enhance prefabrication opportunities.

Changes in construction methods are expected to occur as attempts are made to introduce European building systems into this country. There are at least four major European building firms that are actively seeking licensees in the United States, and others are considering this move. The advantages of these industrialized systems are that they reduce skill content, accelerate the erection procedure, and centralize the control and responsibility for the construction process. However, there are a number of potential problems, such as building codes, bidding procedures, and royalty fees, that must be overcome before these systems can be successful. Consequently, the probability of success for the European-sponsored building system in the United States before 1975 appears quite low.

By 1975, a few U.S. firms will initiate some high-rise building systems that will represent modifications of the European systems. A few of these attempts are expected to be fairly successful. However, in order to gain acceptance, the initiating companies probably will have to relinquish some of their control over the construction process, thus diminishing the value of the building system.

Other expected changes in construction methods are (1) the increased use of large interior subsystems that offer sufficient flexibility to satisfy a wide variety of individual needs and (2) the increased popularity of lift-slab and tilt-up construction techniques, curtain wall systems, and preassembled bridge sections.

Construction equipment will continue to become larger in an attempt to offset rising labor costs. However, as equipment size increases, the equipment will become more specialized and the markets more limited. The crane appears to have a greater potential than any other piece of equipment currently serving the construction industry.

No radical changes in materials and/or products can be visualized in the next 10 years. Although a number of companies are currently conducting extensive research and development programs, the results will not make any sizable impact on the construction market by 1975. Most of these programs are directed toward new markets and new applications for existing materials rather than the development of new materials and/or products. The most rapid gains are expected to be made by plastics, which currently account for only 2 to 3 percent of the total dollars spent for construction materials. Under these conditions, the plastics industry can make large advances in this market with relatively little effect upon the suppliers of other construction materials.

Architectural design is in a constant state of evolution; however, design innovations have been and probably will continue to be subtle in nature. Buildings constructed in 1975 will look much like the buildings being constructed today, but the materials used, their application and assembly, and the organization of the building process will be changed to some degree.

The principal constraints to the growth of prefabrication between now and 1975 will be building codes, zoning regulations, architects, unions, transportation, capital requirements, tradition, and the basic structure of the construction industry. It currently appears that the latter two constraints will be the most difficult to overcome.

Prefabrication will definitely grow during the next decade; however, the growth will be evolutionary in nature—not revolutionary. Much of this growth will be based on the increased acceptance of existing methods and techniques of prefabrication by members of the construction industry, rather than the development of new prefabrication methods. There will be more opportunities for advances in prefabrication in the nonresidential segment of the industry than in any of the other segments.

As a part of this study, an "impact analysis" technique was developed in order to determine the effects of the anticipated advances in technology and prefabrication on each of the affiliated unions. The basis for this analysis is 249 "items" or events that are expected to occur or change during the next 10 years. The estimated impact of these items on the affiliates reveals that (1) prefabrication will offer the Operating Engineers the greatest opportunities for growth whereas it will offer the Painters, Decorators, and Paper Hangers the least, (2) the Operating Engineers will have the greatest need for new skills because of the anticipated changes, and (3) the United Association will be affected the most by reallocation of work from the job site to the factory.

Conclusions

The following conclusions are derived from this research program. For convenience they are presented by five broad categories (1) general, (2) residential—low-rise, (3) nonresidential—including high-rise apartments, (4) nonbuilding, and (5) effects on the affiliates.

GENERAL

(1) The current state of the art of prefabrication is much more advanced than most people realize. Virtually all of the dwelling units and buildings being erected today are using some prefabricated components.

(2) Currently, the majority of the nation's builders, contractors, and building-material manufacturers are involved to some degree in the prefabrication industry.

(3) To date, the reductions in initial building costs derived from prefabrication have not generally met expectations. The probability of a further reduction occuring by 1975 is small unless other cost factors are considered concurrently with prefabrication techniques.

(4) There will be no revolution in the field of prefabrication by 1975. The advances will be slow and evolutionary in nature.

(5) The two largest constraints to the rapid advancement of prefabrication are (a) lack of public acceptance based on tradition and (b) the existing "structure of the industry". Both are nontechnical.

(6) Technology is not lagging in this field, as it currently has the capability of producing almost anything the market demands. In fact, technical advances are probably 10 years ahead of the industry.

RESIDENTIAL—LOW-RISE

(1) The growth rate of prefabrication will continue at a fairly constant rate. However, much of this growth will result from more

builders accepting existing methods, applications, and materials—not from the development of new ones.

(2) More builders will start to use "industrialized" schemes similar to those the home manufacturers are currently using. This can be attributed to (a) builders will be larger, better capitalized, and have more efficient organizations and (b) demand for dwelling units will be greater and the builders will want to take advantage of economies of scale.

(3) Home manufacturers will become increasingly involved as developers. Consequently, decentralization of facilities will prevail, resulting in a sharp increase in the use of on-site prefabricating plants. This move will accomplish better control and reduce transportation costs.

(4) Dwelling units will change very little in overall appearance or shape. There will probably be a slow evolution in materials used, but wood will still be dominant.

(5) Totally factory produced and assembled dwelling units (other than the mobile home) will not be feasible by 1975. Its principal constraint will be the lack of an economical mode of transportation.

(6) Currently the home manufacturer is responsible for "putting into place" 25 to 30 percent of the total cost of a dwelling unit. By 1975 this figure will probably increase to 45 percent.

(7) By 1975 the typical dwelling unit will still require a substantial amount of on-site labor hours during the building process. These requirements will be necessary for the following tasks: site preparation, foundation, mechanical, erection, and finishing.

NONRESIDENTIAL—INCLUDING HIGH-RISE APARTMENTS

(1) There will be more opportunities for new prefabrication advances and developments in this segment than in residential. Reasons include:

Constraints are not quite as strong. For instance, "consumer acceptance" is a more dominant factor in the residential market.

Results of government research programs will indicate needs for the manufacturers to pursue.

(2) More architects will start to take advantage of the opportunities afforded to them by the preassembled and prefinished building components.

(3) High-rise building systems similar to those used in Europe will be introduced in the United States between now and 1975. They will make little impact on the marketplace.

(4) Subsystems, such as those currently being used for integrated ceilings, will continue to make rapid inroads. They will comprise larger and more complex components and will be capable of fulfilling more complete building functions.

(5) The use of prefabricated components for high-rise building applications will increase considerably by 1975. These components will enable the contractors to attain (a) a rapid erection of the basic shell and (b) an efficient, finished arrangement of the building's interior.

(6) The probability of prefabrication reducing on-site mechanical and finishing labor hours is much greater in nonresidential than in residential-type buildings.

(7) Rehabilitation projects will provide manufacturers with numerous opportunities to experiment with various types of unit prefabrication. As a result of these experiments some progress will be made in the area of unitized kitchen and bathroom units by 1975.

(8) There will be a continued trend toward the use of the "package builder" during the next decade. The package builder has his own architectural and engineering staff and offers a fairly complete package to the client. His method of operation is similar to that of the European "system sponsor" except that he is not limited to a particular system nor does he have manufacturing facilities. The growth of the package builder will enhance prefabrication opportunities in the future.

NONBUILDING

(1) This segment will continue to be a leader with respect to overall efficiency in construction.

(2) Nonbuilding will continue to lead other segments in the rate of acceptance of prefabrication because of the limited influence of the following major constraints: building codes, tradition, and architects.

(3) The only constraint on component size will be transportation feasibility.

(4) Many prefabricated bridges will be in use by 1975.

(5) Rising labor costs will force equipment manufacturers to develop larger and more efficient equipment in an attempt to increase productivity.

EFFECTS ON THE AFFILIATES

(1) The anticipated advances in prefabrication and technology during the next decade appear to offer "opportunities" to half of the affiliates and "threats" to the other half.

(2) The Operating Engineers and Electrical Workers will have the greatest opportunities for growth while the Painters, Decorators, and Paper Hangers will have the least.

(3) The Operating Engineers will encounter the greatest need for increased skills by 1975 due to prefabrication and other advances in technology.

(4) The majority of the affiliates will experience movement in their work locations—but none will move from factory to job site because of prefabrication.

(5) The United Association, Carpenters, and Electrical Workers will be the affiliates affected the most by the reallocation of work from job site to factory due to prefabrication.

Method of Conducting the Study

A brief summary of the way this study was conducted is shown in Figure 1. At the outset, preliminary information on the subject of prefabrication was obtained from an extensive literature search, discussions with Battelle staff members, and other miscellaneous sources. This information was then analyzed and categorized by (1) current applications for prefabrication, and (2) potential applications for prefabrication.

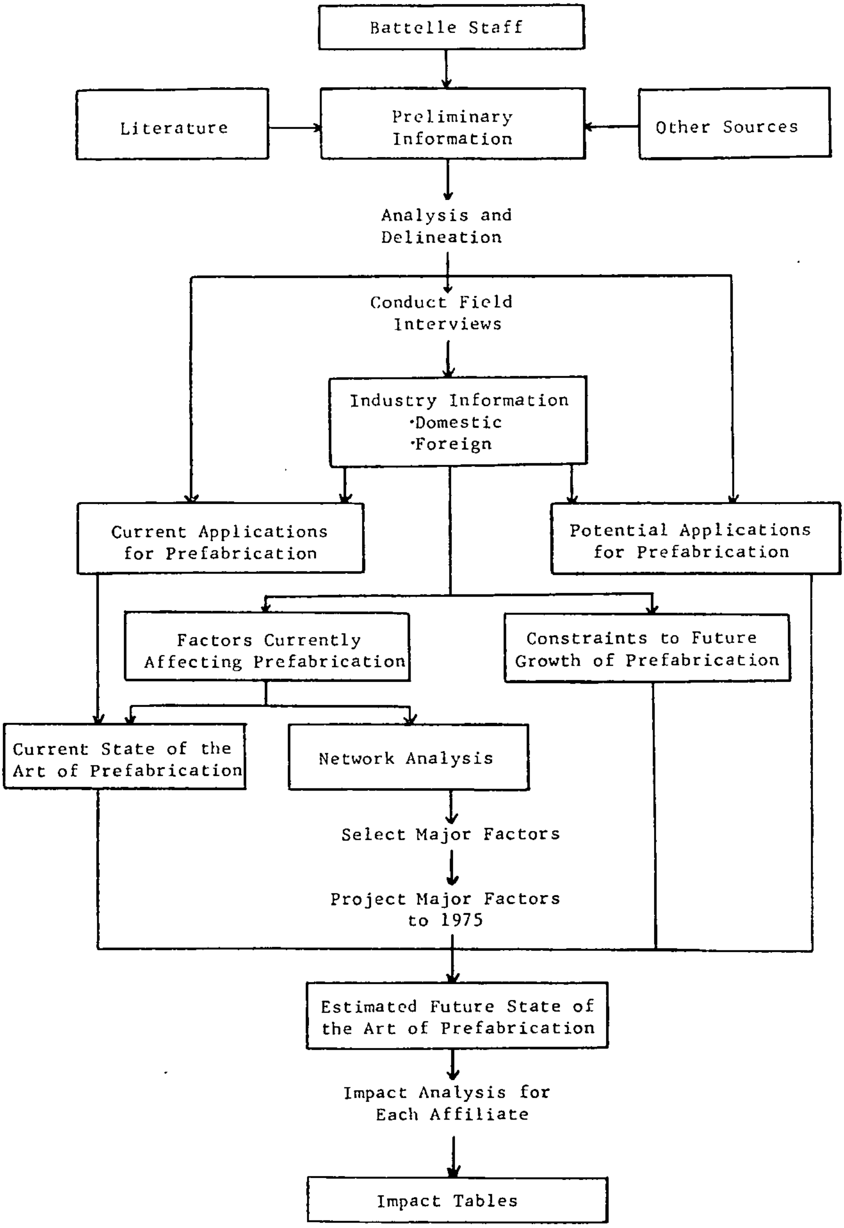

FIGURE 1. BATTELLE'S APPROACH

Field discussions, domestic and foreign, were then conducted with home manufacturers, component manufacturers, builders, contractors, architects, university personnel, consultants, associations, and others knowledgeable in this field. The objectives of these discussions were: (1) To augment and validate the information gathered at the outset of the study, (2) to obtain information pertaining to potential technological advances, and (3) to seek information about various technical, economic, social, or political constraints that might affect the future state of the art of prefabrication. A total of 77 interviews were conducted in the United States and 21 in Europe. Appendix A lists the names and locations of the organizations interviewed during this study.

To aid in estimating the amount and in characterizing the type of construction expected in 1975, Battelle used an analytical technique called a "network analysis". The purpose of this network was to assist in analyzing and weighing the relative importance (either positive or negative) of the technical and economic factors currently influencing prefabrication. Various screening criteria were applied to these factors in order to determine their significance and rank them in order of importance. It was assumed that the important factors in 1967 will also be significant in 1975. With this basic premise in mind, these basic factors were projected to 1975 and served as a basis for estimates concerning the overall construction environment in that year.

The estimated construction environment was adjusted to compensate for the anticipated technological advancements in materials, methods, equipment, and design, plus the various constraints expected to impede the progress of the industry.

All the previous information was then analyzed to derive (1) the current state of the art of prefabrication, and (2) the estimated future state of the art of prefabrication. The estimated future state of the art was then used as a base for developing an "impact analysis" which shows the anticipated effects of the advances in prefabrication and technology on the various affiliates.

WHAT IS PREFABRICATION?

The term "prefabrication" is commonly used throughout the construction industry—yet there is little agreement on the meaning of the word. To some people it means that a structure has been preassembled off site in a factory. For others, a house is considered to be prefabricated if at least two of the large structural components are preassembled at a factory and transported to site for erection. Some consider on-site fabrication of components to be prefabrication, others not. Furthermore, many companies are called "prefabricators" if they specialize in the manufacture of one or more components that are used in the building process.

Why is the term so ambiguous? Much of this confusion exists because prefabrication is a generic term used to describe a manufacturing process through which a building, structure, house, shell, component, or piece is produced. Inherent in this process are certain integral operations such as precutting, preassembly, prefinishing, and final assembly. Hence, all companies that participate in this process—regardless of the degree of involvement—can be called "prefabricators".

The problem of semantics is further substantiated when an attempt is made to differentiate between prefabrication, pre-engineered, preconstructed, industrialized building, building systems, and many other terms starting to be used within the industry. These terms are almost synonymous and imply that an industrialized procedure has been applied to the building process. The use of these additional terms also represents an attempt by the industry to do away with the term prefabrication and its connotations of "cheapness" that became associated with the word immediately following World War II.

It is obvious from this discussion that prefabrication has no precise definition that is applicable throughout the construction industry. For the purposes of this report, prefabrication will be used as a general term to denote either (1) a structure that has been assembled in total or in part from factory-made components or (2) a component that has been preassembled before final placement.

The History of Prefabrication [1]

Prefabrication is not a new development in this country. As early as 1624, the English brought a panelized house of wood to Cape Ann for use by a fishing fleet and the house was subsequently disassembled, moved, and reassembled many times. Throughout the earlier years of our history, new settlements provided a market for early prefabricators—the California Gold Rush of 1849 was a particularly lucrative market. Also, the Union Army in the Civil War used many prefabricated houses in its camps. In fact, railroad freight rates for wooden, portable houses date from around 1870.

Early in this century, the "mail-order house" became popular on the frontiers. Sears, Roebuck Company claims it sold 110,000 houses in 40 years. This was usually a precut house, but the production of these houses was important since it pioneered techniques for the production lines, standardization, and price packaging in the home manufacturing industry.

Concurrent with this development were experiments being carried out with materials other than wood. In 1905 Grosvenor Atterbury, a New York architect, conceived the idea of building a house using precast concrete panels. This system resulted in several hundred homes being built of precast hollow-core panels from 1910 to 1918.

In 1908, Thomas Edison proposed to pour an entire two or three-story house of concrete, but this was found impractical and the idea was abandoned.

Many other systems and methods were tried during the first two decades of this century. Some were successful, many were not, but all of them contributed to the knowledge of this industry.

The industry actually began developing its present-day characteristics around 1930. With the establishment of FHA, it became possible to market homes in a mass volume in normal peace time. Buyers were able to buy homes on terms they could afford, and the "industrialization of housing" became a challenge to our economy. Also, the influence of Frederic Taylor and his principles of scientific management were undoubtedly instrumental in these developments.

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[1] *A Fact Book on Home Manufacturing*, The Home Manufacturers Association, Washington, D.C., pp. 4–5.

American Homes, Inc., one of the leading prefabricators of that time, stated that millions of dollars were spent in an attempt to mass produce and distribute factory-built structures. The goal was to create a vast new industry which, like the automobile industry, would turn out standard models that the public was expected to buy. However, after years of intensive study, the leaders of the prefabrication industry concluded that the way to reduce construction costs was to deliver to the building site parts of the structure which fit and could be assembled without cutting or alteration.

During this same period, others approached the problem of reducing construction costs. Probably the most exhaustive study of the subject was made by Albert Bemis and Associates of Boston Massachusetts. The results of this study were prevented in Volume III of the "Evolving House" published during the 3-year period of 1933 to 1936. In this volume, entitled "Rational Resign", Bemis suggests a typical module as the basis for design and develops a method for establishing standard assembly details and a simplified drafting technique in which all dimensions are referred to a modular grid. Regarding housing, Bemis states "the reorganization that housing needs—and the redesign of structure here presented—is not a change of process. It does not suggest merely transferring to the shop what was previously done in the field. The parts of the house must be given the new forms and features required for versatility of design, economical mass production and ready-field erection". Albert Bemis died in 1936 and his heirs, wishing to see his work continued, organized the Modular Service Association to continue research in the field of modular standards. As a result of this effort, the American Standards Association initiated a project for the coordination of dimensions of building materials and equipment. This was a definite benchmark in the evolution toward prefabrication.

By 1940, there were about 30 firms manufacturing and selling prefabricated homes with approximately 10,000 units being produced between 1935 and 1940.

During World War II, home manufacturing met its severest test. The home manufacturers were faced with the difficult task of providing emergency war housing that would meet three requirements: speed, demountability, and the reduction of on-site labor. This provided the prefabrication industry with a great opportunity—but as a result of this effort, prefabrication gained a reputation as being "cheap" construction.

At the end of the war when there was a national demand for permanent, private housing, the prefabrication industry had to work diligently to overcome the public's concept of a "prefab", which was based on what they had seen during the war.

Around 1950, other types of prefabrication started to make noticeable inroads—such as the pre-engineered metal building and various preassembled components for nonresidential use.

Within the past decade, the prefabrication industry has been growing at a rapid rate, both in the United States and abroad. For instance, the sales of pre-engineered buildings have tripled; the mobile home industry is currently producing about 250,000 units annually; thousands of manufacturers are producing components for the industry; and according to the Home Manufacturers Association, approximately 25 percent of all single-family dwelling units are prefabricated.

The growth of prefabrication in Europe has also been rapid since about 1955. France is probably the furthest advanced in prefabrication, as 15 to 20 percent of all housing developments are industrialized. It is also reported that around 25 percent of the houses built in the Soviet Union are using industrialized procedures. Furthermore, there are currently over 400 industrialized building systems available for licensing throughout Europe. These systems all use aspects of prefabrication.

THE ECONOMICS OF INDUSTRIALISED BUILDING

by

D. Bishop

"In this paper, presented at the Chartered Surveyors Annual Conference 1966, Mr. Bishop contrasts the operating characteristics of traditional building and industrialised building and discusses the impact of the changes that industrialised building will have on the work carried out by quantity surveyors. Mr. Bishop is Head of the Building Operations and Economics Division of the Building Research Station, and this paper deals with the work forming part of a research programme.

Introduction

Much of the attention focused on industrialised building has been concerned with technical developments and their likely impact on particular building types and on the built environment. Less attention has been paid to the economic consequences of industrialisation on an industry which has developed to serve the market created by the demand for buildings from both public and private clients. It is argued in this paper that these changes will have an important effect on the character of the industry and on the operating characteristics of firms and, hence, on the analysis of cost. This is important to quantity surveyors because cost is one measure of the use of the industry's resources, and quantity surveyors are much concerned with estimating costs in the course of advising clients whether they are obtaining value for money.

From the outset, the paper will assume that what is meant by the term 'industrialised building' is common ground; although what the author considers industrialised building to be will emerge as the paper develops. It is necessary, however, to distinguish between the direct and indirect costs of production because much of the argument hinges on this point. Direct costs (C_d) are those which are proportional to output, and indirect cost (C_i) those which must be met whatever the fluctuation in output, at least in the short term. In the first category are included the cost of materials, of labour directly engaged in production (whether employed directly or by sub-contractors) and of its immediate supervisors, the capital cost of plant which can be readily employed on other tasks and consumable stores. In the second are the cost of directors, supervisors, technicians, clerical staff, skilled workers and the cost of plant (including buildings) which cannot be readily deployed on other tasks and the outgoings associated with that plant (including repairs, insurances and rates). The importance of the distinction is that the balance between indirect and direct costs is altered by industrialisation.

The paper will commence by contrasting the operating characteristics of traditional building and industrialised building, from which will emerge the central theme of the paper, the economics of industrialised building. In conclusion, the impact of these changes on quantity surveyors' work will be discussed.

OPERATING CHARACTERISTICS OF TRADITIONAL BUILDING

Building requires both the design and construction of buildings in response to a particular client's (or consortia of clients) requirements and the production of a wide variety of materials and components to serve a general, rather than a particular market.

Demand for many building materials is sensibly uniform in volume and the technical requirements for many materials are consolidated in British Standards, or similarly recognised. Such materials are generally mass-produced, often by continuous processes amenable to automation and other techniques leading to higher productivity. The fact that the index for building material prices (in real terms, with inflation discounted) has fallen in the past decade (figure 1) confirms this point because commodities that are mass-produced tend to have this characteristic in common, since increases in productivity obtained by new techniques offset, or more than offset, increased cost in other directions, e.g., wages, shorter working hours, additional social benefits and the like. Included in this group are the majority of conventional building materials; cement, aggregates, much of tile and brick production, sanitary ware, electrical cables and fittings, steelwork, glass and plastics manufacture and many others. To this extent—amounting to perhaps 40 percent of the cost of building—the industry is industrialised already. Extension of mass-production techniques to materials not now mass-produced is one obvious way of industrialising the industry; but this is a continuing process, perhaps exemplified by development in brick, tile and blockmaking, in which the current target labour requirements for brickmaking are now about one half of the norm accepted in 1947.

In contrast the demand for building, besides being dispersed on sites, is variable in volume, bespoke in character and uncertain in timing, and these characteristics in part dictate the structure of the industry which has developed to satisfy this market.

In any sub-region the building workload will fluctuate with the fortuitous conjunction of orders for major works; and roadworks, electricity generating stations, new hospitals and the like have been known to disrupt local work. Building is bespoke in character, partly because of the obvious need to satisfy a client's requirements and to fit buildings to their physical environment, but partly because there is no marked cost penalty incurred through particularity; that is simplicity of design and the use of standard components often yields no appreciable advantage by way of low tenders. Uncertainty in timing, implicit in the procedures for obtaining planning consent, by-law approval, financial sanction, quite apart from the capriciousness of clients, present contractors with probable commitments subject to indefinite delays. In the face of this market, characterised by uncertainty in volume, in technical characteristics and timing, an industrial structure has evolved which provides adaptability and ensures that its available resources are resonably fully employed.

Let us, therefore, consider the characteristics of the industry's resources commencing with building operations on site.

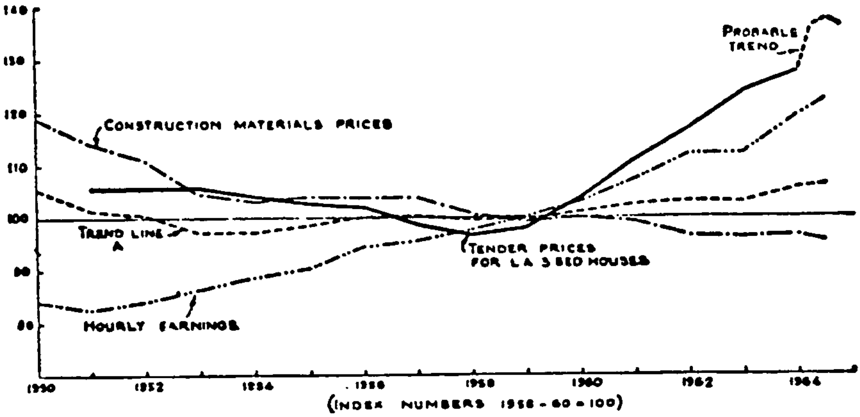

FIGURE 1. Relationship between indices of the cost of materials, earnings and tender prices. Trend line 'A' is produced by combining the indices for materials and labour in the relative proportions found in building, and is one index of the probable movement of tender prices if market forces and changes in productivity are discounted.

The majority of building work involves comparatively simple techniques which are widely understood by the industry at large. In general there are few building techniques which must be operated on a large scale for technical reasons, also the productivity of craft-based operations does not appear to be significantly affected by the size of the enterprise for which operatives work. Moreover, any contractor may choose to hire any or all of the plant and equipment needed to build and thus reduce the need for fixed assets. Absence of fixed work-places and modest requirements for capital makes possible the employment of many sub-contractors, a practice which enables specialisation to an extent not warranted by the size of many individual sites, because each specialist is able to find employment on all sites within daily travelling distance.

As a consequence of the ability to hire equipment and of the extensive practice of sub-contracting, building firms have few resources committed to the construction of any building type or any method of construction. Commitment of resources is, as it were, spread throughout the industry with every enterprise at each level of specialization seeking work on all available sites. Building firms, viewed in this light are merely organisations capable of building and entry to a particular market is often conditioned by an ability to finance and manage work rather than by technical considerations.

Hence, the resources of the conventional building industry are widely dispersed and not deeply committed to construction of anything anywhere: the industry has an amorphous rather than a crystalline structure. There is both strength and weakness in this situation. Strength in the lack of commitment and the ability of the resources to be redeployed without mortal damage on the work available, an attribute not to be lightly dismissed if clients and their advisers wish to maintain the present characteristics of the market. Weakness stems also from this lack of commitment in that operational units have an

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ephemeral nature and there is insufficient time to take advantage of improvement, innovation, development, management, all of which then have marginal rather than decisive returns.

Therefore the majority of the costs of traditional building are direct costs because many of the available resources are dispersed throughout the industry, and are dedicated to no particular ends. Operative labour typically seeks work on the available sites, so that the distribution of the labour force is matched to current demand. Much plant is on hire, and major projects are often undertaken by plant owned by several contractors, both practices increasing overall utilisation. The general practice of building slowly reduces demands on management. Finally, marketing costs are low—mostly confined to estimating—because there are few products, as such, to sell.

Operating Characteristics of Industrialised Building

In industrialised building the processes already described are modified in some or all of the following ways: by substitution of new for conventional materials, by prefabrication of components now assembled *in situ*, by reorganisation of the on-site processes. These will be considered.

(i) substitution of new materials

From the standpoint of substitution, materials may be divided into two groups: the fabric of the building and the fittings and services including joinery, engineering services and decoration. Whilst materials in the first group may be influenced by the method of system building adopted, it is these materials that are essentially cheap, so there would appear little scope for saving on this count except when conventional work is omitted; for example, when accurately-made concrete panels do not require plastering or screeding. Such savings may be substantial and are important because they are independent of other factors. However, most conventional materials are cheap in terms of their performance because, as has been explained above, their manufacture is already industrialised. Therefore, since the cost of materials makes a major contribution to the cost of building, the use of expensive materials should be always viewed with suspicion and questioned in terms of the advantages actually gained.

Comparisons at an elemental level are possible only when the elements have similar functions, for example, external walls, internal loadbearing walls and partitions. The basic prices written into Table I were taken from published lists and make no allowance for discount allowed for bulk or serial purchasing although these may be significant, particularly with new types of materials obtained directly from manufacturers. Also, no allowance is made for any effect of the choice of material on the production process.

The comparatively low cost of conventional materials will be at once noticed, together with the important, almost critical effect of differences in specification of newer forms of construction with the same apparent performance. For instance, the cost of brick loadbearing and external walls is of the same order as that of large concrete panels, except for external walls of sandwich construction in which the insulation, reinforcement and applied facings increase the cost of the panels. Similarly the cost of materials in timber-framed construction is of the same order as brick construction, except when more novel facing materials are specified.

TABLE 1.—ELEMENTAL COMPARISON OF THE COSTS OF MATERIALS

[First item in each case taken as 100]

External walls	Cost
Cavity, brickwork, plastered both sides	100 (115–125 with other facings).
Cavity, brickwork, plastered both sides, but dry lined	115 (130–140 with other facings).
4½ in. dense concrete, lightly reinforced and dry lined internally	90 (210–310 if faced with mosaics).
Sandwich construction with 3-in. outer and 6-in. inner concrete leaves, and polystyrene insulation.	190 (310–430 if faced with mosaics).
Timber framed walls with vapor barrier covered on the inside with plasterboard and externally with vee-jointed softwood boarding, painted.	140–160 (175–250 with other boarding and treatments).
Composite wall board of 1 in. polystyrene sandwiched between ⅛-in. asbestos wallboard, primed 1 side and with special paint texture finish the other.	280.

There is scope and prospect for reductions in the cost of materials in the second group, that is of fittings and services. In some cases severe variety reduction could create a demand on a scale which may make the introduction of new production techniques economically viable. But this must never be taken as the general rule because many production processes show small returns to scale, and the minimum scale of operation of others is very high indeed. The production economics of each group of materials and components must be examined on their own merits. Alternatively a sufficient volume of demand may justify the re-organisation of production and marketing so that sets of equipment may be obtained "off-the-shelf", *e.g.*, the demand for domestic central heating has led to the marketings of central heating boilers, complete with accelerators, controls and motorized valves. But it will be noticed that most or all of such materials and components can be used indifferently in conventional and system building. Therefore any reductions in cost will be to the advantage of the building industry as a whole and not peculiar to system building.

(ii) PREFABRICATION

Prefabricated components usually combine several functions into one component, *e.g.*, timber-framed cladding panels incorporate load-carrying functions with cladding, insulation and internal linings, and prefabrication is chosen on the assumption that it leads necessarily to lower labour requirements, or costs, or both. The extent to which these intentions are realised depends upon whether the *operations* involved in prefabrication are technically *different* from those carried out when a component is built *in situ* in stages in the ordinary way. Sometimes this is the case, *e.g.*, gang-nailing in timber prefabrication or continuous casting in concrete production. Often, however, the actual operations involved in making components may not be much affected by transfer of the work from *in situ* construction to fabrication elsewhere and large gains in productivity cannot be expected, although some advantages may stem from better working conditions and, perhaps, from the possibility of more effective management when work is carried out at fixed workplaces.

TABLE 2.—SCALE OF ACTIVITY

Method	Cycle	Scale
Site casting	weekly	1
Temporary factory	daily	5
Permanent factory:		
Steam curing	8 hours	15
Continuous kiln	4 hours	30
Continuous casting	2½ hours	48
Pressing	10 mins	720

Sometimes, of course, prefabrication opens the way to the use of new materials and new processes, leading to simpler components. One such example would be the traditional rooflight with a timber-framed surround and pitched roof, now almost always replaced by plastics rooflights supported on metal or concrete upstands formed in the structural roof. Changes in techniques are often accompanied by greatly increased minimum scales of operation, because more sophisticated processes are characterised by fast operating cycles and hence large outputs. Increased scales of production may more than offset increased capital expenditure, but the output obtained may force changes in management structure in order to cope with the supply, control and marketing problems implicit in the new volume of production. For example, the weekly output obtained from the more sophisticated methods now available for the production of concrete panels (Table 2), in which the methods of casting are listed in the order of increasing sophistication, must be matched by vigorous marketing methods, or by other administrative action.

(iii) ORGANISATION OF ON-SITE PROCESSES

Conventional building, it will be recalled, relied largely on gangs often organised on a trade basis and each undertaking one or more operations. In general the work of these gangs is not closely supervised, and low non-productive time is ensured by the provision of many more work-places than there are gangs to occupy them. This solution avoids the severe management problems implicit in the organisation of many gangs each tackling operations which are not technically independent of the work of other gangs. Industrialised building seeks to provide an alternative solution, one in which management makes a positive rather than a permissive contribution. To do this an attempt is made to reduce both the volume and complexity of on-site work either by the substitution of prefabricated components for *in situ* work, or by the more effective use of mechanisation, or by designs which produce simple operations which are technically independent and may be tackled by a specialised gang, or by a combination of all three.

In practice this intention is difficult to realise. Factory-made components often replace only part of the corresponding conventional operations, so that the number of operations required to complete the work, and the whole complexity of the process, are increased. Moreover, when prefabricated components are limited to a few basic kinds, some of the difficult and awkward parts of the work involved in construction are left to traditional processes. Experience has shown that the labour cost for this work is high and is a substantial proportion of a total which would have been required had the whole of the job been undertaken in the ordinary way. Hence, great care should be taken in design so that factory-components replace the whole of the traditional operation rather than leave a small part of it to be completed at a relatively high cost, and the aim should be to reduce the total number of operations as well.

Mechanism often affects only part of an operation and the work remaining may require the attention of a normally constituted gang. In these circumstances the only possible gain is an increased tempo of work, and this is frequently dictated by progress elsewhere on the site. Similarly, advantage can be taken of independent operations only when good management ensures that the gangs and the materials are at hand when required, and that which is intended to be done, is done at each stage of construction.

These difficulties are not estoppels. Given the necessary knowledge and drive on the part of designers and supervisors, the intention to manage work in an industrial sense can be realised and appreciable reductions in labour requirements and increased building speed obtained. In practice considerable time is needed for designers to obtain the necessary skills (which can stem only from a real appreciation of the practical problems involved) and for management to establish effective control. Therefore work must be directed to particular rather than general ends, and there is a commitment in time in a way that does not occur in conventional building.

Increased Proportion of Direct Costs in Industrialized Building

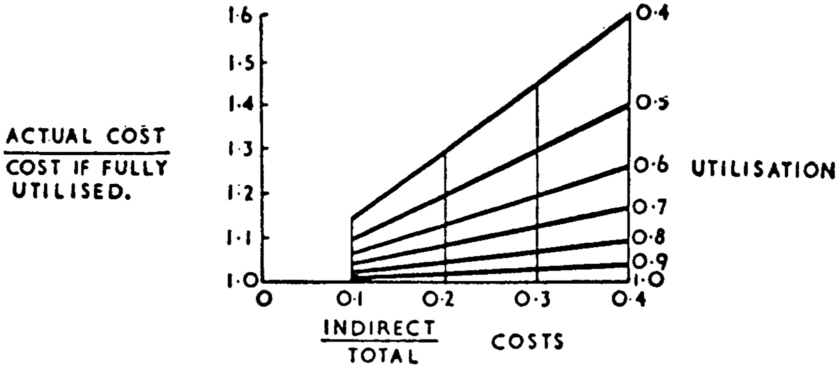
Many factors in industrialised building operate to decrease the proportion of the total cost which can be counted as direct costs of production. There is, of course, increased capital investment and the consequent increase in capital charges and process costs. Also there is the necessity to market products, to match the volume obtained from new techniques with efficient buying, stockholding, maintenance, training, supervision and inspection, all of which increase the demands made on management and add to the indirect costs of production. Moreover, operatives trained to operate a particular process cannot be dismissed immediately there is insufficient work to keep them fully employed. Should this be done, there will be an inevitable hiatus after additional work is obtained whilst operatives are recruited and trained and improvement, consequent on experience, takes place. Hence a substantial proportion of the operative labour—whether or not skilled—must be considered as indirect costs, as least in the short term.

Direct and Indirect Costs

The distinction between direct (C_d) and indirect (C_i) costs of production was made in the introduction of this paper, and it is now necessary to consider the consequences of altering the proportion between them.

The charge for indirect costs, per unit produced, is inversely proportional to the ratio of the quantity actually produced to that intended, that is to the overall utilisation (U).

In other words the actual cost:



$$C_a = C_d + \frac{1}{\bar{U}} C_i (0 < \bar{U} \leq 1) \text{-----------------} (1)$$

FIGURE 2. *Effect of utilisation on costs.*

These circumstances are shown at Figure 2 from which it will be seen that the ratio of actual cost (C_a) to cost (C) at full utilisation is increased if the ratio of indirect to total costs is increased; that is ownership of special purpose plant, the employment of a higher proportion of permanent staff leads to increased actual costs unless offset by the operating advantages obtained—higher productivity, better utilisation, etc.

For reasons already discussed, the overall utilisation of firms which build conventionally is likely to be relatively high. Utilisation with system building will often be lower, sometimes much lower than that intended, because many internal and external factors reduce output, and compensating periods during which work proceeds at a faster tempo than that intended seldom occur. Productivity is low when a new process or system is first commissioned and improvement continues for a protracted period before the target output is reached. Other factors which reduce output include the time lost when a contract is delayed by clients for financial or other reasons, intervals whilst production equipment is modified, perhaps to produce a new type of dwelling, and hiatuses on sites when erection is prevented through bad weather or delayed whilst cranes move from one building to another, or from one site to the next. Some external factors may also restrict production; these include the effect of labour disputes, delayed deliveries of materials, and inability to obtain orders. Whatever the causes, the consequences are the same—the ratio of the actual to the intended output is reduced or utilisation is lowered, and actual costs increased.

For the purpose of this discussion, costs will be expressed as per unit per day capacity, that is the actual costs will be scaled to a system—open or closed—producing 245 units (*i.e.*, 5×49 weeks) a year. This enables comparison to be made between systems operating at different scales. The selection of the unit is arbitrary, it may be dwellings, or 1000 sq ft floor panels, or classrooms: the unit considered in this paper will be a two-bedroomed local authority flat.

Direct costs will be considered to be the total of:

(i) materials (m);
(ii) the cost of specialist sub-contractors' work (l);
(iii) directly employed labour ($l_d\varpi_d$, where ϖ_d is the average daily earnings of directly employed operatives and l_d is the directly employed labour requirements per dwelling including non-specalist sub-contractors; in man-days; 9-hour day, 5-day week assumed); (for simplicity it has been assumed that no equipment is hired because equipment on hire is a substitute for the directly employed operatives);
(iv) consumable stores will be ignored (see process on-costs (vii) below);

and indirect costs the total of:

(v) indirect labour costs; typically skilled operatives, administrative, technical and clerical workers—all more or less permanently employed ($l_t\varpi_t$);
(vi) capital charges due to amortisation, maintenance and interest. These are discussed in the Appendix, in which it is shown that the daily capital charge per dwelling per day capacity at the intended output is:

$$C_c = c_o(W + 0.041r)$$

Where c_o is the total investment in development and fixed assets in £1000s per unit per day installed capacity; W the daily charge due to amortisation and maintenance for different composition of assets and varying economic lives (Appendix Table 1), 0.041 the daily charge arising from a 1 percent rate of interest and r the rate of interest;
(vii) process on-costs and other outgoings (f), *e.g.*, rates, telephone charges, publicity and process charges—heating, steam and lighting;
(viii) cost of working capital ($0.33C$) is the daily charge arising from an 8-percent interest rate on c the working capital of 1000s per dwelling per day capacity.

That is:

$$C_a = m + l_{sc} + l_d\bar{w}_d + \frac{1}{U}(l_t w_t + c_o(W + 0{\cdot}041r) + f) + 0{\cdot}33c \text{-----} (2)$$

The effect of industrialization on each of these factors will be discussed:
(i) Materials: cost probably increased, see above.
(ii) Specialist subcontractors' work. A distinction is made between specialist subcontractors on the one hand and general subcontractors on the other. The former fix materials, components, or equipment (often specified by the client) and the cost of this work is almost wholly predetermined and only influenced to a small extent by industrialised building, as such: hence this work can be considered as part of the cost of materials, and will

be omitted from the remainder of this discussion together with the cost of materials since both are not part of the value added by the production process. In other words, it is assumed that industrialisation does not involve increased costs of materials (possibly an optimistic assumption!). But general subcontractors (whether nominated by the client or selected by the main contractor) merely replace directly employed labour and will be considered as such.

(iii) Directly employed labour ($l_d\bar{w}_d$). This includes three elements, hourly paid labour (including on-costs directly associated with the employment of labour, bonus, statutory insurances, holidays with pay. Selective Employment Tax, etc., currently amounting to approximately 65 percent) of basic wage rates, subcontractors, and plant hired to assist (and by implication to replace) directly-employed labour. This assumes that contractors select the combination which is most convenient but that costs are not much thereby affected. All operative labour excluding that employed by specialist subcontractors is considered as directly employed labour.

(iv) Sometimes the transfer of work from site to factory may alter wage rates, hence earnings, and hence costs. Operatives in the building industry in some countries are highly paid in comparison to those in other industries, and a substantial financial advantage is gained by the mere transfer of work from sites to factories. In the United States construction industry, for example, the wages of skilled workers are almost 90 percent higher and of unskilled workers roughly 30 percent higher than operatives in manufacturing industries. In the United Kingdom the wage rates in the construction industry are slightly below those in manufacturing industries, therefore, the transfer of work from site to factory in this country is less financially attractive than in others.

(v) Indirect labour costs (l_4w_4) are affected by the demand by industrialised building for management skills, for technical expertise, and for operatives skilled in particular processes, which may increase the proportion of indirect employees (p) from roughly 1 to 8 in conventional building to, perhaps, 1 in 3 or higher (for the industry as a whole the proportions are roughly 1 in 5). The ratio of the earnings of administrative technical and clerical staff to operatives' earnings (q) appears to be associated with the size of the firm, with values of about 1.12 for large and small firms and with higher values for medium size firms. The product of the two ratios (pq) is a measure of indirect labour costs relative to direct labour costs. For the industry as a whole this is in the range of 0.15 to 0.35. It will be assumed that the higher values of (pq) are associated with system building. Also, as has been explained above, as building becomes more industrialised, the proportion of operatives (s) who must be considered as indirect costs is increased.

That is labour cost:

$$C_l=\bar{w}_d l_d(1-s)+\frac{1}{\mathrm{U}}(w_d l_d s+\bar{w}_i l_i)=w_d l_d[(1-s)+\frac{1}{\mathrm{U}}(s+pq)] \text{----} (3)$$

(vi) Capital costs ($c_0(W+0.041r)$) are also likely to be increased by industrialised building in any or all of the following three ways: the amount of capital invested, the incidence of amortisation, the rate of interest charged.

The investment per unit capacity is nearly always increased by industrialisation although not to the extent often expected, because cycle times become shorter as equipment becomes more sophisticated. Hence, a high investment may be offset by greater output because more is produced in a given time; also shift work may be possible. In conventional building the investment per dwelling per day capacity may be of the order of £50–60,000 and the investment in system building—large panel construction, for example—may vary from roughly this amount to twice as much.

Amortisation costs are likely to be increased since investors may expect a shorter economic life from their assets invested in industrialised building because of particularity and threat of early obsolescence. Reference to the Appendix Table 1 shows that three categories of life are distinguished—short, medium, and long—and it will be at once appreciated that these are merely convenient labels. Short economic life is based on a 3-year life for all assets, and the medium and long lives on 7 and 15 years (on average), respectively, and Table 1A gives the life and maintenance costs assumed for the different assets. It will be seen that the daily charges per £1,000 invested range from roughly £0.80 to £1.80 for system building (the higher part of the range being the more likely) and from roughly £0.90 to £1.15 for conventional building (the lower part of the range being the more likely).

Interest charges may also be higher for industrialised building, owing to the need to attract risk capital in the face of an uncertain market. A 20 per cent rate of interest has been assumed to be required when a short economic life is expected, and 15 per cent and 10 percent rates for medium and long economic lives respectively.

(vii) Other outgoings (f); many of these costs must be incurred whatever the utilisation, including general expenses (such as rates or telephone charges), process on-costs (such as lighting and heating) and publicity on sales. Little is known about the extent of the costs which are possibly proportional to the degree of industrialisation, and thence to capital investment (that is $f=c_0g$). For the purposes of this paper these costs will be assumed to be £0·25 per £1000 per unit capacity or £25 per dwelling built by a system with relatively high capital investment.

(viii) Working capital ($0{\cdot}33c$) is difficult to define because the amount required is influenced by many considerations including the speed of building, the intervals between interim payments, the relationship between the payments incurred and the actual costs of the work done (a relationship which may change for different stages of the work), and the credit rating of the contractor. A rate of return of 8 per cent has been assumed on working capital, a rate in excess of bank rate, since this 'capital' will be often in the form of an overdraft. The amount required is independent of utilisation, because if these funds are not required, they can be invested. Finally, the amount required will not differ greatly between conventional and system building, unless system builders find it necessary to stockpile components, in which case requirements for working capital will be sharply increased. Therefore, because this paper is concerned with differences in process costs, rather than total costs, working capital will be henceforth ignored.

That is the process cost

$$C_p = l_d\bar{w}_d[(1-s) + \frac{1}{\bar{U}}(s+pq)] + \frac{c_o}{\bar{U}}[W + 0.041r + g] \qquad (4)$$

in which

l_d	the requirements for operative labour per unit (all operative labour including non-specialist sub-contractors, and the 'labour' equivalent of hired plant);
$\bar{w}_d$	operative earnings, including on-costs;
s	the proportion of operative labour which must be considered as indirect costs;
pq	the relative cost of ATC labour: $(l_i w_i = (pq) l_d \bar{w}_d)$
$\bar{U}$	overall utilisation of the system;
c_o	capital investment per unit/day capacity;
W	amortisation and maintenance charges;
$0.041r$	daily charge for 1 per cent interest rate;
g	on-costs/£1000 capital $(X = W + 0.041r + g)$

Process Costs Compared

It is clear from the discussion above that industrialisation nearly always involves increased capital investment and other indirect costs and often results in decreased utilization because of particularity. Hence, if industrialisation is to be economically worthwhile, these costs must be offset by reduced labour costs (*i.e.*, by increased labour productivity).

It is often assumed that conventional building necessarily leads to high labour requirements and that industrialisation results in markedly lower labour requirements. But this is not the case. It appears that a labour requirement of about 2400 manhours per dwelling (including siteworks but excluding roads and main sewers) may be assumed when building is just allowed to happen; of between 1300 to 1800 manhours when contractors experienced in house-building operate on larger sites; 800 to 1300 manhours when work is undertaken by contractors who specialize in conventional house construction; and terraced houses, embodying some prefabricated elements, are built with a labour expenditure of about 700 manhours by contractors specializing in this form of construction. The present evidence suggests that the average labour requirement is about 1800 manhours per dwelling.

There is a similar variability in performance of industrialised building both between systems,* as would be expected, and when one system

*See footnote to Table 3.

is built by different contractors on different sites. Current evidence shows that the systems now available often have a site labour requirement in the range of 700 to 1300 manhours. That is, it is yet to be shown that there is a significant difference between the labour requirements for building two-story dwellings by 'conventional' and by 'system' building, when both are built by contractors of ability, adequately financed and who have their organisation and resources under their control. The differences between the labour requirements for conventional and system building is likely to increase in tall buildings because these are inherently more complicated and the work involved is more amenable to industrialisation.

Although the labour requirements of conventional and system building may not differ much when both are tackled by contractors of ability, the average labour requirements for system building might be expected to be lower than the average labour requirements for conventional construction. This is important, because the national output is determined by the average labour requirement rather than by the relatively few examples of low labour requirements. Therefore the important comparison is between the process cost of conventional building on average and system building brought to that stage of development where it can be undertaken by a contractor of average ability, perhaps working in association with an established system builder or component producer.

Suppose that a building system of this kind extended to the superstructure and the finishings of two-storey dwellings and had some influence on foundations. The work directly affected by industrialisation would be about 70 percent of the total at the most, the remainder being site works, foundations and part of the work of specialists. (Incidentally, there seems little point in a system which does not extend beyond the structure because the savings realised in the finishings are proportionally greater that those obtained in the structure.) What then are the comparative process costs of this and conventional construction built with a labour requirement in the range 1400–1800 manhours?

Process Costs Examined

The assumptions written into a comparison made between the process costs for conventional construction and some form of industrialised building are set out in Table 3.

Change in the variables, labour requirements, capital investment, amortisation and interest charges, and the utilisation achieved produce considerable variations in the process cost, hence a direct unique comparison is impossible. The process cost of the conventional system is affected by three variables and it will be seen that the effect of changes in one variable is dependent on the values of the others. For example, in the conventional system a variation of 100 manhours produces a change of £55–57 in the process cost dependent on the value of $\bar{u}$; a variation of $0{\cdot}1\bar{u}$ produces a change of £24–40 in the process cost dependent on the labour requirements and the economic life assumed. These variations are greater in the industrialised system, in which four variables are considered; for example, a variation of 100 manhours produces a change of £64–80 and a change of $0{\cdot}1\bar{u}$ produces a change of £39–68 and £75–120 at capital investments of £50 000 to £100 000 dwelling/day respectively depending on the labour requirements and economic life.

These relationships are most easily shown on a series of carpet graphs, Figure 3, in which the quantitative effect of changes in the various variables can be seen at a glance. The vertical scale of this figure is the process cost per dwelling. Each carpet graph represents the range of process cost at a given level of capital investment, the graph on the left representing conventional building; the three on the right industrialised building with capital investment of £50 000, £100 000 and £150 000 per dwelling per day capacity respectively.

For example, the process cost of an industrialised system obtaining a utilisation of 0·7 and with a labour requirement of 700 manhours and a £50 000 investment dwelling/day capacity assumed at a short economic life would be £715 (point A) and this could be reduced to £645 (point B) if a medium economic life was assumed. At a medium economic life an increase utilisation from 0•7 to 0•8 reduces the process cost by £50 and a decrease of utilisation from 0•7 to 0•6 increases it by £60 and so on. The process cost at intermediate levels of investment may be obtained by direct interpolation; for example, point 'C' gives the process cost of £777 for a labour requirement of 800 manhours, an investment of £80 000 (unit/day) at a medium economic life, and a utilisation of 0•8.

TABLE 3.—*Process cost comparison: assumptions made.*

Factor	Conventional	System [1]
Overall average labor requirements (man-hours) (l^d).	1,800–1,400	900–630.
Earnings £ ($\overline{w}^d$) (9-hour day)	4.25	4.25.
Proportion of l^d considered as indirect costs (s).	0	0.3.
Administrative, technical, and clerical labor costs as proportion of $l^d\overline{w}^d(pq)$.	0.15	0.30.
Capital invested	£50,000	£50,100, £100,000, and £150,000.
Utilization	0.9–0.7	0.9–0.6.
Capital and interest charges	Long life	Medium life.
	10 percent interest	15 percent interest.
	(X=1.54)	(X=1.95).
	Medium life	Short life.
	15 percent interest	20 percent interest.
	(X=2.01)	(X=2.86).

[1] System in the sense of '. . .continuity of production; standardization; integration of the different stages of the production process; high degree of organization of work; mechanization to replace manual labor . . .'

That is

$$\text{conventional} \quad C_p = 4.25\,£ld\left(1+\frac{0.15}{\bar{u}}\right)+50\,\frac{(X)}{(\bar{u})}$$

(ld, $\bar{u}$, X variable)

$$\text{system} \quad C_p = 4.25\,£ld\left((0.7+\frac{0.6}{\bar{u}}\right)+c_o\,\frac{(X)}{(\bar{u})}$$

(ld, c_o, $\bar{u}$, X variable)

Figure 3 clearly illustrates the known fact that firms with obviously different characteristics can compete in the same market. The range of process cost depends both on the efficiency of the process and on market factors, neither of which are made apparent in the conventional approach to estimating. This is not to deny the usefulness of cost comparisons, but only to emphasise the penumbra of uncertainty implicit in all economic activity. If selection is to be made, if development is to be effectively directed, if clients are to be properly advised, methods of cost comparison must reflect the interplay of these factors shown to have an important effect on cost.

Industrialisation and the Work of Quantity Surveyors

The environment, the previous experience of the developer, the scale of operation and the technical design of the building, all influence the development and economy of systems of construction and every solution has an individual character that cannot be separated from its circumstances. Therefore the building process must be considered as a whole, since one sequence of work inevitably affects and is affected by others. This inter-action between operations cannot be distinguished by conventional methods of estimating, which specify average and not particular conditions.

As an alternative a comparison can be carried out on paper and some of the advantages of an experimental situation retained without incurring the cost of field work. Such "quasi-experimental" techniques have the advantage that the assumptions on which the comparison rests are made explicit and the effect of departure from the assumptions can be examined. The method aims at reproducing, as far as possible, an experimental situation giving a direct comparison between alternative methods of construction.

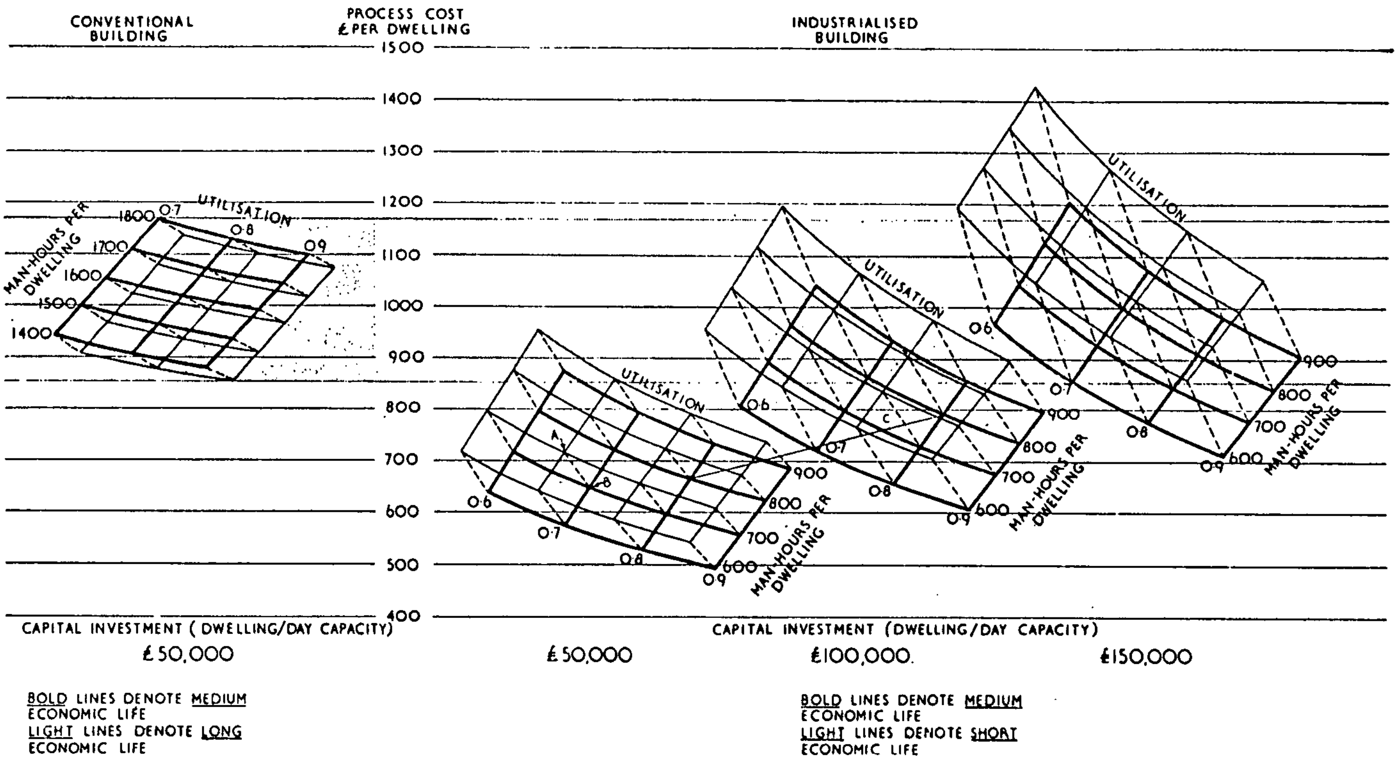


FIGURE 3.—*Process costs compared.*

The steps* required are:

(1) A statement is prepared of the environment in which the comparison is assumed to be made: this includes the size of the contracts, number and disposition of sites, rate of progress and the general level of the labour and material costs.

(2) Buildings are designed in which the same plan is employed for the different methods of construction.

(3) For each form of construction a schedule is prepared setting out the work to be done to construct the building. A separate schedule is prepared for materials and for plant and transport.

(4) Following the necessary c.p.m. analysis and resource leveling a programme is made for the work of both factory and site which states the composition of gangs, elapsed time and the appropriate plant.

(5) This information is used to calculate the cost of labour and plant including amortisation, interest charges and the cost of consumable stores. The cost of setting up the site and the factory is calculated separately.

(6) The four components of cost (materials, labour, overheads including plant, and preliminary site work) are distributed first to building operations and then to elements.

(7) The effect on the comparison of varying the basic assumptions is explored.

This approach to cost comparison entails a marked departure from quantity surveying practice as conventionally understood. These evolved at a time when the work of the industry was based on craft processes, in which the tasks of handling, fabrication and assembly are often combined in a single operation undertaken by individuals or gangs working independently and assisted only to a small extent by mechanical plant. In the circumstances it is reasonable to suppose that the total cost will approximate to the cost of the separate operations, considered individually: that is the assumption implicit in bills of quantities is that synthesis produces acceptable results. Different circumstances prevail in industrialised building and analysis is more appropriate than synthesis, because cost is determined by the functioning of the whole process, rather than by various individual operations, each considered on its own merits.

For the purpose of this paper, the method outlined will be labelled "production analysis", although this term has a slightly different connotation in other industries. In these, production analysis attempts to represent the functioning of manufacturing systems and calls for an understanding of the production techniques involved, including their manning and operation. Also required is a knowledge of industrial costing and of the way in which firms operate. As important, is the acceptance of uncertainty as a fact of life, concealed by the conventional approach to pricing but displayed by production analysis. The advantage gained is that analysis distinguishes more clearly the effect on cost of standardisation, of a requirement for specials, of delays in timing, of continuity of operation, of improvement in performance through development and experience, of the market. These are impor-

*This approach to cost comparison was more fully described in *Construction of multi-storey flats—the economics of large panel methods* by W. J. Reiners and D. Bishop. *The Builder*, 27 April 1962.

tant factors, of interest to clients and contractors alike, and it is important that their effect on cost is known if the resources now commited to industrialization are to be effectively deployed.

Adoption of these methods would make two immediate demands. Firstly, reorientation of the education of quantity surveyors to include the analysis of manufacturing systems and to emphasise the techniques of construction. Secondly, a combined effort by the industry as a whole to provide information about the demand for resources by different techniques, information essential if the costs of industrialisations are to be properly analysed.

ACKNOWLEDGEMENT

This paper deals with the work forming part of the programme of the Building Research Station, and is published by permission of the Director.

APPENDIX

Capital charges

The capital invested in any building method must meet the development costs specific to the method, the cost of fixed assets, and provide sufficient working capital to bridge the interval between outgoings and receipts.

Development includes design and testing of both the system and the production process, if this is novel. In addition there is the cost of construction of prototypes, an essential stage in any novel construction. Fixed assets include, in addition to the cost of factory buildings, factory and site equipment, vehicles and the like, the cost of services on site or in factories, and fencing, roads and other irrecoverable items. Account must also be taken of the actual or potential reduction of the demand for capital through the use of hired equipment. Finally, sufficient working capital is required to finance work and to bridge the interval between receipt and payments to labour and to creditors. This amount is clearly proportional to the output, and published comparisons suggests this is between 2 per cent and 3 per cent of turnover, or about £10 000 to £15 000 per dwelling per day capacity.

A measure of the capital invested in different methods of building is given by the investment per unit capacity, the total investment divided by the output, where the daily output is the number of dwellings the system is able to produce daily when all stages of fabrication and construction are in balance.

The cost of the capital invested must be recovered by charges sufficient to amortize the investment and to meet the rate of interest necessary to attract capital. Amortization can be calculated in the ordinary way [1] on an actuarial basis and frequently includes the cost of maintenance. Their incidence is determined by the composition of the assets and by the expected economic life of the assets. Since development of a system must be followed by redevelopment, if any industrialised process is to remain in the van, development costs should be recovered continuously as other capital. Capital invested in the buildings may be amortised over a relatively long life, thus reflecting resale value. Similarly, general production equipment, which can be used

[1] *Survey of the annual cost of contractors' mechanical plant. The Contract Journal* 1956, vol. 77 (4004), pp. 1018–1023.

indifferently for building, may be amortised over a longer life than plant specific to a special purpose.

Consider large concrete panels production (factory and site equipment) in which the investment might be 25 per cent in buildings and other permanent work, 25 per cent in general equipment (such as cranes, concrete batching plant and steamraising boilers), 30 per cent in the actual production equipment and 20 per cent in vehicles. In conventional building the investment might be divided in the proportions of 15, 35, 15 and 35 per cent respectively. Neither the proportions nor the life assumed are important and other values may be inserted without seriously disturbing the calculated charges. Table IA shows the resulting amortization and maintenance costs reduced to the daily cost per £1000 invested.

TABLE 1-A.—AMORTIZATION AND MAINTENANCE COSTS

Assumption	Life, assumed years			Cost per day [1] per £1,000 invested (W)
	Buildings	General plant	Process plant or vehicles	
System:				
Short life	3	3	3	£1.79
Medium life	10	7	5	£1.08
Long life	30	15	7	£0.81
Conventional:				
Medium life	10	7	5	£1.14
Long life	30	15	7	£0.88

[1] On the basis of 245 days work a year.

Assumed annual maintenance costs: Buildings 5 per cent (including heating); Process plant 15 per cent; General plant 10 per cent; Vehicles 20 per cent (including tyres).

The second component of the capital charge, the expected return on the investment (r per cent per year) reflects confidence. With new enterprises, high rates, probably in the order of 20 per cent, will be required to attract risk capital. As systems become established interest rates will presumably fall to the general level obtained in other industries. It is also convenient to express these as a daily charge, thus, a 1 per cent interest rate produces a daily charge of £0.041 per day per £1000 invested.

Hence the capital charges per unit of output at optimum utilisation:

$$Cc_o=\frac{1}{n_o}[1{\cdot}31C_1+WC_2+0{\cdot}041r(C_1+C_2)]+0{\cdot}041rc \text{------} \quad (A1)$$

in which n_o is the target output, C_1, C_2 the investment in development and in fixed assets (in £1000's) and W is the daily cost of amortization and maintenance per £1000 invested: r is the current rate of interest and c the working capital per day capacity.

If investment in development and in the fixed assets per unit capacity are considered as one (c_o), and a fixed rate of interest (8 per cent) is assumed on the working capital, which might well be in the form of an overdraft (A_1) simplifies to:

$$C_{co}=c_o(W+0{\cdot}041r)+0{\cdot}33c \text{----------------} \quad (A2)$$

in which c_o is the total investment per unit capacity, excluding the working capital.

INDUSTRIALISED BUILDING, DESIGN AND PRODUCTIVITY*

United Kingdom and European experience in this field will clearly interest those in developing countries who may be thinking of the introduction of industrialised building techniques. Since the essence of such techniques is the production of long runs of standardised components or the assembly of prefabricated units on mass-production lines, only a small number of systems can exist in any one country, since a building programme can offer only a limited capacity to a few manufacturers. Technically the trend is towards the design of components which are interchangeable between systems, a trend which will be encouraged by the forthcoming metrication of the British building industry.

The following Notes are based on papers by Donald Bishop, Director of Quantity Surveying Development and Chief Quantity Surveyor of the Ministry of Public Building and Works, and formerly of the Building Research Station. The papers in turn draw upon the work of many colleagues in the Production Division of the Station.

I. System Building and Productivity

Continuing our examination of system building, this Note deals with experience in three European countries, Sweden, France and Russia. The course of development in each case is peculiar to the country and is a compromise between the various demands of social and industrial needs and the resources available, labour, materials, and capital.

In each country, the development of industrialised building has been caused rather by the demand for more accommodation than by the need to build more cheaply. The development of building systems has influenced the traditional building industries, which have taken up many features of industrialised building, such as more integration of design and production, standardisation, more effective supervision and control, to improve productivity.

There is surprisingly little reliable and compatible information on the extent and success of industrialised building in various European countries. This is partly because of difficulties encountered in collecting information of this kind. For example, the very term industrialisation admits of many definitions. The treatment is therefore partial and to some extent subjective.

Throughout Europe the conventional dwelling type is the block of walk-up flats, a building with three four or five storeys demanding good sound insulation and adequate fire resistance, requirements that are satisfied at low cost by masonry or reinforced concrete construction. For this, amongst other reasons, large panel construction forms a large part of industrialised building, and is discussed in this Note.

Sweden.—Although Sweden escaped war damage and had no legacy of slums, there was in the immediate post-war years, serious over-

*NOTE—No. 123, *Overseas Building Notes*, February 1968. Overseas Division, Building Research Station, Garston Watford Herts, England.

crowding. As a consequence of this, and stimulated by grants and subsidies and by the increasing affluence of the economy, there has been a continuous demand for greater output of dwellings. In the main this has been met by greater productivity, arising from many factors, including the rationalisation of traditional methods of construction, the use of aerated concrete products, the training of site supervisors, and the widespread acceptance of standardisation for components and functional parts of buildings. In addition, several systems of large panel construction distinguished by their high standard of fabrication and finish have become established.

There are few permanent factories, because only a few areas have the potential demand for dwellings to warrant investment in fixed equipment. Some contractors place moulds alongside the buildings under construction to avoid double handling; other establish temporary factories.

Two factors in Sweden could be expected to favour non-traditional methods of building. First, the predictably long winters are less likely to delay construction when building components are prefabricated and construction involves little in situ work. Second, the method of incentive payments on a uniform system of piece-work throughout the industry, has produced wage rates especially favourable to building craftsmen, who are amongst the highest-paid operatives in Sweden. The wage differentials between building craftsmen and building labourers on the one hand and between the building industries and the manufacturing industries on the other favour those building methods which demand less on-site labour, particularly craftsmen.

Despite this, systems of large panel construction have been found to have an average advantage, in terms of labour requirements, of only 16 per cent and 2 per cent for the construction of high and low rise buildings respectively advantages small in comparison with variations in productivity.

The comparatively small scale of operation, inevitable where population is scattered, may have thwarted the continued development of systems already established. It is more likely, however, that many features of industrialisation have been adopted in conventional construction, e.g. standard designs for functional parts of buildings, incorporation of many standard fittings, bulk purchasing, more effective organisation, improved methods of winter building; that is, that conventional construction has become more systematised.

The part played by housing associations is also important, because the design groups employed by the larger housing associations have some continuing experience and scope to develop rationalised designs. Also the associations place serial contracts for the supply of fittings and fixtures, of standard design and very high quality, which may account for 20 per cent of the total cost of construction. These fittings and fixtures are used in conventional and system building alike.

France.—Between the wars, rent control in France made housing unattractive as an investment, and the rate of construction did not match current needs. These factors were aggravated during the last war when more than one million dwellings were destroyed. Although economic reconstruction gave priority to transport and industry, a four-fold increase in output of dwellings has been attained since the early fifties. Local authorities in France do not themselves build or own houses but operate through housing associations known collectively as the Offices des HLM (Moderate Rental Housing Association) which are required to provide dwellings at controlled rents for several categories of tenants. The HLM legislation also governs the provision of social housing by private individuals by way of State subsidies and by mortgages, the latter administered through Crédit Foncier.

Loans and subsidies are available providing the designs prepared satisfy specifications which include the minimum area and ceiling price for buildings of defined standards as laid down by the Secretariat for Housing. The net effect of this policy has been to promote standardisation of components and building types and designs, and to encourage the development of larger sites, all measures known to increase productivity.

At first the introduction of better building methods was stimulated by the development of an industrialised sector which involved a programme using special contract procedures and making use of standard components. Later a special craft sector of the house building industry was established. Contractors were invited to submit details of building systems expected to improve productivity. Contractors admitted to the scheme after technical examination are placed on an approved list from which HLM officers may choose the scheme they prefer. Thus encouraged, many systems of prefabrication were developed during the middle fifties.

Development then took place on the basis of permanent factories, or of temporary factories. In both cases intermittent casting in fixed moulds was used, rather than continuous casting, presumably because the volume of production did not demand a high degree of mechanisation and the market required an ability to change at least some of the moulds from contract to contract. Most of the systems use some form of sandwich construction for the external walls, and comparatively large concrete panels for the internal walls and floors.

By 1959 several systems had been used for a fairly wide range of dwelling types, and were considered as firmly established. They appeared to compete with one another, and to be able to build successfully at or below the ceiling prices set by HLM. Total prefabrication methods accounted for about 15–20 per cent of the market and the systems then established were competitive with, but not decisively cheaper than, the rationalised construction methods stimulated by the craft sector.

In the following years two technical devices were developed to meet administrative problems created by the changes taking place in the French building industry. One, the Agrèment system, enabled new materials and techniques to obtain the insurance cover necessary to meet a legal liability for major defects over ten years, and at the same time provided potential users with much useful technical information. The other provided a means of comparing design of construction schemes priced at or close to the official ceiling, but offering different accommodation and advantages to the user.

When in 1963, the annual housing target raised from 300,000 to 500,000 dwellings interest was stimulated in the further development of industrialised building, interest also sharpened by a rapid rise in wage rates and by a lack of skilled operatives. It is now expected that industrialised building will account for 200,000 of the 500,000 dwellings to be built, that is two-thirds of all multi-story dwellings.

The Secretariat for Housing have many administrative devices to encourage the development of industrialized building. In the first place the housing programme is controlled by the Offices des HLM, which can effectively improve both performance and technical standards. There is also the reservation policy by which a portion of the housing programme is open only to those firms able to undertake sizeable schemes of industrialised building. Continuity of work is used to induce firms to offer schemes of acceptable performance standards at a price ten per cent less than the official ceiling. The prize is considerable; five year contracts for as many as 1,000 dwellings a year. Finally there is a move to encourage the production of components.

Russia.—For many years the building industry in the USSR has been dominated by demand for more construction of every kind to make good the ravages of war and to meet the needs of an expanding society. Although the available statistical information is difficult to interpret, it seems certain that the number of dwellings constructed annually has increased three-fold since the early fifties. The contribution made by industrialised building is concentrated on a few urban areas. What is more certain is the direction of technical development.

In the immediate post-war years much prominence was given to the achievement of higher output by organising working teams in which one craftsman was served by several labourers, with tasks arranged so that the craftsman dealt only with that part of the job demanding actual skill. In the early fifties the introduction of large block construction, in which precast concrete building blocks weighing between 1–3 tons are built as masonry, continued this drive to make better use of the skilled labour available. At the same time type-design for components and whole buildings were developed.

This, and the development of new cranes, opened the way to large panel construction, a development that has been energetically pursued and is now the dominant method of industrialised building construction.

Designs for large panel buildings were initially based on Russian experience in masonry and brick construction, and massive panels were used, especially for loadbearing and external walls. More recently waffle panels, that is panels with thin webs stiffened by ribs, were developed; pairs of panels are ranged together in different ways forming floors, or loadbearing walls, or external walls, thermal or acoustical insulation being placed in the cavities as required. Although the concept of a universal panel is attractive, experience has shown economic and practical disadvantages, for example, uneconomic amounts of reinforcement, difficult assembly, and questionable durability. The present trend of design follows that evolved in Western Europe, and much greater attention is now being paid to variety of layout and to the appearance of buildings.

In the USSR the available effort in research and development can be concentrated on specific issues. In the building industry, the issues given the highest priority appear to be the development of new production processes, including the development and application of new building materials. Because of this, progress in the building industry has taken a different course from elsewhere in Europe, where the emphasis has been on the built environment rather than on production engineering. The results of this process in the Soviet Union are to be found in the creation of a new process-dependent industry. Some of the equipment is highly sophisticated, involving semi-automatic processes and short cycle times. Together with an emphasis on improving amenity and environment this new industry should be able to fulfill the dominant role allocated to it.

The progress of industrialised building in Western European countries has been remarkably consistent, especially in view of differences in climate, the availability of materials (e.g. some countries have cheap and abundant bricks) and the differing scales of activity. In each country industrialisation of the building industry has been brought about by the need for additional capacity rather than by a desire for lower costs. Encouraged by favourable conditions, (perhaps created by governmental intervention) the first phase has been the energetic development of many building systems. (Systems in the sense of "* * * continuity of production; standardisation; integration of the different stages of the production process; high degree of organisation of work; mechanisation to replace manual labour . . .") These systems demand a measure of standardisation, an attempt to integrate the different stages of the whole production process, and more effective organisation of work. In addition, new construction methods have been introduced, although these have often affected only a relatively small part of the whole building process, and have usually involved only a modest amount of process development.

The traditional building industry has responded to this challenge by adopting the non-process features of industrialised systems, better integration of design and production, standardisation, and more effective supervision, and has thereby increased its own productivity. Consequently non-traditional low-rise dwellings have not been significantly cheaper to build than those built by traditional methods, but have been able to use resources (materials and labour) not otherwise used in dwelling construction, for example the substitution of concrete for brickwork, the participation of civil engineering contractors, the employment of semi-skilled operatives in place of craftsmen. In high-rise dwelling in particular non-traditional construction may lead to lower labour requirements and, possibly, to lower costs.

In Sweden and France the development of industrialised building has been furthered by the activities of outside official or semi-official bodies. Designers and system developers have been brought together, creating working relationships differeing from those obtaining elsewhere in their industries. Two issues are important. Firstly, the standardisation of performance requirements, of components and, in some instances, of technical details. As far as is known these standards which must be narrowly drawn if they are effectively to promote "industrialised" building or component production have always been imposed from without rather than arisen from within the industry, a surprising fact in view of the need for standardisation of industrialised building (open or closed) is to flourish. Secondly, the creation of circumstances likely to encourage firms to invest money, skill and effort in systematic, long-term development. In the absence of these circumstances the development of systems has stopped when each system was shown to be technically sound and economically viable. However, when development has continued to ensure that the design, the production process and work on site are efficient and compatible, such systems (the minority) have continued to improve their performance.

There is some evidence that systematic development is an important and characteristic feature of any industrialised production; for example, in the aircraft industry (an assembly process, analogous to building) the labour requirements for aircraft construction are reduced by roughly 20 per cent each time the batch size is doubled, and this improvement continues for many years. There is also the scale of investment necessary to bring modern industrial processes to fruition. In the absence of a competitive market in the USSR, the response of the traditional industry to the challenge of industrialisation is apparently less marked. Much of the potential advantage which could be gained by an improvement in productivity of the traditional industry is probably lost. What is gained, however, is an ability to invest in process development on a large scale. Whilst the present outcome, in terms of buildings and the built environment, leaves room for improvement, a process-dependent industry has been quickly developed with an improved productivity in relation to that obtained in conventional building.

Finally modern industrial processes often work with short cycle times, or continuous shifts, or both; and these features set the economic scale of operation at a high level. This, with conventional building, may be only a few dwellings a year, but in the case of large panel construction an output of roughly 150 to 250 dwellings a year is required when the system is site cast, and much greater outputs are necessary with more sophisticated systems, a fact which has been recognised by the introduction of the "sector" in France. Hence investment in process development cannot be viewed as a technical activity only because the processes developed will be economically viable only when the capacity created is usefully employed. This pre-supposes a predictable demand for dwellings, very different from the piecemeal demand created by many independent clients, each insisting on arbitrary standards of performance, size and style.

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2. Design and Productivity

This Note considers the interaction between architectural design and building productivity. It is argued that design and architectural practice should take account of production processes and the environment they demand. Many issues are left to one side because their outcome does not affect relationships between design and building productivity. Other issues are accepted as common ground, including the necessity to uphold and improve building and environmental standards.

Circumstances dictate the contribution designers can make to productivity. Designers of individual buildings, by considering the way each stage of construction can be tackled, can produce designs that are easy to build. Designers who concentrate on a particular building type or always employ similar construction techniques have an opportunity to encourage, and sometimes promote, the introduction of new techniques and new components. Finally there is scope in industrialised building for innovation and for the integration of design and production.

At a tactical level a designer may be concerned with the simplification of site operations. Obviously awkward work can be eliminated, perhaps by the introduction of components, and the rest should then fall into well-defined tasks which can be tackled by a man or gang without interruption or attendance by other men or gangs. This enables a satisfactory balance to be struck between the tempo of work on the one hand and the incidence of non-productive time of men and equipment on the other, without making undue demands for operational control in order to achieve the intended rate of progress. This requires both a knowledge of and a sympathy for construction, including the techniques involved and the organisation of work.

At a strategic level wider issues are involved. The building industry at present is amorphous in character in that its resources are widely dispersed. It is an industry which must be adaptable, so that its resources can be deployed on whatever work is available, wherever this is. The employment of sub-contractors, the availability of plant on hire, the presence of a casual labour force, all contribute to flexibility but create production units which have short life. There is little incentive for building firms to invest heavily either in forward planning or in development, because there is no certainty that the work in hand will be required again, at least in the short term, or that specially trained operatives can be found permanent employment.

Investment of capital and management and technical skills is worth while only when there is reasonable certainty that the type of work to which a firm is committed can be sold at a reasonable price. Perhaps for these reasons improvement in productivity occurs relatively slowly, often by chance, and frequently as a result of innovations in other industries, especially in the building materials industry.

The improvement in performance observed on many building sites arises in part from the higher incidence of non-productive time at the beginning and end of construction, caused by an imbalance between the number of gangs and the available workplaces. The remaining gain in productivity is often a matter of chance and is masked by other factors which may advance or retard progress.

In conventional construction the man hours for any operation usually reach a fairly steady average after the first few dwellings have been completed; the difference between the average labour requirements for work early in construction and when a steady tempo is reached has been found to be about 8 percent (Fig. 1). This difference rises to about 12 percent for houses of unconventional construction, and to about 33 percent for the new operations involved in this construction.

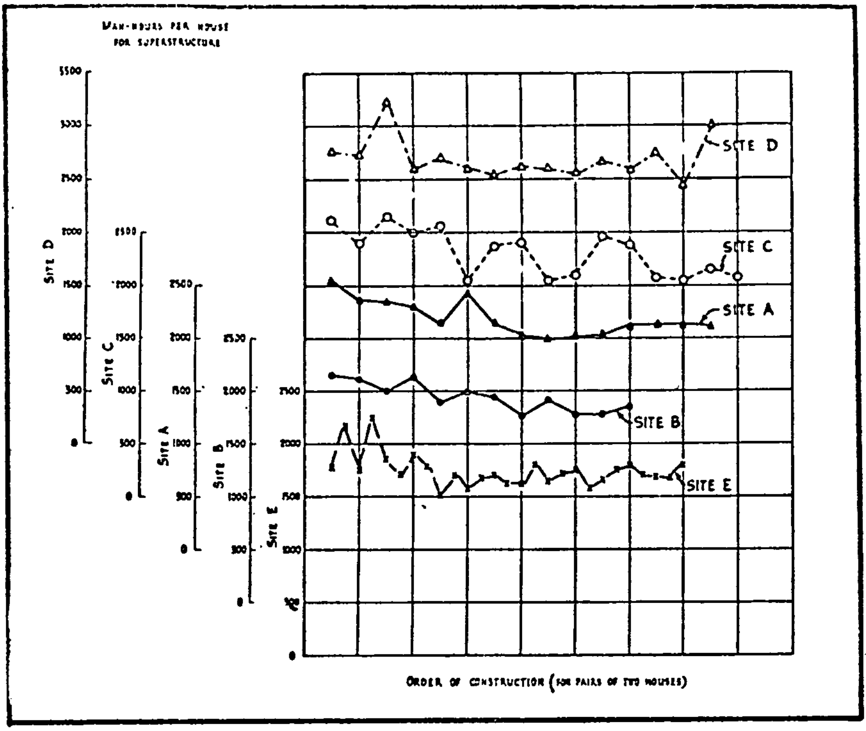

Fig 1. Improvement curves for identical traditional houses on five sites

For house-building there has been a steady reduction in average labour requirement during the past fifteen years, from about 2650 manhours to about 1800 manhours per dwelling, or an improvement of about 2½ percent per annum. In the same period the lowest labour requirement has fallen more rapidly from about1300 manhours to 700 manhours per dwelling, or an improvement of about 4¼ percent per annum. The first rate of improvement compares unfavourably with the second which is more like that achieved in other industries, where firms invest in systematic development. (It must be remembered, however, that the pattern of building has changed over the years and some of the newer types of layouts involve considerable labour on site works and sub-structures.)

In contrast, substantial improvement of performance with repetition has been encountered in other industries. On long production-runs, productivity increases as operatives become more expert, as management solves organizational problems, and as engineers successively improve the design and the production methods and equipment available. As an example, in the aircraft industry, similar to the building industry in that it is concerned with the assembly of components bought in, during the production of the B–17 the manhour requirements fell by a factor of 10 during production which extended for almost 20 years, or an improvement over 12 percent per annum (Fig. 2). At first it was though that improvement occurred only when production involved a considerable amount of operative work, but later studies have shown that similar results are obtained when the production method is almost entirely plant-dependent; for example in the petro-chemical industry the throughputs of catalytic cracking plants were continuously extended as management and production engineers saw opportunities to remove bottlenecks.

Is the environment in which the building industry operates likely to lead to long-term improvement, which alone may have a decisive effect on productivity?

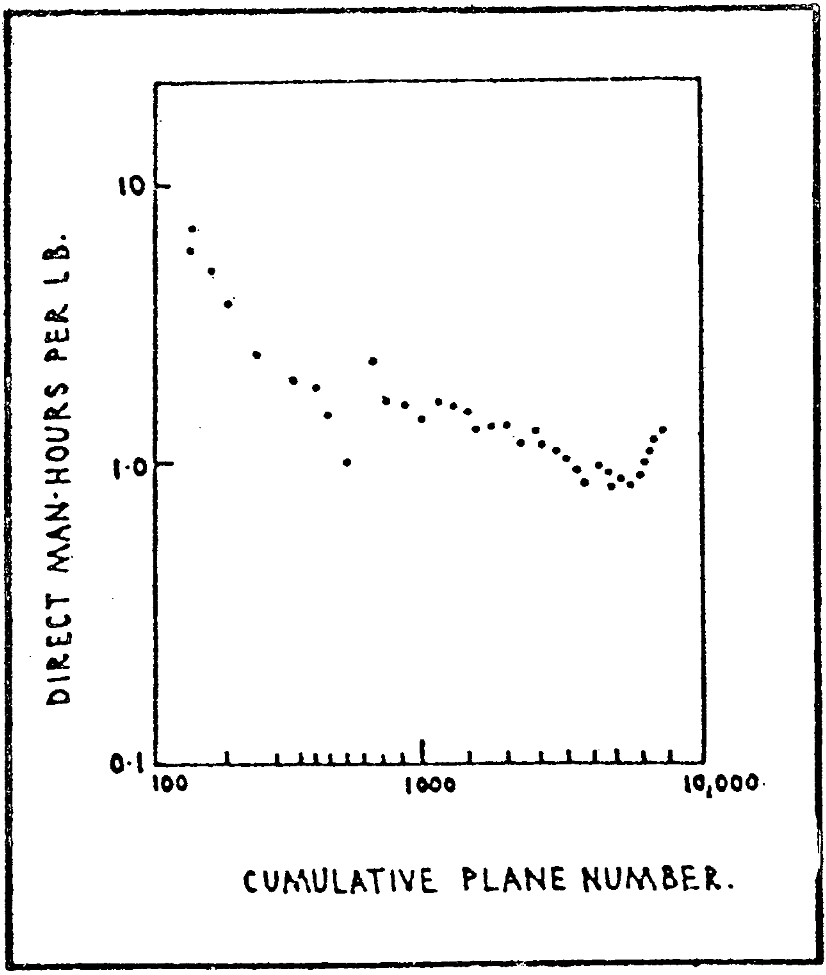

Fig 2. Improvement obtained during production of Boeing B–17

As already stated, detailed design can aim to simplify work, or at least to eliminate work that is obviously difficult, and to yield work which can be tackled by a gang without interruption by other gangs. For instance by simplification, e.g. arranging brickwork in long runs between quoins; by ensuring continuity, e.g. using joists hangers so that bricklayers' work is not interrupted whilst carpenters set joists; or arranging pre-cast concrete stair flights to be self-supporting from one floor to another rather than by building-in half-landings; by separating the work of gangs, e.g. detailing claddings so that joints and flashings can be completed independently of the erection gang and in one operation; by reducing the number of separate operations, e.g. by detailing reinforcement and construction joints so that concrete floors and walls may be cast in one operation; and by making mechanization feasible, e.g. specifying flooring of uniform thickness so that the screeds may be finished at one level using power floats, and so on.

Such refinements demand an intimate knowledge of building operations and a feel for the manipulation of materials (including formwork) in a way which is almost akin to craft work. Although a building thus designed will be easy to build, this may not be immediately apparent to contractors' estimators pricing bills of quantities. Hence it is important that tendering documents should enable estimators to identify quickly the implications of a design from the standpoint of construction. If this is not so, contractors may not be able to differentiate between buildings which are cheap to construct and those which are not, and there will be little encouragement for designers to develop building types, system or conventional, that are easy to build.

Many designers will wish to adopt new techniques in the hope of obtaining faster construction or lower prices, or both. In so doing they will create new circumstances which will affect both the work to be done by a gang, and the relationship between the gang directly involved and the rest of the work on site.

Such new circumstances were encountered in a study of the effect of introducing spray applied plastering, a comparatively modest innovation in which the backing coat (and wet screeds if required) is pumped from the mixer to the point of delivery and applied by an air-assisted spray. In view of the shortage of labour, several plastering contractors were operating spray-application pumps with the intention of reducing purely manual work, and a study of these pumps has been made by the Building Research Station in collaboration with the National Federation of Plastering Contractors.

A comparison of the productivity achieved using hand-applied plastering and spray-applied plastering showed there was little difference, on average, between them. About 20–25 manhours per 100 yd ^{2} (84 m ^{2}) were required for hand applied and about 20 manhours per 100 yd ^{2} (84 m ^{2}) for spray applied backing coats, although one gang had a labour requirement as low as 12 manhours. In a detailed case study of the effect of introducing one very co-operative gang to spray applied plastering, it was found that the gang, which had a high level of productivity on hand applied plastering, had its work disrupted when first introduced to spray applied plastering. This was because of acquiring new skills in spray application to obtain a relatively plane surface in one pass, of the use of derby floats rather than rules and of the adjustment of the mix to obtain pumpable mortars. There was the time taken whilst the gang in general, and the plant operator in particular, learned to maintain the new equipment. Finally there were the problems faced by the individual plasterers who, instead of working as individuals assisted by labours, had to work as a coherent gang with each operative specializing on a particular task, at least between work breaks. By the end of the experiment the gang had achieved a level of productivity with the pump equal to that when working by hand. Their non-productive time had increased dramatically from about 4 percent when working by hand to about 40 per cent when working by machine although 30 per cent of the available time must be spent on attending the machine. Therefore no direct advantage was obtained from the use of pumps although, had the firm been able to find other work for the gang, the experience gained might have led to higher productivity on the next job. There were two further complications. Firstly, main contractors, who release work to a normal plastering gang at a daily rate of about 120yd^2 (100m^2) must release work at a rate of about 700yd^2 (580m^2) per day to a spray-plastering gang. Secondly, the cost of training the gang amounted to about £500 in wages alone; but plasterers typically move from firm to firm, so that there is little assurance that money invested in training on one site will assist higher productivity on future sites.

But all of these difficulties may be overcome. Technical problems can be solved; job training can be given; new bonus rates can be agreed. But the effort in money and time must be worth while before a new technique can be adopted. Architects wishing to introduce new techniques must therefore design in a way that makes use of the technique feasible, and persist in this practice for a considerable time.

Design and prefabricated components.—Many current developments involve the substitution of factory-made components for the work of several trades now built in-situ, with the intention of simplifying site operations and obtaining cheaper costs. Whether these intentions are realized is determined by the interplay of many factors, which determine the effect of a component on site work. There is also the cost of prefabrication. The use of a component frequently cuts across the work of several trades removing from each some, but not all, of its work. This may decrease productivity for the conventional work remaining, partly because the remaining work may be more awkward, and partly because the non-productive elements, setting up, clearing away, will not be reduced in proportion to the work omitted. Moreover the work of each trade is composed of the main operations, which account for the bulk of the work done, and a large number of incidental jobs. Bricklayers, for instance, work about 70 per cent of their time laying bricks, and the rest on a large number of incidental tasks, many in preparation for a following trade, tasks often fitted in to the normal work sequence. Such incidental tasks are unlikely to be eliminated by complete substitution of part of a trade's work.

A classic example was encountered in the "Alternative Method of House Construction" experiment published some six years ago, but still valid and important to all concerned with innovation and development. In this experiment 440 houses of four different types were built on five sites. Type one house was conventional with brick/brick external walls; type two had the inner leaf of the internal walls built of plaster panels. For structural and other reasons the party wall and the flues were built in brickwork. The intention was to reduce bricklayers' hours on the one hand and to eliminate the bulk of plastering on the other.

In the bricklaying work, the outer wall normally required eight operations for erection from damp-proof course to roof plate, whereas sixteen separate operations were involved in the new form of construction. Every change of operation resulted in some non-productive time. There was little difference in overall rates of bricklaying between the two house types on two sites. On one site each house type had a diffierent gang, and this accounted for some of the difference in productivity. For like work (the party wall) the differences between house types were not considerable; productivity for the brickwork remaining in the type two houses was sharply reduced.

A similar story emerged from a study of the plasterer's work. The plastering remaining in the type two house was to party walls and chimney breast. The party wall was identical with that in the traditional house, except that it connected with plaster panels at junctions with other walls. There was a substantial increase in man-hours in the type two houses, attributable partly to the smaller quantity of plastering in this house type and partly to the lack of continuity. Similar results were seen in the rates for plastering the chimney breast and the spine wall. In the type one house the spine wall and chimney breast were in brick and were finished in two-coat plaster work, whereas in the type two house the chimney breast only was dealt with in this way, the spine wall being in plaster panels. Here besides the smaller quantity of work and the lack of continuity in the type two house the work that remained was more difficult than that eliminated.

Therefore the introduction of a new component will demand investigation to determine:

(i) the effect on work preceding it—must this work be completed in any but the normal sequence of construction?—the requirement for accuracy—the requirement for special fixings, anchorages, etc.

(ii) the work requirement of the component—its effect on the operations of the trade(s) affected by its introduction—the work involved in handling and assembly—whether there is need for, and does the amount of work on site warrant, the employment of a specialist gang?

(iii) the effect of the component on subsequent work—a greater requirement for making good—special finishes (for example, when concrete panels decorated with a textured paper to conceal the imperfections form part of a room together with plasterboard partitioning, which may be decorated directly with emulsion paint, both surfaces are usually decorated with the more expensive paper).

Ideally a component should replace the whole of a conventional group of operations without special treatment. Many such components already developed will play a major part in obtaining higher productivity by rationalizing traditional construction.

It is not always easy to discern the effect of introducing a component even when designers make a thorough analysis: field experience and observation is necessary and systematic development essential. Again, this is a situation demanding time: time for a component to be developed, appraised and redeveloped, and time for contractors and operatives to appreciate the work requirements of the component and integrate them with normal building operations.

Whether the use of a component is justified is also determined by the cost of production. Sometimes prefabrication makes possible new techniques, which are inherently more productive than site processes. For example production of concrete floor panels by extrusion casting or by long-line prestressing needs less reinforcement and less labour than the use of normally reinforced concrete. But few components are produced in ways that are radically different from site processes, and this necessarily limits the possible savings on direct production costs. Factory prefabrication also incurs considerable indirect production costs or overheads not encountered on site. Also the range of components will be limited so that overall utilization is likely to be lower than that in conventional building in which firms are adaptable and can undertake a wide range of work. These two factors, higher incidence of indirect costs and lower utilization, demand a considerable increase in productivity (or decrease in direct production costs) to offset them.

General rules may be said to include:

(i) Reduction of cost of materials.—This is normally difficult, because conventional materials are cheap in relation to their performance. Sometimes opportunities occur to lower the cost of materials (e.g. prestressed concrete reduced reinforcement costs); in other cases it may be possible to change the form of a component and therefore lower material costs by eliminating parts necessary to the conventional design. Often, however, standardization is at a disadvantage because each component must be capable of meeting the most severe conditions encountered in any of its uses.

(ii) Employing cheap labour.—In the United Kingdom this means using female labour on non-shift work. In other countries factory labour is paid less than site labour, and this alone offers a considerable inducement to transfer work from site to factory.

(iii) Improving production methods.—Processes usable on site are nearly always cheaper when used on site. Other processes not adapted to site use, including most continuously operated processes with a short cycle time, can be operated economically only at a large volume of production. Therefore this aspect must be considered, together with the question of standardization to reduce variety.

(iv) Combining several elements into one component—to increase complexity. A good example is the roof deck developed for the California Schools Project. This component includes the structure, the deck, weatherings, soffits, air-conditioning equipment and electrical services.

Design and industrialized building.—In an industrialized building the themes already discussed merge together; craft processes are modified, new materials may combine the properties of several conventional materials, prefabrication eliminates some operations, simplifies others; finally the use of prefabricated components may make better management of on-site processes possible.

Materials as used in building may be divided into two groups; the fabric of the buildings and the fittings and services including joinery, engineering services and decoration. Whilst materials in the first group may be influenced by the method of building adopted, conventional materials are cheap, so there would appear to be little scope for saving on this count except when conventional work is omitted (for example accurately made concrete panels do not require plastering or screeding). There is some scope and prospect for reductions in the cost of fittings and services. In some cases reduction of variety could create a demand on a scale which might make new production techniques economically viable. But this is not a general rule, because many production processes operate only on a small scale, while the minimum scale of operation of others is very high. Alternatively sufficient demand justify the re-organization of production and marketing, so that sets of equipment may be obtained 'off-the-shelf', e.g. the demand for domestic central heating has led to the marketing of central heating boilers, complete with accelerators, controls and motorized valves. But most or all of such materials and components may be used alike in conventional and industrialized building. Therefore any reductions in cost will be to the advantage of the building industry as a whole and not to industrialized building in particular.

The same considerations apply to prefabrication, or the substitution of components for in-situ work. When an industrialized building method is component-based, it is necessary to ensure that the joining methods are compatible and that in-situ work is not required to join, to weatherproof, to complete the awkward parts, to form fire stops, etc., because such work is always expensive. Better management of on-site processes is always an important (and often the decisive) feature of industrialized building. Conventional building, it will be recalled, relies largely on gangs organized on a trade basis, each undertaking one or more operation. In general the work of these gangs is not closely supervised, and low non-productive time is ensured by providing many more workplaces than there are gangs to occupy them. Industrialized building seeks to provide an alternative solution which management makes a positive rather than a permissive contribution. To do this an attempt is made to reduce both the volume and complexity of on-site work by substituting prefabricated components, or by the more effective use of mechanization, or by designs which produce simple technically independent operations to be tackled by a specialized gang, or by a combination of all three methods.

In practice this intention is difficult to realize. Factory-made components, as has been explained already, often replace only part of the corresponding conventional operations, so that the number of operations required to complete the work, and the whole complexity of the process, is increased. Mechanization often affects only part of an operation and the work remaining may require the attention of a normally constituted gang. In these circumstances the only possible gain is an increased tempo of work, but this may be dictated by progress elsewhere on the site. Similarly, advantages can be taken of independent operations only when good management ensures that the gangs and the materials are at hand when required, and that which is intended to be done is done, at each stage of construction.

These difficulties may be surmounted given the necessary knowledge and drive on the part of designers and supervisors. The intention to manage work in an industrial sense can be realised and appreciable reductions in labour requirements and increased building speed obtained. In practice considerable time is needed for designers to develop a system and for management to establish effective control and production resources. Thus every attempt to improve productivity entails systematic development and effective control. Both are necessary conditions.

Development.—Production development (Fig. 3) involves several stages before the main phase of the development begins and continues. First there is the innovation which often stems from past experience. This is followed by a phase of experimental development in which design, mock-ups, production development, experiments to settle technical features of the building and the production method, proceed until an acceptable solution is found. An essential feature of this phase is an appraisal of the development from the standpoints of technical performance, production methods and cost. Only when this last has been determined is it likely that the necessary capital will be made available.

Development now enters the prototype phase involving design, production, more experimental development and appraisal. Fewer options are now open. This phase is likely to be expensive, even when the prototype can be built as part of a project already required. One important feature, frequently overlooked, is to observe production (of special components) and construction in the field. Direct observation by well established activity-sampling methods is essential if production costs are to be correctly allocated and the operational consequences of design and management recognized. This information is vital for the redevelopment of the system, if system it is, in the most promising directions. With this phase completed, it should be possible to estimate the economic viability of the system and, if favourable, to secure capital and proceed to the first production cycle.

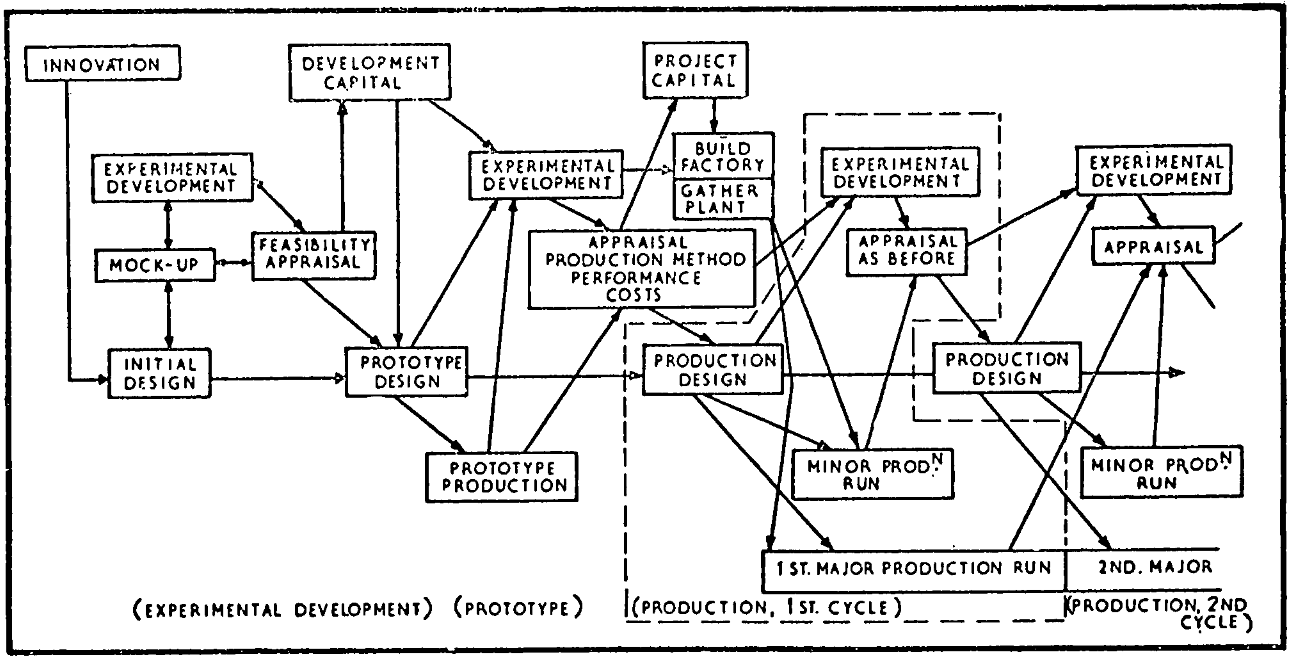

Fig 3. Production development

At this stage the development should be redesigned in the light of information already obtained, and the necessary production facilities be provided. Thus, possibly four years after conception, the innovation will be ready for the first production run. The main part of this will be part of the ordinary commercial operations of the organization concerned, with sufficient cost feed-back necessary to establish effective control. Another part of the programme, to be completed reasonably quickly, must be regarded as an extension of the development process and appraised, as was the prototype-phase. This time, however, the appraisal will also include the longer term performance of the prototype buildings, as a first indication of durability. Associated with this phase will be further experimental development, suggested by ideas and problems stemming in part from the design for this phase of production and in part from the experience gained in production.

This cycle of production, appraisal, experimental development and redesign is a continuous and continuing activity which is one important characteristic of industrialized processes. Important because it alone is likely to realize the substantial improvement in productivity recorded in other industries. It will be noticed that development is not technique-dependent. Rather it requires the will and ability to invest money, technical and management skills and time, an investment which is not likely to be made unless the investors have confidence in the future of the market and in their ability to control the required resources. It is this latter point which is our last concern.

Effective Control.—Resources in the conventional building industry, it will be remembered, are widely dispersed and not deeply committed. There is both strength and weakness in this situation. Strength in the lack of commitment and the ability to deploy the resources without mortal damage on the work available, an attribute not to be lightly dismissed particularly if clients and their advisors wish to maintain the present characteristics of the market. Weakness arises also from this lack of commitment in that operational units are short-lived and there is insufficient time to take advantage of improvement, innovation, development, management, all of which they have marginal rather than decisive effects. Effective control has been shown to underlie all successful attempts to improve productivity of individual operations, to introduce components and to develop industrialized building. For example, to be successful, spray-applied plastering demands on-the-job training, the organization of individual plasterers to work as coherent gangs, some restatement of industrial relations, the co-operation of main and sub-contractors and the design of the buildings to yield continuous work. Similarly a new component demands systematic development, and may often upset the balance of work between trades and increase the cost of the work remaining, unless these consequences are countered by improved organization. With industrialization, the integration of site operations demands the certain availability of trained operatives and of plant and materials, in addition to systemtic development. Therefore steps to increse productivity entail improved control of the resources involved and an investment which can be recovered only in the course of time.

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(Appendix follows:)

APPENDIX

Factors Affecting the Productivity of Building Operations

VARIABILITY OF PERFORMANCE

Considerable variations in performance are encountered whenever comparisons are made between individuals, groups or firms. This is particularly so in the absence of agreed targets or norms, because it appears that output is influenced as much by the targets set as by the rewards offered (i) and the existence of norms, however set and at whatever level established, may be expected to reduce variability. In the building industry in the United Kingdom there is comparatively little information about the relative performance of operatives in terms of labour requirements for specific operations, or of firms in terms of either return on capitol or other economic indices. Therefore considerable variability might be expected and is, in fact, encountered. This is not surprising because quite small variations in the gang strengths and the time to complete a job produce noticeable differences in productivity; for example, a variation of plus/minus 10 per cent in both the manning rate and the tempo of work produces a range of 1.5 :1 in productivity and, similarly, a variation of plus/minus 20 per cent a range of 2.3 :1; and variations of this order are encountered in all types of construction.

The labour requirements for any repetitive operation on any site will, under normal circumstances, be in the range of roughly 1 :4 and variations of the order of 1 :10 are not uncommon. (Because of this, spot checks on labour requirements have little meaning and it is always necessary to relate these to observations made over long periods.) When the large number of operations comprising a building are combined, the level of variability is naturally reduced but remains considerable (2, 3).

PRODUCTIVITY AND INDIVIDUAL OPERATIONS

Work involved in construction may be broken down into a number, sometimes a large number, of operations each of which can be tackled by a man or by a gang without interruption by other men or gangs. Some craft operations may involve only a man or a small gang of men without a requirement for assistance from other men or plant, for example tilers on traditional housing: other operations may involve gangs which must arrange their work to fit in with other gangs, for example, bricklayers build in stages to allow joists to be pitched by carpenters or concrete floor panels to be placed by crane. In craft operations the speed of work is mainly dictated by the ability and drive of operatives, by the availability of work and materials and, to a lesser extent, by the design of the building. The productivity of non-craft operations is influenced by this and by other factors in that the design of the building, the detailed design of the equipment used and the general sequences of construction all considerably affect the progress and the manning strength of gangs; shuttering is one example of this type of operation, deep excavation another.

Little is known in detail about the factors which affect the productivity of operatives and for the majority of tasks there is no accepted way of deciding what is a fair day's pay for a fair day's work. Productivity varies considerably even for identical work; for example, in one study (4) involving the construction of 170 three-bedroomed, two-storey, semi-detached houses on five sites by five different contractors, the manhour requirement for plastering a house varied from 140 to 350 manhours on the five sites, and there was considerable variability on some sites especially those on which several gangs were employed (Fig. 1.A). This variability exists at an operational level, for example the manhour requirements for the application of backing coats have been observed to vary from 7 manhours to 30 manhours per 100 yd ^{2}.

Incentives loom large in any discussion of productivity, and are frequently mentioned as the sure way of ensuring high productivity. The available evidence is not conclusive. Surveys (5) of productivity in house-building showed that in 1948–49 the manhours per house were about 20 per cent lower on contracts with target bonus schemes than on contracts with standard wages only. At that time target bonus schemes were operated on about one quarter of all contracts which could have been expected to attract the more able operatives. Since then, two events have changed the picture; a general and sometimes acute, shortage of operatives and a growth of labour-only subcontracting, particularly in house building.

But even contractors are not so sorely pressed for labour and when the counter attraction of labour-only work does not exist, it is far from certain that incentives, per se, are effective. A detailed study (1) showed that the outputs of bricklayers were related to the targets set so that if bonus payments were, in turn, related to targets, operatives with widely differing outputs would have received similar bonuses. The targets set reflected the past performance of the firms concerned. Also shown was the need for flexibility in operating the scheme and for well-defined channels of communication within firms (between estimating, planning, production and surveying departments). Therefore the effect of incentives cannot be isolated from the firm concerned, and an effective incentive scheme is likely to be found when there is good management, and all that goes with it, including high productivity!

Some of the differences observed stem from techniques. Detailed studies of the work of bricklayers (6) has shown that one important factor is whether bricklayers take advantage of the opportunity provided by long walls to lay many bricks in one operation. Some operatives build long walls as short walls and spread a mortar bed sufficient for about a dozen bricks; others spread a bed for roughly 70 bricks in one operation and productivity appears to be correlated with this. At present there is little or no systematic operative training in production techniques (in contrast to craft practice). The former are mainly taught on site where the instruction received depends upon the inclination and the skill of the craftsmen to whom an apprentice is attached. Although increased productivity may result from direct monetary incentives, it is probable that more could be gained by systematic training, by good organisation, and by successful human relations.

Operations may be divided into three phases; setting-up, working, clearing away. Setting-up includes receiving instructions, appraising the job, obtaining materials, preparing the workplace, organising the gang; in some tasks this is done afresh at each workplace, in others the amount at each workplace is small compared with the work involved on arrival on site—for example, specialist plumbers may set up a small yard to prefabricate pipework. There is also an element of secondary setting-up whenever work commences at a workplace, or after an interval, (new day, tea break, etc.). Work then ensues (unless interrupted) until the end of a working period when, depending upon the craft involved, there is some work entailed in collecting tools, clearing up, sweeping out. It therefore follows that productivity is to some extent affected by the amount of work to be done at each workplace, because the time spent in setting up and in clearing away will be sensibly constant.

Consider, for example, plasterers who will normally complete the rendering coat to a single house as a continuous operation. Supposing the work to be done is successively reduced by the use of prefabricated partition and self-finished wall panels. In these circumstances productivity for the plastering remaining gradually diminished so that if three-quarters of the work is omitted the remaining quarter takes rather more than half the original manhours. Hence as much work as possible should be done at each workplace; alternatively small operations should be tackled by specialist sub-gangs able to move rapidly from workplace to workplace, in effect treating all workplaces as a single workplace. Bitty building must result in low productivity unless the site is sufficiently large to permit a considerable degree of gang specialisation.

Finally there is the situation in which a gang serves a plant dominated operation, such as the several gangs involved in in-situ concrete construction. In these circumstances the number of men in each sub-gang is determined in part by the amount of work to be done, and in part by the physical requirements of a task—for example, large areas of formwork may require a minimum gang of, say, 6 in order to secure the formwork. The tempo of work is usually determined by a critical operation and often it will not be possible to arrange the balance of work and the number of men so that the gangs, other than the gang employed on the critical operation, are fully employed; in concrete construction, for example, the time required to assemble the formwork for the stair and lift well in multi-storey structures often determines the tempo of work for the remainder of construction, and attempts to accelerate the work of other operations may merely increase idle time. Also of importance, if formwork and concrete are to be crane handled, is the number of gangs served by a crane, because if several gangs are to be served by a crane on the assumption that it must be fully utilised, it is inevitable that some gangs will have idle time. In these circumstances, therefore, the several gangs operate as one gang, and their work must be appraised as a whole.

Thus far it has been assumed that an operative or gang is working independently and that progress is not hampered by interference by other operations or from other causes. This is, of course, not the case and progress is frequently delayed for a number of reasons. Observable non-productive time on building sites is typically low, seldom exceeding 15 per cent and on average about 10 per cent of paid manhours. In practice it is difficult to determine what is non-productive time, partly because it is not always evident whether an operative is or is not working, e.g. walking to collect essential stores, collecting information, moving to a new workplace, and partly because there is no reliable method of assessing the normal tempo of work. Actual delays are not always evident as non-productive time; Parkinson's Law operates and delays may be anticipated by extending the task in hand (probably unconsciously) to fill the time available; therefore the actual incidence of non-productive time is probably higher unless effective control is maintained.

PRODUCTIVITY AND SITE ORGANISATION

The previous section concentrated on the work of individuals and gangs, the organisation of these gangs on a site will be now considered. It will be remembered that the work in construction can be broken down into a number of operations, with each operation being tackled by identifiable gangs with or without the assistance of plant. Because of the dispersed nature of building, each operation is normally carried out at a number, sometimes a large number, of workplaces, e.g. contracts consist of a number of dwellings in low-rise construction, a number of storeys each with a number of flats or maisonettes in high-rise construction, or a number of classrooms of ancillary assembly areas in schools, etc. Therefore a gang tackling an operation will move from workplace to workplace to be followed by gangs tackling subsequent operations. In these circumstances a queuing situation arises in which the available workplaces may be considered as customers awaiting service by the next gang in the sequence of construction (7, 8).

Consider the situation shown in Fig. 2A, in which the vertical axis represents workplaces numbered 1, 2, 3 .... and the horizontal axis the time scale in whatever unit is appropriate. Gang I, starts an operation at interval 1 with an average elapsed time of, say, ½ time units at each workplace. This gang is followed by gang II tackling the next operation, whatever that might be, an operation which may be done in the same elapsed time as the previous operation (gang II), more slowly (gang III) or more quickly (gang IV). In fact the elapsed time for each operation will vary about its mean, therefore the problem arises as to the interval which should be left between gangs tackling successive operations, to ensure that gangs are not delayed or threatened by delays by the preceding gangs.

In practice the situation is normally more complicted because some gangs may tackle several operations, dependent on their trade, with intervening operations being tackled by other gangs.

The situation is further complicated by the employment of specialists subcontractors, many of whom tackle comparatively limited operations and, for their own organisational purposes, expect to have a substantial proportion of their work available each time they enter a site. Such a situation is shown in Fig. 2A and it will be seen that gang V leaves the site when it overruns the preceding gang. Although this may appear to be inefficient as far as any particular site is concerned, this practice leads to comparatively high utilisation of operatives in the industry.

If there is no particular necessity to build quickly, the difficult organisational problems implicit in this situation may be solved by creating a large number of possible workplaces for every gang, so that each gang will be able to find a job somewhere on the site on completion of a task. The extreme solution is for each gang to complete one operation throughout the whole site before the next gang commences work, leading to an inordinately long building time; therefore a balance must be struck between building speed on one hand and the headway between gangs on the other. Building slowly makes fewer demands on management and nearly always leads to lower non-productive time but increases overheads and funding costs; building quickly probably increases non-productive time (unless the contractor achieves good control over the required resources—labour, plant, materials) but reduces overhead costs to contractors; also early completion obtains a more rapid return on the client's investment.

It must be emphasised that the circumstances described are ideal. All too often a shortage of labour, a rapid turnover of the operatives available, technical hitches, delayed delivery of materials and—sotto voce here—lack of instruction, or too many instructions, or inadequate instructions by the architect, all combine to make mockery of planning and day-to-day control an esoteric art (Fig. 3a).

Only passing reference will be made to mechanisation because the broad principles governing its employment are the same as those already discussed. The general issues have been discussed elsewhere (9, 10) and are too extensive to summarize here. One ground for mechanisation, a shortage of labour, often results in the substitution of plant for men and may affect only the operation directly involved. More frequently, however, mechanisation results in a quickening in the tempo of work and its consequences and cost must be appraised with respect to the whole job. Again it is important to avoid queuing situations which arise when one item of plant—a tower crane perhaps—serves several gangs and when only a small amount of work is to be done at each workplace. It will be seen, therefore, that the principles of production control described above apply with equal force to manual and mechanised operations.

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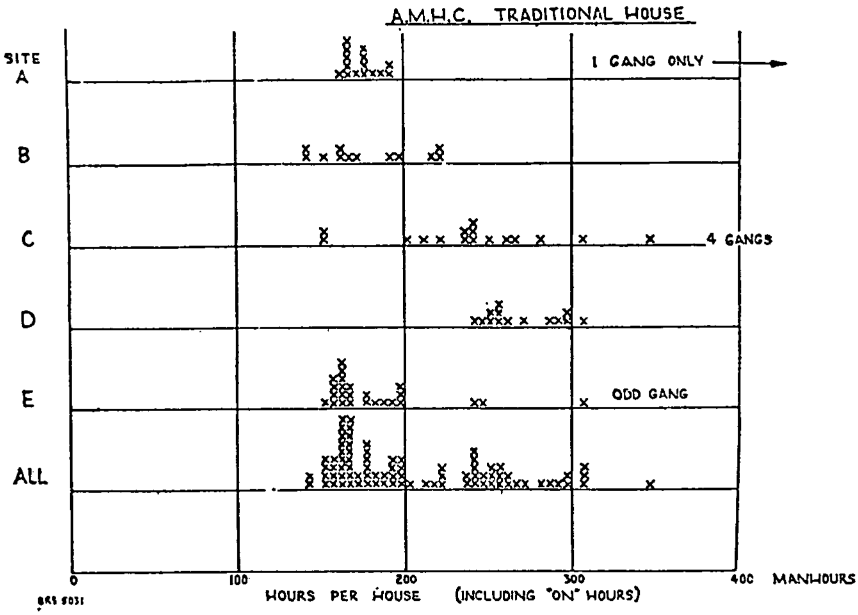

Fig. 1A. Manhours recorded on five sites for plasterers labourers.

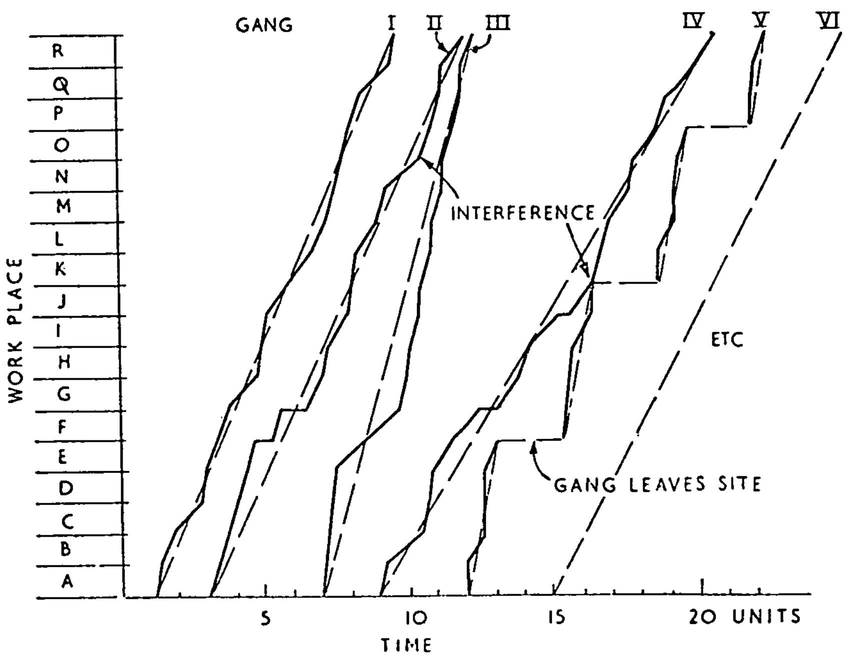

Fig. 2A. Cyclogram of site operations

GRAPH OF PROGRESS

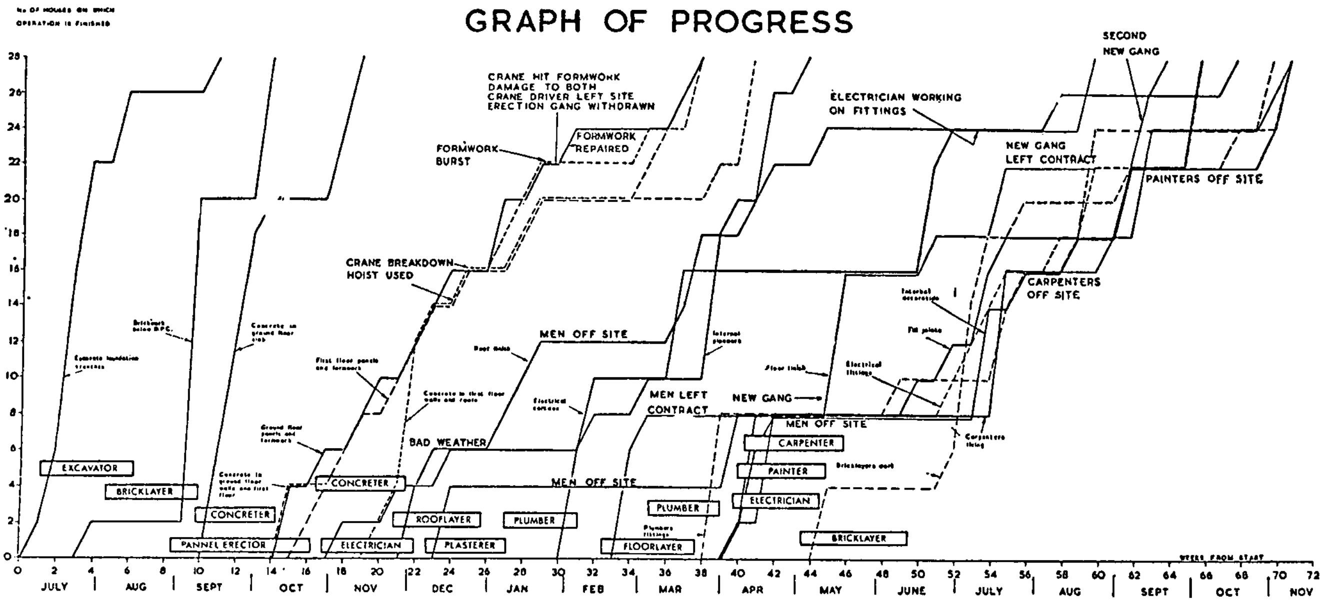

Fig. 3A. This graph is for a group of 28 semi-detached houses. The structure of the houses was of concrete poured round an interior of factory-made panels which needed a minimum of finishing on site.

The graph shows that the panels and concrete were placed at a steady rate of about 2 houses per week, except for two periods when the crane broke down. The advantage of this was lost because the finishing stage took 6 to 8 months. The foundations were built unnecessarily quickly; consequently the last houses waited at the ground floor slab stage for 4 months in midwinter.

There were many delays, shown by horizontal lines, and the reasons for some of them are indicated.

Information from the Building Research Station

The Building Research Station is active in nearly all areas of building technology and civil and structural engineering. Its *Research Programme* (2), published for the first time in 1966, lists all the current research projects, and the annual report *Building Research* (1) gives a more discursive account of the Station's activities. Results of the Station's work normally appear first in the technical or scientific press, being afterwards reprinted separately as *Current Papers* (2). These appear in four series, of which the Design, Construction and Engineering Series can be mailed regularly to any address, free of charge. The Research Series is normally mailed regularly only to research organizations and libraries, but individual papers can be made available. There are also a number of *Miscellaneous Papers*. More extensive reports of the Station's work are published by the Stationery Office in individual form or as series, such as the *National Building Studies* (1), *Factory Building Studies* (1) and *Tropical Building Studies* (1). The Station has also produced a number of textbooks, notably *Principles of Modern Building* (1), and others on thermal insulations, lighting, and building operatives work. These are likewise published by the Stationery Office.

(1) Obtainable from Her Majesty's Stationery Office, PO Box 569, London S.E.1.

(2) Obtainable from the Building Research Station, Garston Watford Herts. England.

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BUILDING PRODUCT ANALYSIS THROUGH AGREMENT*

by

JOSEPH EDEN

The following article on Agrement, a system of testing and certifying building materials, was taken from a lecture given by Joseph Eden, Director of Agrement for the British Ministry of Building and Public Works, as part of the Division of International Affairs Seminar Series.

It was Bernard Shaw who said that every man was an anarchist—that he believed in government of other people, but not of himself. Nevertheless, in civilized countries we accept controls which are necessary to protect our own environment and, in building, a degree of control is necessary to protect the safety and health of the community and to ensure that amenities do not deteriorate. In addition, the building owner or tenant himself should get the environment he expects and it should last for as long as he expects.

For these reasons most countries have adopted some form of building regulations or obligatory codes, either local or national. Where such controls are weak or ineffective, it is perhaps inevitable that other forms of control have taken their place—a refusal to lend money for building unless arbitarily determined requirements are met, difficult insurance conditions, and planning restrictions on speculative private enterprise estates, for example.

While no one would say that all controls should be swept away, and few will insist that they should be centrally rather than locally administered and by public rather than private sources, the fact remains that in many countries both the rigidity and the variety of requirements greatly inhibit innovative developments in building methods. The problem is to encourage innovation in building while protecting the community.

In the United Kingdom, we operate to some degree under several types of control. Until a few years ago, each local authority framed and operated its own codes or by-laws. The first steps towards unification was obtained by the central issue of a non-obligatory set of 'Model By-laws' that in time came to be accepted in part or in whole by most local authorities. An additional step was taken in 1965 when the local by-laws were eliminated and the central Building Regulations were enacted for Scotland and England and Wales. In Northern Ireland the Building Regulations are still being framed.

Although the Building Regulations have been centrally framed, they are locally operated and enforced. Each local authority has the power to waive a clause but cannot frame a new one without reference to the central authority.

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Although the new regulations attempt to specify the performance required from building components in measurable scientific terms rather than insisting upon standard design details, there is no doubt that they still present a considerable hurdle for a component manufacturer with a new product. Not only do the regulations refer to the British Standards which rapidly become out of date, but they are locally interpreted, which can lead to difficulties for a manufacturer with nationwide scope.

There is, of course, the debate over whether building regulations should be centrally or locally operated. It is my position that, except in very small countries, complete centralisation is very cumbersome and undesirable from the point of view of the local community. In a country the size of the United States it is, of course, impossible. Nevertheless, no local authority can be expected to have the expertise to protect itself completely against the difficulties which arise from the misuse of materials and poor design, while on the other hand, there may be expert local knowledge about some aspects, e.g., soil conditions and climate, that are not readily available centrally.

While building regulations, whether centrally or locally administered, may adequately protect the community, there is no doubt that they restrict innovation. As Kipling said in a rather bad poem:

> "How very little since things were made
> Things have altered in the building trade."

Most present day innovations occur in the development of components and many of these are developed outside the building industry itself. Thus it is component manufacturers who suffer most from the rigidity and variety of interpretation of building regulations and who would benefit most from unification. If we are to modernize the industry, we must make it possible for good innovations to be accepted without too much difficulty.

The Agrement System

The Agrement System, which operates in slightly different forms in France, Belgium, Holland, Italy, Portugal, Spain, and the U.K., has been described as an approval system and is compared with other rubber stamping systems which have led to rigidity. These comparisons are, I think, unfair, because the Agrement certificate is not to much a rubber stamp as an expression of informed opinion about the probable performance of a material or component under specified conditions.

The Agrement Board in the U.K. was set up as a result of the work of a government committee of enquiry to look into the Agrement system as operated in France and to consider the need for a similar system of certification in the U.K. The Board was set up as an independent government-sponsored organization, with members appointed by the government but drawn from the various sectors of industry.

The Board has been in business for nearly 3 years and has issued about 20 certificates, with another 10 likely to be issued before the end of 1968. It is hoped that it will be operating at the level of approximately 100 certificates per year before the end of 1969. The Board has used the Building Research Station almost exclusively as its agent for carrying out the necessary investigations, enquiries, and tests and forming the assessments.

Operation of the Agrement System in U.K.

The systems in the U.K. operates as follows. Any manufacturer can approach the Agrement Board for a confidential investigation of his new building product at his own expense. He must state the application or applications for his product in building and the Board, assisted by the Building Research Station (BRS), will outline the programme of assessment that it intends to follow. The costs are figured, the manufacturer signs a contract with the Board, and pays in advance. In the event of an early failure or other difficulty, the investigation can be halted, and any unused sums of money returned. The manufacturer always gets a ful and confidential report of the investigation. In approved cases, he will also get a certificate, usually a four page document, giving the Board's opinion of the suitability of the product for particular uses under the following five general headings:

1. Safety. This category covers structural stability, deformations, fire resistance, combustibility, spread of flame, toxicity of the material or fumes; behavior against impacts, and other rough usage; other accident hazards; other health hazards.
2. Habitability. Includes performance in normal usage, including such matters as thermal and accoustic insulation, light and ventilation, resistance to the elements, etc.
3. Durability. Resistance to wear, weathering, or other disintegrating influences, permanence of appearance, etc.
4. Quality control. Whether the firm is capable of maintaining its standards in production.

The above general headings are used by all Agrement Commissions in Europe, and in cases of export there are some arrangements for the transference of certificates from one country to another. In the United Kingdom the Agrement Board conducts investigations under two additional headings:

6. Practicability. Transport, storage requirements, handling methods, any special techniques needed for installation or erection.
7. Maintenance. Scheduled maintenance instruction.

A typical assessment of a new product is as follows:

1. Visits to the factory or factories are usually undertaken first in order to determine whether the product is in production or under development. In the latter case it must be decided whether to delay the investigation or to undertake a preliminary investigation. These visits are also made to inspect the quality control procedure, to select representative samples for testing and further examination, and generally to form an opinion about the firm's capabilities.

If an article is manufactured abroad it is necessary to visit the foreign factory, arrange for a reputable foreign organization to make the inspection, or concentrate upon the quality control methods employed by the importer.

2. Visits to sites are undertaken for two purposes. First, to see how the products arrive, inspect the process of installation, and not any practical difficulties in use. Second, visits are made to the earliest known example of use of the product to assess its durability. This is invariably the most difficult part of any assessment of a new product.

A suggested rule is that the life of a component should be the period during which the cost of maintenance accumulates to equal the first cost, presumably including installation and replacement. This works quite well for low maintenance high initial cost components, but not so well, for example, for a sheet of window glass which may cost more to replace than its first cost.

We now believe that it is reasonable to expect different life durations for different components, and that in asessing a required life, one must take into account the expected life of existing components with a similar purpose, the first cost and the cost of maintenance.

The actual assessment of probable life of a new product is a difficult process and it is necessary to have access to expert opinion about the nature of failures in similar materials, information on aspects of design likely to increase durability, what happens to existing components, climate, conditions to be expected and above all, previous experience in the use of the new product in practice. Unless related by research to actual practice, accelerated weathering tests can do more than verify expert opinion. A positive result may be informative, a negative result relatively useless.

3. Tests are carried out when necessary to verify special claims, or to give further evidence of the behaviour of the product under special conditions. These are usually empirical and rarely simulate exactly what actually occurs in practice. A test failure, therefore, does not necessarily mean the refusal of a certificate.

4. A review is made of all evidence provided by the firm and collected during the investigation by an experienced person and consultation among experts in various relevant fields takes place. The report is prepared and recommendations about certification are made.

5. These recommendations are discussed with any public bodies—such as the Building Regulations Sub-Committee—which have a legitimate interest in the proposals.

A certificate is valid for up to three years, but may be renewed after a second investigation aimed at noting differences which have occured in design and manufacture. Copies of certificates are printed in large numbers so that a manufacturer may purchase any quantity for advertising purposes, but he may not reproduce the certificate himself though he may quote from it. Copies are also sent automatically to a list of subscribers, which includes most local authorities. The Ministry of Housing, which lends money to local authorities for public housebuilding, supports the Agrement Scheme and ciruclates information and certificates to local authorities. It often happens that points arise during an Agrement investigation that are relevant to the Building Regulations. There may be a question of interpretation of the regulations, or it may appear that a clause is contravened but should be waived. The Agrement Board has no power to interpret the law (a judicial function) or to waive clause of the regulations (only allowed by individual local authorities). In such cases, however, the certificate often gives an opinion as to what should be done, normally after consultation with the Building Regulations Sub-committee (the people who draft the regulations).

Certificates thus issued are proving very helpful to local authorities, architects, and builders in interpreting the usefulness of a new product, and also to manufacturers in getting new products launched.

Experience with the System

Having been closely concerned with operation of the Agrement system in the U.K. since its inception, a few notes about our experience may be of interest:

1. The cost of an Agrement investigation appears high to many manufacturers ($2,500–$7,500). There are a number of reasons for this:

(a) The cost of administering the system is higher than was expected. Initial discussions with would-be clients are much more protracted than expected. Many clients do not foresee the possible application of their product, so that much time is spent on what amounts to a free consultative service. It has also been found that negotiations after the completion of the investigations and before the issue of a certificate both with the client, who often wants to change the product, and with authorities such as the Building Regulations Sub-committee, the Water Boards and so forth are most time consuming.

(b) It was first thought that the majority of assessments could be made using existing knowledge and testing equipment to be found at BRS and in private testing establishments. This has not proved to be the case. It has been necessary to spend large sums on the development of new test methods.

(c) Continual publicity has been necessary to get the new certification system widely known.

2. The process of assessing a new product requires that someone conceive of a testing program. When methods are worked out, it is worth recording them for future use, and if they are of sufficient general interest, to publish them as a guide to manufacturers. A number of these Methods of Assessment and Tests (MOATs) have been published by the Agrement Board, some based on 'Directives Communes' which have already been internationally agreed upon by the European Union of Agrement, and some original developed in the U.K. which are being offered to this organization.

The publication of these MOATs by the Agrement Board has come at a time when the attention of architects, particularly in the public sector, is being increasingly directed towards defining specifications of building components of all types in terms of performance, rather than in terms of specific construction. The British Standards Institution, a private body of long standing, operating with private and public funds, which produces hundreds of specifications of all types every year, is also moving in this direction. It has always been thought that Agrement certification could be the first step towards the issue of a British Standard.

This process seems to be working very much faster than expected. The mere knowledge that the Agrement Board is examining a particular class of product, that it is about to issue a MOAT, or that testing rigs are being built at BRS, is often enough to start manufacturers agitating for a standard based on performance, and to cause them to design and build their own test rigs to determine the performance of their own products. For example, the industry's whole attitude to windows has been changed as a result of the issue of an Agrement Board MOAT.

Although the process sometimes causes friction I think it is a very healthy one for the industry. If an Agrement Board MOAT sets targets which are too high in practice, a subsequent British Standard can lower them to a more practical level.

3. In order to publicize its work the Agrement Board has started a list of subscribers, who, for an annual fee, receive copies of all new certificates, information sheets summarizing current MOATSs, and news letters.

4. A somewhat controversial problem which faces the Board is deciding when a new product is an innovation and when it is not. Current thinking is influenced by certain members of the architectural profession who are refusing to use products unless they are certified by the Agrement Board or comply with a British Standard. Personnally, I do not approve of this definition, which encourages the Board to undertake the certification of many proved building products that are not innovations. To my mind the certification of such products does not perform a public service, but merely increases cost. On the other hand it seems to be legitimate to invade the field of products for which there are British Standards, if the new product make a significant advance in performance. To my mind it is not admissable, although this has been considered on occasion, to investigate a product in an attempt to lower a British Standard. Such investigations, if necessary, are better carried out by the British Standards Institution itself. The guiding principle should be whether the certification performs a public service.

Conclusion

In conclusion, it may be said that the Agrement Board in England is performing a public service in controlling and improving quality. While it has been rather slow in gaining acceptance among manufacturers, those holding certificates have no doubt about the improved sales which result. The Board is refining its administrative procedures and rapidly increasing the amount of work undertaken.

In most other Agrement organizations, the State contributes financially to the cost of the certification. In France, where the system is most advanced and covers the broadest field, the State contribution is on the order of 50 percent. In Great Britain, however, the Government expects the Agrement Board to be self-supporting within the next few years, drawing its entire expenses from industry.

In the absence of a State Testing House, such as is provided in most European countries, with freedom to spend state money where necessary on the development of testing methods and equipment, it seems doubtful that complete economic independence can be maintained. It is possible that in future the Agrement Board's functions may be extended to undertake development testing and the drafting of performance specifications, and may receive as a consequence some permanent state grant.

SYSTEM HOUSING—THE SHELTER INDUSTRY IN NORTHERN EUROPE*

by

R. E. Platts

Introduction

The manifest successes in the system production of housing in Northern Europe are becoming more appreciated in Canada, or at least less easily depreciated. Some recognition is granted to the relevance of the leading system schemes to our own production of urban housing. Less well understood is the industry structure that has spawned the healthy system ventures—the total structure, encompassing producers, labour, the design and control professions, and the State itself. Certainly this deeper picture of vertical integration produces extremes of reaction here; uneasy disparagement from some, acclamation from others.

In the light of the surge in multi-family housing in Canada and the interest of some large producers in full systems, the Division of Building Research arranged a field and factory study with leading system contractors in Northern Europe, September 1966 to September 1967. Eight systems were given fairly complete study on large projects usually in full output, while field reviews of less depth were carried out on eight others. Quite apart from the study's purpose of assessing the realities of production and design of the advanced systems, the flow of projects yielded tacit insight into the strength of the integrated industry. The technical realities are summarized below with confidence; some inter-relationships of the industry structure are then sketched knowing that lessons are there.

The New State-of-the-Art

The sampling of system housing in the 1-year field study was broader than the narrow selection of main studies would suggest. In several cases a single system was observed in two countries on varied projects, sometimes subject to such extremes as excellent job management on one project as opposed to little at all on another, and fragmented markets with scores of small systems enterprises in one country as against grouped markets and co-ordinated large enterprises in another. The secondary studies allowed selective sampling of a further variety of evolving systems and subsystems. From all of this a composite picture of the best of system housing can be given. Remarkably, a few single system ventures exhibit many similar attributes.

The intent of such planning for market continuity is to increase productivity in the housing sector—the only way to get new housing

*Habitat, Volume XI, Number 3, Sept. 14, 1968 (reprinted with permission).

into more hands without cutting back on other needs or desires. Subsidization is not a large factor in the areas that have shown the total system advances. Rental subsidies for families with children appear to be of the same order in Scandinavia as the Family Allowance in Canada. The building financing facilities may make no distinction between system and traditional approaches but may demand a qualifying level of productivity. Equally important is the tying of State credit funds to long-term planning: in some areas financing is available in blocks of 2 to 5 years if the company can show a program committed to clients for that period of time. This of course favours the larger companies who use vertically integrated systems to win such a market with predictable price and quality.

Among the largest contractors the controversy between full system building and improved traditional building is largely over—the decision has been taken, the systems machinery developed and set in motion. Central plants are operating two shifts a day and the sites are geared to the plants to form a true assembly line extension of the plant, no matter how far the one is from the other. The full systems of relatively few large finished parts and few site trades promote good order and fast flow, and in fact demand them, to make economic use of equipment and stock. A single crane and crew of seven will maintain a surprisingly steady pace of 120 and even 150 lifts a day to erect 2 to 3½ dwellings a day, or two or more floors a week on high-rise blocks.

The large-panel concrete systems now include in precast form all crosswalls and gables, floors, elevator shafts, stairs, landings, lobbies, refuse chutes and ducts, sometimes unit bathrooms and partial kitchens and even precast foundations and basements. The panels are erected ready for direct painting or wallpapering after minimal patching. The interiors and services—which together involve ⅔ the cost of a building—are now advanced subsystems: precise light partitions, doors, cabinetry, trim and closet-walls prefinished in vinyl film or baked enamels, and cast-in-panel services and trim raceways together with the unit cores. All of this is quickly placed and joined within the precise structure with negligible handling damage. The same interior subsystems are now being adopted within steel frame systems. These are evolving toward the use of performed covers between floor and suspended ceiling planes as fire protection to attain the large-part simplicity of the precast buildings.

Such total systems allow completion of large projects—low-rise complexes or high point blocks—within half a year. Thus, fast turnover and the attendant savings in construction financing have become as important in the systems picture as reliable cost control, quality control, and direct cost savings. In comparison with traditional jobs, full system contractors speak of direct savings of 10% and even 20% with a further 5% gained through shortened construction financing. Starting with sand and gravel (but not including cabinetry manufacture) these contractors use about 800 man-hours to produce a three-bedroom dwelling unit with flexibility of design; some require as little as 500 man-hours, more or less evenly divided between factory and site. (Site labour alone for apartments in North America is reported to be typically 1100–1400 manhours.) Furthermore, it must be stated that in Scandinavia such systems are expected to, and do, produce a higher level of design and quality than is normal here. Amenities are comparable; hardware, openings, cabinetry and finishes are generally better, and so are the technical points of sound, thermal and weather control, precision, interchangeability—and simplicity. All this is not an average picture in any country: it is the state-of-the-art recently attained by the leading contractors after years of development.

Production Requires Market Continuity

First let it be stated that the housing task in much of Northern Europe is not significantly different from our own. Particularly in Scandinavia, the population is grouped in relatively isolated, mushrooming pockets, and all want high quality cold-climate housing. The proportion of multi-family housing is now also comparable, housing projects are about the size of our larger ones, and private contractors produce them. The identity of the client is the point of departure from our familiar picture. The housing client in Northern Europe s often a large, independent non-profit society or co-operative, or the State itself in its municipal or other form. Alternatively, the State may choose to set policy as if it were the final client, in its simple mandate that people be well housed. The effect, strengthened in the last few years, is the fostering of a market continuity and reliability not prevalent here.

The company can aspire to compete for projects anywhere, free from locally-imposed diversity. The building regulations are increasingly performance codes and are uniform in actual adoption and use. Municipal approval itself is most often in the hands of a technical man, while the central authority is there as the final arbiter if needed. The contractor can comport himself as a true manufacturer for an important mass market, a national, reputable, permanent enterprise with access to capitalization befitting the job.

It can be argued that the cause-and-effect picture given above is too cleancut and favourable. Examination of the rather different situation elsewhere, however, supports the same interpretation of the interdependence of the industry and its politico-economic environment. Despite the attention long given to housing problems and system innovation in the United Kingdom, the market there remains very fragmented and the industry largely so. In municipalities small and large, "lay committees" must authorize all projects and construction methods. Companies must sit before each public authority to discuss possible access to a job that is usually small or discontinuous. When large contracts are won, the local authority may not comprehend the projected system, speed and seldom assembles, clears and releases the land in time: thus many system jobs are delayed. The much-discussed "consortia" grouping of municipalities has rarely been put into effective practice—the recent scheme of the Yorkshire Development Group is one laudable exception. Several such large package jobs are allowing full-flow production with techniques approaching total systems, with control of all supply inputs, to very good effect. Otherwise, the scores of partial systems that have sprung from builders and architects are vying for scattered small projects, with their shops running at half capacity or less.

Production Requires Producers

The successful total system building ventures in Northern Europe are generally the creation of heavy engineering contractors, not of normal builders or architects and seldom of materials groups. They have come from large concerns who can contribute the management, capital, planning and technical forces required for the mammoth job of housing production. Having little intimacy with the local, fragmented building world of authorities, distribution chains, crafts, design professions and the legal mystiques of land, they tend to see the business as a simple matter of: "Housing for the millions means housing by the millions".

These ventures reflect a philosophy that may still be surprising in the building business but is a first principle in any serious mass production industry: one interest—the producer—must control all input to create the desired finished product. In Scandinavia the producer fits comfortably into the scale of the other forces behind housing: the large client, along with the state's interest and controls; the comprehensive consulting organization, which sometimes is united with or is the producer; and the comprehensive industrial union. Quite often the most exemplary jobs are executed as "Totalkontract" schemes, which are something akin to "package deals". The producer assembles and develops the land and produces the housing complexes offering the client the desired program of design, place, time, quality and price.

The scale of these enterprises is not altogether alien to Canadian contracting. A factory producing over 1,000 units a year, 2,000 if on double shift, costs in the order of $1,200,000. Site equipment to match the factory's double shift, erecting on site on one shift, would cost about the same, so that the investment is over $3,000,000. The roadbuilders and dambuilders of Canada often have more than this investment in plant.

The producer owns the concrete factory and offers the complete building structure as a fairly flexible closed or semiclosed system, as described earlier. Design freedom is quite broad, especially on large projects. The producer may also make all services and the modular prefinished "interior systems". More often he will co-ordinate and buy such interior systems from the several advanced manufacturers who now serve most of Scandinavia. These offer "open" or "catalogue" kits of remarkable quality, finish and precision. The producer is free to form flexible layouts confident that their precision matches the structure's accuracy: tight runs of 40 ft. of combination partitions and cabinetry were seen to fit against precast crosswalls within an end tolerance of several millimeters. This is not academic, it is done.

Such control can be traced back with the interior systems themselves to certain small-house prefabrication ventures in Scandinavia begun two decades ago. These established that wood house components can be precise and prefinished with revealed joints and no on-site cover-up, whether the components form final structure or quality cabinetry. Such developments have extended through the interiors of multi-family housing blocks and now include complete exterior wall systems as well. As the large producers are free to choose any materials, on a cost/performance basis within a rational building code milieu, it is now common to find prefinished wood frame walls (incorporating various noncombustible skins) enclosing system buildings low and high. The component suppliers offer such choices with assurance of tight control of quality and delivery scheduling; the producer pulls all these capabilities into the total system.

All Men in All Seasons

Four attributes can now be seen in many fast-paced total system projects that together give a healthy tone to the building process: (1) most of the men are reasonably free to work at a wide range of tasks and receive quick training to fit man and task; (2) the working conditions, safety aspects and amenities are very good; (3) system "close-in" and protective measures can keep both materials and men in comfortable order in all seasons; (4) the morale and pride of labour reflects the foregoing—and results in more houses, well produced.

The first attribute is one of the significant by-products of the accommodation between organized labour and equally-organized industry in Scandinavia. Comprehensive industrial-type unions can cover the total system building scene, factory and field, with nothing to gain (and much to lose) from fighting for narrow definition or protection of "craft" interest. Furthermore, the very simplicity of the precise, dry, large-part systems encourages the rational use of men. No electrician can argue that his skills are necessary to set in place a 5-ton floor panel because it contains one ceiling outlet. The on-site trades are becoming "assemblers" or general "monteurs."

Because the building as an end product is the interest and responsibility of the one party, the producer, the interaction of all job factors is seen and understood. Management as much as labour knows the benefits of good site offices, cafeterias, locker rooms and facilities, and even clothing design. The comprehensive union sits down with management in the project planning stages and helps professionally with the feasibility assessments, incentive and piece-rate schemes, and even the project schedule and the "learning curve" allowances.

Job roads are completed and preventive maintenance schedules set up so that delays or equipment breakdowns are no longer a critical part of the scene. The large-panel systems now close in quickly and in the winter the heating lines and radiators can be hooked up as each floor is erected. Each storey can then be heated to allow grouting or patching to go ahead. Oil fired construction heaters feature flexible exhaust and intake ducts so that the interior air remains harmless to man and mortar. Except for the interference of high winds with panel "montage" (and this is being resolved) the work runs smoothly in most weather conditions. More than half the labour is done in the heated factories and shops in any case, and this fits the tacit policy assumption found in Northern Europe: the preference and evolution of labour is toward indoor working conditions.

And in Canada

The mounting need for urban housing will continue to encourage the trend to multi-family complexes. At the same time, some of the European pattern of political-economic encouragement of low-cost housing, rational land assembly and production continuity is beginning to appear here. Still well ahead of such forces is the industry's increasing correction of its fragmentation: the leading housing and office complexes downtown or in suburbs or "New Towns" are quite normally creations of single interests, the developer-builder-owners. Certainly among these active groups there is no aversion to the "package" philosophy: the advantages of the "totalkontract" approach are fully appreciated. The coordination of all inputs—including design—is the basis of any true industry.

Well pleased with the year-round effectiveness of patrial factory systems in single family housing, such larger forces across Canada are now assessing the multi-family system successes in Northern Europe. Organized labour is also becoming conversant with the need for industrial union coverage of the evolving building industry. Already such comprehensive factory-field arrangements have been set up with precast concrete producers. Evident too is a stronger appreciation of the need for unifomity of building codes to allow the evolution of healthy national or at least regional enterprises. While still obscured by the traditional local, fragmented interactions between clients, builders, suppliers, crafts, design professions and land and legal interests, the potential inherent in the total system approach is better perceived and the industry is responding.

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