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A SYSTEM-BUILDING DESIGN PHILOSOPHY[1]

by

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THE BASIC PHILOSOPHY

A designer must work as a member of a team in building a home, a complete dwelling, as the best compromise between apparently conflicting interests - price, quality, materials, man-hours, speed of erection, functional requirements, useful space, sociological requirements, maintenance, rent,aesthetics, etc. All these interests overlap.

In an industrialized country it seems logical to try to solve the housing problem by pre-fabrication, and organized and well-planned schedules, with a high degree of industrialization based upon continuity and repetition.

Continuity is basically a political problem, whereas

repetition is basically one of design philosophy.

A philosophy of design for precast concrete structures has no value when considered in isolation. (Concrete is by the way only one of several means of achieving a defined aim, the complete home). The structure of precast floors and walls, although representing only perhaps 20 per cent of the total expenditure is the basis for the industrialization of the complete home, and it is this complete home that must govern the philosophy of design.

Dry, fast, accurate and well-timed erection methods create opportunities for manufacture, supply and installation of pre-finished components, such as bathrooms, facades, prefinished kitchens, doors, floors, and units of every kind.

The most important requirements for industrialization are detailed planning and organization and a deliberate standardization and co-ordination of orders for building components. This can be achieved by voluntary liaison between clients, establishing the big schemes and the continuity - if not the Government is forced to use its economical power to achieve the co-ordination.

The savings are illustrated by a few examples from Danish experience, see table 1 and 2:

Man-hours for all factory and site operations in 1970 are 50 per cent of the man-hours spent on a traditional block as constructed by 1950 methods (bricks). The figure is 25 per cent for site-labour - and the man-hours for skilled labour have been reduced to 15 per cent within a decade (the figures have been adjusted for price index, size, and quality).

MAN-HOURS PER FLAT

TABLE 1

TOTAL EXPENDITURE	Factory	On site	Total
TRADITIONAL FLATS, 1950 (Bricks, in situ concrete)	300	1400	1700
INDUSTRIALIZED FLATS, 1970	450	400	850

ON-SITE OPERATIONS (Average from many schemes)	Skilled (Trade)	Unskilled and Semi-skilled	Total
TRADITIONAL FLATS, 1950 (Bricks, in situ concrete)	1000	400	1400
COMPOSITE STRUCTURES (Bricks, floor elements)	600	300	900
INDUSTRIALIZED FLATS, 1960	250	250	500
INDUSTRIALIZED FLATS, 1970 (4 flats per day)	180	190	x) 370

x) MAN-HOURS PER FLAT ON SITE MAY BE SUBDIVIDED AS FOLLOWS:

Erection, jointing	120
Sanitation, plumbing, etc.	25
Electricity	35
Paint, joinery	135
Total above basement	315
Foundation, basements air-raid shelters, etc.	40-70
Total approx.	370

The figures include idle time, but exclude laundries, boiler house, public sewers,and landscaping.

BREAK-DOWN OF COSTS (EXAMPLE) TABLE 2

Foundation, basement, air-raid shelters, box-rooms			12%
Structure, components supplied			
	floors	7%	
	walls	6%	
	gables	2%	
	facades	11%	
	stairs	1%	
	balconies	5%	
	light partitions	1%	33%
Structure, erection, jointing			
	floors, walls, gables	5%	
	facades, balconies	2%	
	light partitions	1%	8%
Roof			4%
Water, heating, sanitary installations, etc.			7%
Ventilation			1%
Electricity, TV aerial			3%
Flooring			6%
Joinery	kitchen	5%	
	wardrobes	3%	
	doors	3%	
	skirtings	2%	13%
Paint, etc.			2%
Refrigerator, cooker, etc.			5%
Heating mains, boiler house, laundry			4%
Miscellaneous			2%
Total			100%

Traditional pre-cut kitchen furniture, delivered, installed, adjusted, cut to size, furnished with cover strips and painted three times on site, was substituted by pre-finished, factory-made furniture, mechanically sprayed to give a finish of far higher quality and better value. The furniture was delivered and installed (the latter being a simple moving-in or hanging on a wall) at the original delivery cost - a total saving of all the traditional site expenditure, to say nothing of the saving in labour (90 per cent with improved quality into the bargain).

Structure and Finishing, Conflicting Functions

The general trend is the transfer of the labour from site to factory.

Components tend to separate into two groups:

Firstly, rather simple, highly industrialized components delivered either to assembly factories (examples: standard reinforcement, etc.) or directly to the site (examples: simple precast components such as floors and walls, pre-finished doors, joinery, etc.); they fulfill one (two) function(s).

Secondly, sophisticated components manufactured perhaps by less highly mechanized methods, but nevertheless well-planned and designed for repetitive use on many schemes (examples: complete bathrooms, precast facades); they fulfill a number of functions.

Separation of functions, and of the corresponding components, allows each contractor to provide a variety of layouts even though he has only a limited range of components to choose from.

Standardization

My remarks so far apply to any component, not just to precast concrete components. The investment in plant must be matched by public and private efforts to achieve dimensional co-ordination and standardization, by a country, a group of manufacturers (or customers), a builder or within a scheme.

The degree of standardization found in European countries (the term includes dimensional co-ordination, the use of modules and the private efforts of a factory) ranges from virtually nothing to projects for building thousands of identical dwellings; this is particularly noticeable as one travels from south to east. The best solution may well lie somewhere in between these extremes.

Standardization may be based upon a combination of the desire for efficiency and the wish for independence between design and manufacture, so that a given scheme when designed may be offered for tender to several contractors. The reasons for this include a belief in the value of competitive building and a realization that a simplified design will simultaneously be valid for more than one site, or that components for different schemes may be manufactured on the same production line.

Alternatively, private "standardization" may try to achieve the basis for a limited variation in manufacture, so that factories can rationalize by concentrating on a few layouts.

Standardization may be based upon a national standard, or may be the result of private initiative within a group or groups of companies. Possible means of achieving standardization are listed below:

Dimensional co-ordination, of which

Modular co-ordination is a sub-division.

Danish examples are: The co-ordination of kitchen joinery, cookers, and refrigerators on a 10 cm module (see figure 5), and the structural planning grid for floor and wall components (see figure 1).

Standards (including specifications, quality gradings and codes) for preferred dimensions, qualities, requirements of specified units (stairs, refrigerators, electrical switches, etc.) or for materials.

That the storey height should be the same throughout a country is too obvious an example of standardization - or is it ?

Functional requirements in building codes, etc. These are far more useful than conservative specifications of approved elements.

Benefits of Standardization

Easier design, by reason of speed, savings in man-hours, elimination of unnecessary choices and the general application of a sense of discipline which may also simplify the design or items not directly related to the standard system.

Easier manufacture, using a simplified manufacturing programme, a limited number of possible variants, an opportunity for rationalization by means of a higher degree of repetition of each operation, although in the manufacture of a component, each individual operation may be combined with others in different patterns.

Easier erection and completion by the repeated use of specialized equipment and the resulting absence of running-in problems. Also, of course, a saving in human effort or thought (workmanship, speed, understanding, control, making good).

Each country must find its own compromise between the most efficient scheme of construction (all flats identical) and a certain flexibility, allowing individuals the dwelling they want. Certain types of dwelling, or certain regions of a country, may provide a natural basis for a few standards defining layouts, production schedules or even the complete home.

Generally, a standard system must aim at the simplification of a product, in such a way that mass production is feasible but flexibility is still possible.

Some countries have used quite some time on useless discussions on open versus closed systems. They are usually almost alike. The definitions are also rather vague.

In a closed system a structure of a given geometry allows for a (very) limited number of layouts. In an open system, any layout within the discipline (usually a structural grid) may be feasible. (Compare standard-layout and multi-layout systems below.)

No contractor yet, as far as I know, is big enough to have a refrigerator manufactured specially for his own system; but a good refrigerator, mass-produced, low-priced, is bought by many builders and installed as part of the house. It follows that the discussion of open versus closed systems is of limited value. Apart from the question of flexible versus rigid layout geometry (upon which depends the amount of variation in the production programme for some, but not all, precast units), the problems and benefits of both systems are the same.

Both systems are primarily customers for the same basic materials and both supply the same components, even possibly installing the same mass-produced plastic bath rooms, based upon a public or company standard. An organization covering everything from the preliminary design to the final tenancy have the obvious advantage of complete planning, and have a good chance of achieving repetition (if not of the identical layouts then of the organizational pattern).

Finished and Unfinished Systems

A distinction between finished and unfinished systems - that is, between systems that specify every detail of the building and those that do not - is of importance. A system based upon a factory making precast units may be unfinished if it does not cover the completion of the house, whereas an organization , not producing anything itself, but conforming to a strict organizational pattern (and to a planned purchase of precast units as part of the total acquisition of all components), may be a finished system. As already stated on page 2, the most important requirements for industrialization are detailed planning and organization, and a deliberate standardization and co-ordination of orders for building components. The structure of precast floors and walls, although representing only perhaps 20 per cent of the total expenditure is the basis for the industrialization: Dry, fast, accurate, and well-timed erection methods create opportunities for manufacture, supply,and installation of prefinished components and units of every kind. A convincing overall economy is the result. The tool is a finished-system-pattern, probably set up by a client or a manufacturer.

Teamwork

One may argue that all this has nothing to do with design philosophy. Yet the design must fit in, and the designer must fit in, possibly as a paid employee, possibly as the organizer.

The above reasoning is not an attempt to confuse the issue. We are talking of industrial design where the architect, the consulting engineer,and the contractor, in the traditional sense of these works, play relatively minor roles. Organizers and planners are the key people. The aim is to provide complete homes of optimum quality and quantity, ideal from not only a financial, but a human point of view.

We are so good at planning and mass-production that housing may be geared to the industry, not to the human beings living in the completed home.

The key-man in the planning must be the tenant, possibly represented by sociologists, psycologists, architects, etc., with industrialization as a tool, not the aim.

PRECAST COMPONENTS AND SYSTEM BUILDING

How does the above apply to the design of precast components, taking into account the joints, the means of erection, and the relationship between components, possibly under the discipline of some kind of system ? What about important problems such as tolerances, demoulding techniques, and erection methods ? The design must respect these requirements.

Gearing of Design to Production

Design must be geared to production. This is easier if the client has appointed - before the design begins - one contractor with a well-established technique. If the builder is his own designer, the problem is simplified, becoming one of co-ordination and feed back. The gearing of design to production is a more complex problem if the result of the design is to be submitted for open tender. The designer must then choose between the following alternatives:

(1) He can make a sketchy design and leave the execution of the complete design - by himself or by the chosen contractor - untill after the selection among the tendering contractors. In this situation the tender is based upon guesses and uncertainties, and so is the selection.

(2) He may design according to the descipline of a system or manufacturing technique known to him. If so, the tendering is unfair to the other systems.

(3) Finally, he may design according to his own ideas which may provoke the industry into creating something new and better (if he is a good designer), but more likely will simply lead to the tendering of too high prices or the submission of alternative designs, whereupon the poor client is again faced with the difficult task of choosing between many uncertain prices and qualities.

Generally, the design is based upon a general knowledge of the possible techniques and aims at something capable of being considered by any of the tendering contractors. If the degree of standardization in the relevant field is high, this may be possible. However, all tenders from any system will be slightly higher than necessary, for the design of certain items will not conform to the production techniques; a revised design, adapted to the selected contractor's methods is necessary. This should slightly reduce the price, especially with very fair contractors (unless the bid was already based upon the assumption that, after selection, the design would be modified to facilitate production).

The Pre-Selected Contractor

The most efficient design, and the lowest price, generally occur when the design has been carried out with a particular technique in mind.

The disadvantage of trying to design to one system - whether or not the designer and the contractor are independent - is the possibility of conservatism. New techniques may be introduced more reluctantly if the conflict of ideas between designers and manufacturers does not take place. On the other hand, competition will generally force the contractor to improve his techniques continuously. So will the public and private exchange of ideas and experience in committees, working groups, etc.

This need for innovation also influences the design philosophy. Even the most closed system must be flexible. Nobody can afford to invest in a technique that is rigid in every detail. Development is so fast that, even if a given system is years ahead of its competitors when established, it will be well behind in five years' time. Such a system may shock and prove unacceptable or expensive, because of the need for investment, when fresh; ten years later it will again prove too expensive or unacceptable because it is outdated. Flexibility, that is the inclusion of opportunities for innovation, must be based upon a clever forecast of the future.

Development, too, is quite often not continuous, but based upon a daring jump ahead. A hard life for designers, manufacturers, and investors, but a challenging one.

Types of Organization

It is possible, from the factory's point of view, to distinguish between five different types of organization. They may be defined as follows:

(A) The supplier. A factory produces concrete units for the open market. The factory is a supplier, a sub-contractor, and must base its production either on what is wanted or on a discipline which may be an official standard, a modular co-ordination standard or a factory standard.

The supplier must always conpete with others. He has no influence on the overall design philosophy, and may not even influence that of his own product. The contracts too are in other hands, with the result that he has no decesive influence on the continuity of his own production. An investment in highly mechanized production, involving high depreciation costs, is risky unless the market is very stable and the supplier very sure of his own capacity for innovation. This very "open" type of organization is advantageous for all concerned, so long as there exists bodies well qualified to plan and organize schemes involving a high degree of continuity and repetition, i.e. the supplier is dependent upon political decisions.

(E) The multi-layout system. Factory production and site erection are carried out by the same company or by a group of more or less formally collaborating companies. The system controls everything from the first manufactured unit to the complete structure, including possibly and preferably, the finishing as well. The system controls design either by the issue of a manual or by the inclusion of the design group in the system. Production is probably based upon dimensional co-ordination, modules, and standards and, as in A, is prepared to deliver to many sites with different layouts. The clients are offered a large variety of layout - or even any layout within the discipline.

This arrangement allows access to more clients, more schemes and a bigger share of the market. On the other hand, in circumstances of simultaneous and rather rapid change in a number of layouts - the change can be too rapid - an adaptable discipline and a sophisticated organization are needed. One risks being forced to accept somewhat undisciplined solutions (the system, after all, advertises its flexibility), which often results in less discipline on the next scheme. Furthermore, the repetitive use of standard units combined with flexibility in a variety of layouts, is counteracted by the necessary compromise between the structural units and the services, facades, etc.

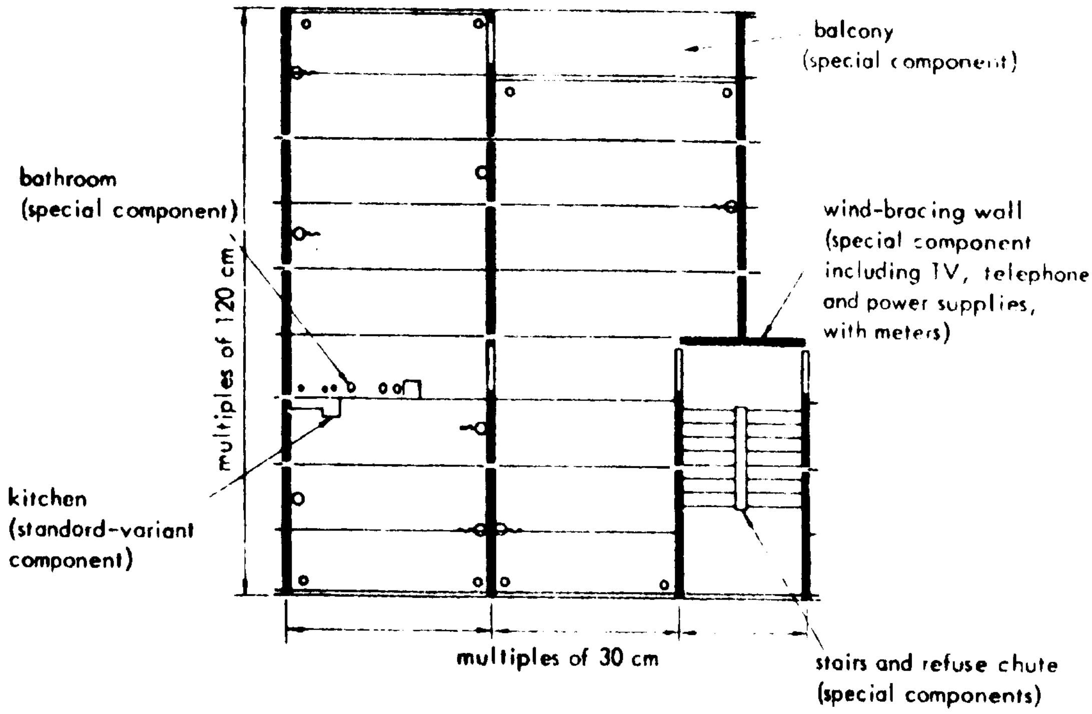


FIGURE 1. Modular system for a 2.5 ton multi-layout system. The system uses a 30 x 120 cm structural grid, load-bearing cross-walls and a structurally independent facade. Maximum use is made of simple components with standardization of "specials". Bathrooms are identical in all flats. Kitchens are fitted with standard joinery and include a standard plumbing-ventilation unit housed in a standard recess. (See figure 5).

The standard bathroom and kitchen are separated to allow maximum freedom in planning.

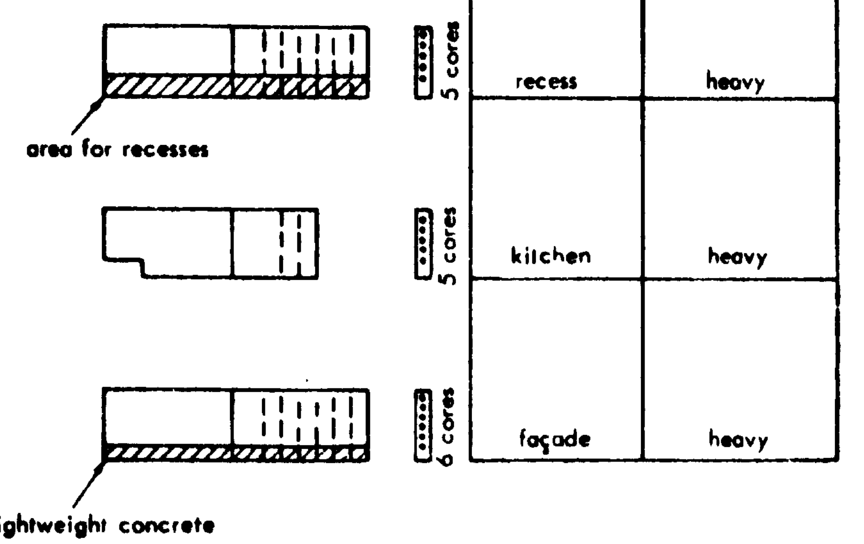


FIGURE 2. Standard floors for a 2.5 ton multi-layout system (16 per flat). Bathroom floors, stairs and balconies are special units (4 per flat).

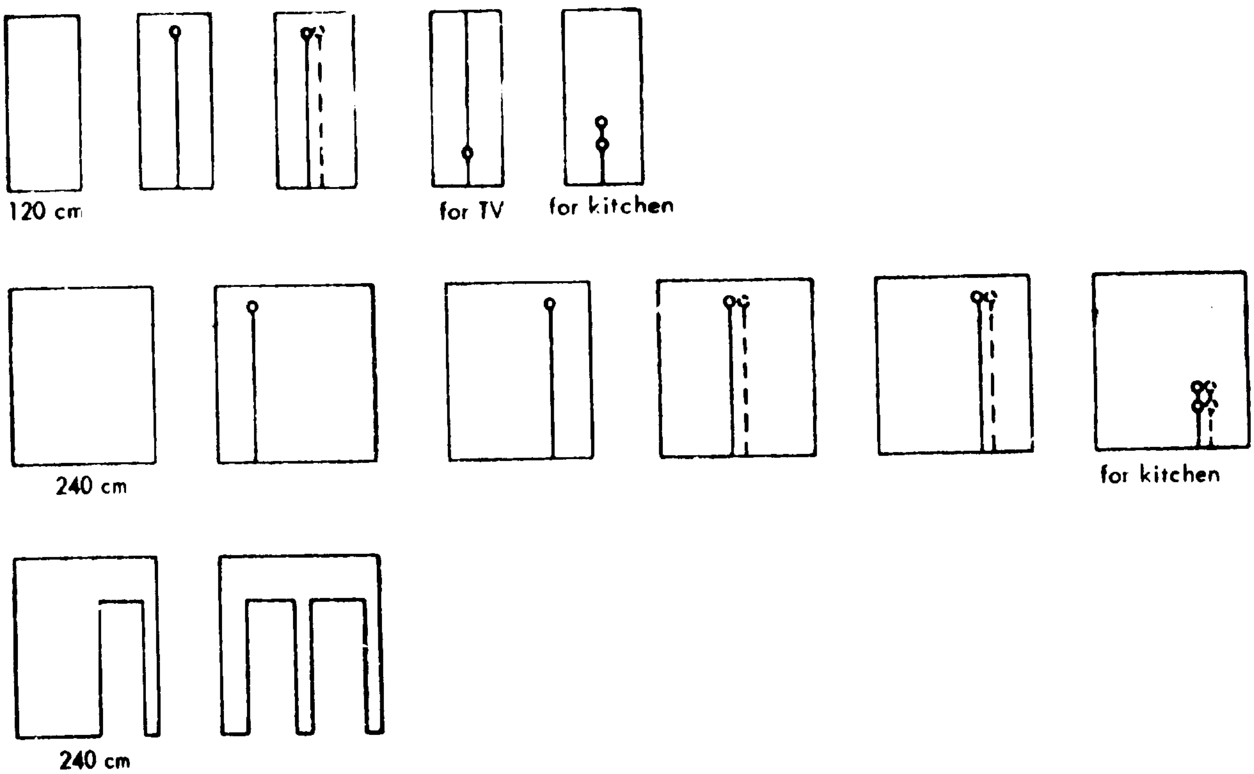


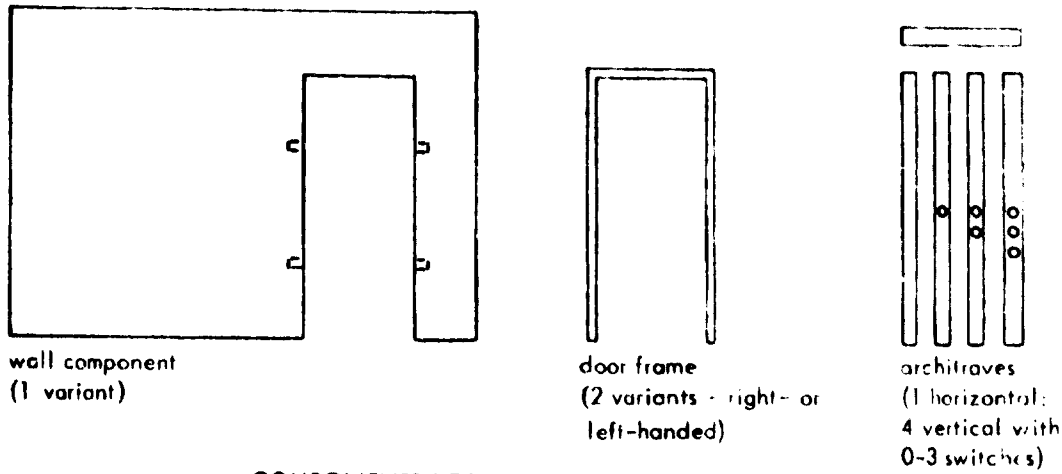
FIGURE 3. Standard walls for a 2.5 ton multi-layout (11 per flat). Electrical outlets and door openings are shown. Wind-bracing walls are special units (½ per flat).

A similar 5 ton system could be based upon 240 and 360 cm walls with the same flexibility in planning.

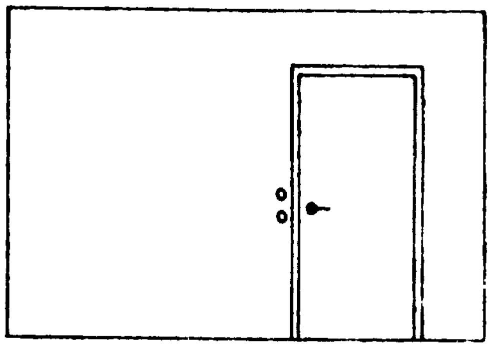
The Simple Units. The repetition so vital for mass production may easily be applied to identical or almost identical precast components by means of dimensional co-ordination, possibly using a modular system (see figures 1, 2, 3). From the remaining precast units, the factory must either face an inefficient production of different components in small numbers or must standardize the possible variations in services, etc. (Figures 4 and 5).

The Complex Unit. From this a conclusion may be drawn which will apply to almost any kind of system: if a certain unit must necessarily be designed as a more complex unit than usual, it may well be taken off the high-efficiency production line and produced by a special technique. If so, as many special functions as possible should be placed within the geometry of this already complex unit, so that the other units remain simple. For systems with very large units the technique may be based upon the assumption that all components will be equally complex.

The services, like the structural units, have to conform to a system. This is a virtue from the point of view of the suppliers of service units, bathrooms, facades, etc. However, if the services are cast into the structural units, the number of "variants" and "specials" in the structural "system" as well as in the service"systems" tend to increase rapidly with the use of the possibilities within a multi-layout system.



COMPONENTS FOR MULTI-LAYOUT SYSTEM



PRE-SELECTED COMBINATION FOR STANDARD LAYOUT SYSTEM

FIGURE 4. Wall unit with single door opening. (Example of separation of functions.) In a multi-layout system the components are supplied to the site separately and can be combined in the nearly 200 ways an actual design process may require. In a standard layout system the unit is supplied with a pre-selected combination of the parts.

Separation of Functions. A cleverly planned separation of each of the conflicting functions may maintain flexibility and at the same time offer a number of different specializing suppliers an opportunity to mass-produce special parts, or components, such as bathrooms or facades. Mass-production of these components could be carried out by several contractors working to several systems, although a clear understanding of the system by the suppliers is essential.

The multi-layout system does offer the market a degree of flexibility, thereby possibly ensuring for itself a regular stream of orders and continuity of production.

(C) The Standard-Layout System. Basically, this system is not very different from the multi-layout system. Most standard layout systems offer in practice a variety of layouts within a given geometry. Layouts are revised every now and then to meet new requirements. Components for services, facades, joinery, etc., identical to those used in multi-layout systems are bought from suppliers.

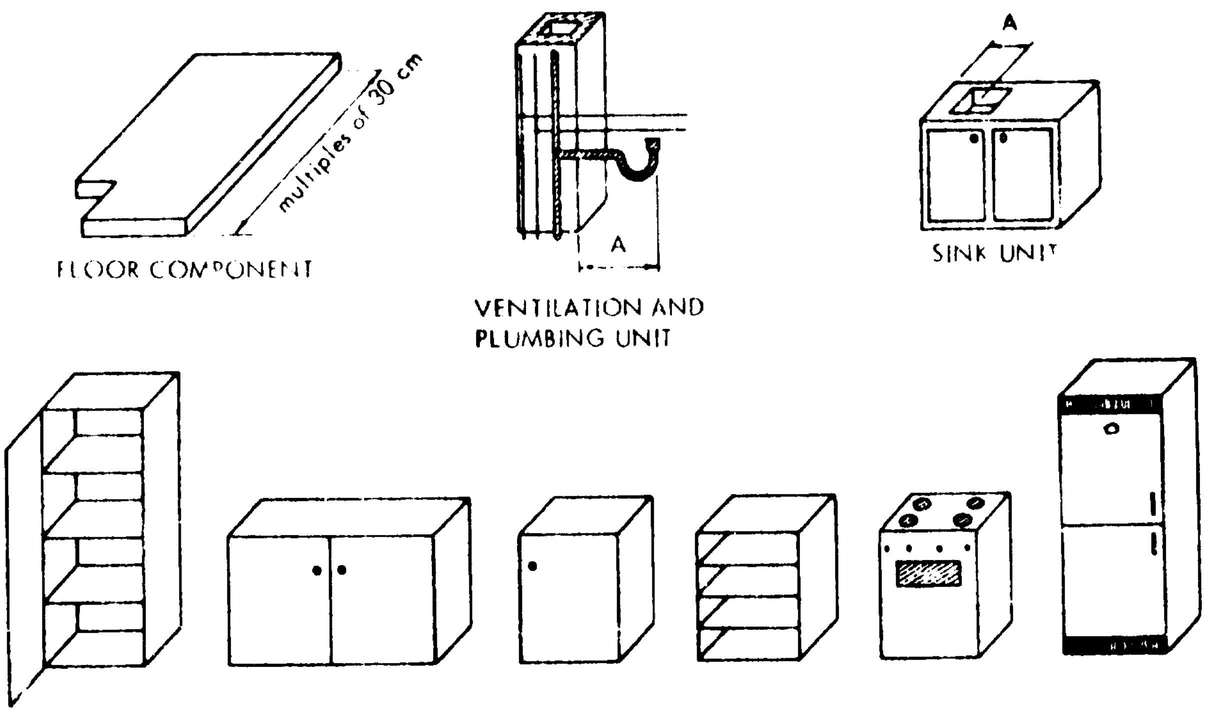


FIGURE 5. Kitchen units and fittings. (Example of separation of functions.) Each of the three units at the top of the figure can be either right- or left-handed. The ventilation and plumbing unit can be combined with the floor unit to give four different positions of the sink unit around each floor joint.

The fittings in the lower half of the figure are co-ordinated dimensionally, yet separated functionally. This enables them to be arranged in an almost unlimited number of different ways. (Example of a 10 cm module used in Scandinavia.)

Because of the limited range of layouts, and the geometrical discipline, the variations in a standard layout system are limited. The system can provide orders for a continuous production of a number of absolutely identical "specials", or else it can be adapted to the "best buy" from the established range on the market. Its own precast units and erection techniques can be designed with the utmost efficiency in mind. Even complicated units can be repeated, thus making the rationalization of comple components possible. Everything is geared to the limited range of layouts.

The disadvantage may lie in the marketing. How many identical homes can one sell ? Slight variations in design, especially in the design of facades, may make the same thing look different in the customer's eyes. The more this is done to please the customers, the more closely does a standard layout system become a multi-layout system.

The market trend is definitely in favour of standard layout systems in a form similar to that of marketing of automobiles: A revised model is offered at regular intervals (say 3-5 years), quite often with an overlapping period between the models.

However, more complex schemes, e.g. blocks with bigger balconies, sculptural facades, variations in number of stories, terraces, internal access areas, integrated social facilities, etc., etc., are now under construction in various regions as a result of criticism of a previous "over-rationalized" uniformity, and a demand for homes more in line with modern sociological thinking. Apparently, this will favour multi-layout systems. In practice, all Danish systems at present offer complex scheme facilities as well as streamlined low-cost but high quality "models" for blocks of flats. Component sizes are increasing as a result of economic analysis of new technology. With increasing size the number of cast-in "extras" such as doors, electrical outlets, brackets for facades, recesses for adjoining walls, etc., increase in each unit - they are now "specials", useful only in the given layout.

(D) The Box System. This can be regarded as an extension of the standard layout system, but there are certain differences. The layouts are here governed by a strict discipline as all the boxes must fit together, and as the number of different box-sizes must be limited; the sizes of rooms are thus strictly standardized to one, two (or three) boxes.

The system represents a very logical approach, as the room is completed in the factory. Site labour is at a minimum. The disadvantages are, amongst other things, production costs, factory area (huge components, taking up a great deal of space during the curing time), transport costs (possibly high due to transport regulations); finally, the limited choice of layout may be contrary to the customer's wishes. However, Habitat 67 (Montreal) and some U.S. "Breakthrough Programme" systems are complex box systems, initially very costly, but possibly reasonable when under strict control of "disciplined flexibility".

Internal Flexibility

Recently, the planners have asked for the possibility of rearranging the layout by moving light walls.

Thus, the home can be adjusted to meet different requirements when children are born - or leave the home.

Box-systems are out, if one asks for flexibility. Load-bearing wall-systems are not too good either.

Column-slab-systems, and beam-column-systems are good, but also costly, possibly increasing the price of the structure by 50 per cent, i.e. the total costs by 10-15 per cent.

Each type of system offers possibilities for continuity and repetition, and market conditions are critical. The more flexibility a country wants, and can afford, the less likely it is to adopt standard layout systems or box systems.

ADAPTATION OF A SYSTEM IN A DEVELOPING COUNTRY

The paper deals with a Scandinavian approach to design, which may not apply to other countries, although the philosophy as such is of a general nature.

The necessity of industrialization is in Scandinavia due to a housing shortage that cannot be overcome by traditional methods, as the necessary labour is not available. An outer sign of this labour shortage is sharply rising wages.

Other countries have developed highly productive construction methods for other reasons. Some countries in Asia and Africa are, at present, developing prefabrication of housing, as production in factories gives far better quality and control with the product. If the labour has little training, is unskilled, industrialization gives a faster way of recruiting building workers. Each man shall be trained to repeat simple processes, there is no need to teach him a craft.

Some countries are taking up industrialization for political reasons. Machinery is the only way, if the Government wants homes fast as part of the transition into a modern state.

The general reason - in all countries - for industrialization is the increased output in housing-construction.

This did not say that industrialization always means precast concrete or organizational patterns like the Scandinavian ones described in the paper. The thinking - the philosophy - of the paper may be adopted. The methods must be adapted. Furthermore, the Scandinavian countries have a well-developed, long established, high quality industry for many building parts as prefinished windows, doors, kitchens, etc.

Thus, the process of industrializing the building industry concentrated on setting up factories for prefabricated structures as precast concrete elements (and timber-framed room-sized units for single-storey houses), whereas the completion of the home was regarded as the organizational problem of using the fast, dry, accurate structure as the basis for well-planned and well-timed delivery and installation of prefinished parts.

Steel and aluminium, quite obvious materials for fast erection in other countries, were too expensive. Plastics are coming, but it is a new field, still with dubious features and little experience.

The best compromise based upon local conditions can only be found by careful analysis of available labour, investments, traditions, needs, and requirements.

Therefore, the choice of system must be made under a teamwork with participation of clients, architects, engineers, the Government, etc. Analogous conclusions can be drawn from the experience stated in the paper - and much know-how and experience can be transferred and adjusted.

Most systems are so much alike in a number of processes that it is almost impossible to distinguish between them. They are - if good - based upon know-how and experience and brains capable of finding the optimum under given circumstances, an approach without preconceived ideas, ending up with local variants of a general philosophy, a system with built-in prerequisites to development and expansion, whether the starting point is mechanized or not.

It may for example be said that Danish systems now operate in more than 20 countries in all parts of the world. How different are these systems from French or Russian systems ? or from any other system ? But the "systems" are very different in the various countries.

Heat-insulation and double glazing as well as bracingwalls for seismic forces are simple, outer signs of particular local conditions.

Planning, rationalization and factory-organization will be useful in all countries. The degree of mechanization must be decided upon in relation to available materials, the technology, the industrial tradition and maybe in relation to the efficiency, skill and wages of the available labour.

Cost-Analysis ?

It may be possible to summarize the above reasoning by a naïve formula, introducing some of the basic parameters in the pricing-process of a prefabricated component.

I assume that the prerequisites to industrialized housing are established (or under way), i.e.

A nation-wide uniform building-code, based upon functional requirements.

A system of dimensional coordination, including modular coordination.

A long-term building- and housing-policy formulated by the parliament, including financing and quality-definitions.

A labour-policy, including training-programmes.

A town-planning and development policy geared to the possible general industrial development of the country.

An established design-contracting pattern for the planning and execution of repetitive housing schemes.

The development policy is especially crucial as the available (economical) resources within the country are interdependent. The success of the heavy industry or of the export sector will often be considered a prerequisite to expansion in housing: The industry must provide a surplus before better housing is launched, although good industries require good labour with acceptable home-conditions, i.e. good housing among other things.

Therefore, town-plan-decisions (low- or high-rise, sewers, roads, etc.) combined with labour-policies (what kind of industries should mechanize first, when is the building industry to follow, etc.) are very important factors to have analysed before the risks of investing in a new building industry are undertaken.

Furthermore, it is of prime importance to analyse the total costs of a final product - that is the completed home in order to find an optimum on a national basis and/or for the total (series of) scheme(s).

Cost-break-downs are possibly of interest for the cost-plan and for the quantity-surveyors, but the actual price of a specified component has no interest except as part of the total costs. Savings in one field may save in another; complex units, having several functions, cannot be compared with traditional constructions, combining functions in a different way; etc., etc.

The total costs may be evaluated in money (per home or square-meter), taking quality into account, or may be evaluated from a national viewpoint, i.e. compared with the available resources of (skilled/unskilled) man-power and/or capital and/or new materials.

The total costs have two aspects, the building costs (the investment) and the running costs (tax, interest, depreciation, maintenance, repair, renewal and possibly demolition in x years). The first costs, the money due now are, unfortunately, quite often the decisive factor.

The total costs are a function of the quality (set by tradition), and quite often of the desired output (set by the need and/or the politicians), as well as of the resources.

Quality comprises floorage and technical standard, but most certainly aesthetics, environment, usefulness, and other human factors as well, so that one cannot express quality in terms of money.

Any cost-analysis is of little value, unless the human factor is taken into account. Industrializing takes some planning and capital. The design of good homes requires respect for and understanding of the human mind, which is not satisfied just by so and so many square-meters of shelter.

Still, one has to start the analysis somewhere, and having made the initial decisions, one may analyse groups of similar components separately, e.g. a series of floor components.

The Price of a Component

The unit price, P, of a component may be divided up as follows:

$$P = M + \alpha \cdot L + \beta \cdot I$$

1. M, signifying here materials, is a part of the unit price, which is almost independent of the manufacturing process, except for a possible wast, when quality and materials are specified.

   M varies with quality.

   M changes of course, together with the manufacturing process, if the use of another material is analysed.

2. α·L, signifying here labour, is a part of the unit price, and is the product of

α, an efficiency-factor

and L, proportional to the wages.

α expresses the degree of organization, planning, the use of auxiliary tools, the avoidance of idle time (also due to storm, rain, frost, etc.). The minimum value is $\alpha = 1$ in the best organized factory.

L is proportional to an hourly pay, or to an item in a price-rate system, as the local labour-agreement may be, and L expresses the lowest labour-unit-price in the factory.

L increases usually with increasing labour-shortage.

L is usually slightly higher for skilled than for semi-skilled and unskilled labour. The ratio of skilled and unskilled labour-wages is exceptionally high in the U.S., and many building methods are determined by union-decisions rather than by rational analysis.

L may be lower on well-organized sites without seasonal variations in employment.

A lower price may be achieved by better planning (lower α), by new methods (lower I), or by improved saleability (lower β). The output will usually increase simultaneously, and so will the profit. To increase output by employing more men may mean more shifts per day, or more machinery, or may be a result of better planning of the given process.

A craftsman is trained for 4-5 years whereas a "specialist" factory-worker may be trained in two months.

The greatest increase in output is achieved by mechanization and the use of semi-skilled factory-workers.

α·L signifies the labour costs. The product is often a constant within large geographical regions, as competition results in better planning (low α) in areas with high wages (high L), at least for products with a relatively low transport cost.

α·L is often a function of local tradition and of local sense of quality: In Europe, countries with higher private standard of living have better working conditions on the sites, with mutual respect and consideration for the work of other gangs.

Finally, the relationship between wages, output, productivity, quality, and private standard should be more closely analysed. Presumably, the industrialization of an area is speeded up if the housing standards are raised simultaneously.

3. The machinery-part of the unit price is the product of

β, an efficiency factor

and I, proportional to the ratio of the machinery costs and the maximum number of components, the factory is able to produce.

β expresses the degree of utilization of the machinery, and is usually primarily dependent upon political decisions, the stop-go policy employed to regulate national budget problems. If the government has established a long term policy, β expresses the saleability of the product, in comparison with the maximum output (which could be based upon one, two, or three shifts per day, as may be indicated by labour agreements and manufacturing methods). The minimum value is β = 1 on a very stable market.

Thus, α expresses the skill of the manufacturer, whereas β expresses the skill of the housing-policy.

I expresses the lowest possible unit price, proportional to the ratio of the machinery costs and the maximum output.

The machinery costs comprises:

Interest and depreciation (amortizing) of the capital (and manpower) invested in the machinery (and the planning),

The running costs and maintenance including the "indirect labour",

Planning,sales and other costs ensuring the lowest possible α and β (may include political activity).

4. The unit price comprises the parts 1, 2, and 3 above.

If the material is chosen, M is (almost) a constant, and the method is decided upon by analysing α•L + β•I.

L and I are not independent, as L, the wages, decreases with increasing I, machinery-investment. The capacity increases as well. Too often the effect is nil, if β increases due to lack of possibility to sell the increasing output.

The formula, α•L + β•I, illustrates the relationship between some basic parameters, where each parameter is a more or less implicit function of a number of non-predictable circumstances on the market and within government influence, such as housing-shortage, lack of man-power, capital restrictions, supply of materials, wage-levels, in relation to different unions and methods, the manufacturer's talents for organization, building policy, housing policy, etc., etc.

I, the investment etc., may be a donation to a developing country, or it may come as a loan on more or less profitable conditions of amortization (interest and depreciation). The interest level, the refundment-time, the tax and depreciation legislation as well as the maintenance and the availability of (reasonably priced) spare parts are quite decisive factors for the decision on the degree of mechanization.

However, β, is often the decisive factor. This may be illustrated by the figures presented to the "System Approach to Building" conference in Canada, 1968, by Mr. Kenneth M. Wood, Bison Wall Frame, Great Britain.

May I quote from the report, pages 68-69 and 76:

"A contractor embarks on the production of a building system with the intention of making a profit. A profit which is large enough when extended over the life of the system not only to amortize his plant and pay interest on the capital employed, but also to make a profit reasonable in relation to the effort involved. To make this possible it is essential that the manufacturer/contractor shall be able to maintain his plant output at a high average percentage of productive capacity for a long period. In very few countries it is now commercially possible to amortize a plant over the period of a single contract and it is necessary to look upon a plant manufacturing a building system as having a life similar to that of any other plant.

Table 3 gives some idea of the percentage of working capacity which must be attained to ensure adequate profitability. Although these figures are for a prefabricated concrete system they are unlikely to be very different whatever the material involved. A plant capable of producing a dwelling a day is assumed to have a full capacity of 250 dwellings a year, so that 200 dwellings a year represents 80% capacity. The chart shows that there are two items where the cost per dwelling is virtually independent of the utilization of the plant. These two, material and labour directly employed on production and erection, amount to approximately 50% of the selling price. The other items are, however, in the short term, independent of the rate of production and rise steeply as production falls. Thus, at 80% capacity one would expect to show a return of 10% on turnover, and of 20% of capital employed, at 60% there would be a loss of 3% on turnover and 4.5% on capital employed, whilst at 100% there would be a profit of 18% on turnover and 45% on capital employed. I would emphasize two things, first that profitability varies very rapidly with the throughput of work and second that labour directly employed on production and erection represents a comparatively small proportion of cost and that highly sophisticated manufacturing methods, which may reduce by a third the normal direct labour costs, will have less benefit than an increase in factory throughput. There is generally a conflict between saleability and the sort of standardization which permits a high degree of mechanization."

And later:

"making an allowance for interest on capital employed, break-even is achieved at about 70% of full capacity.

It is a fundamental principle for any manufacturer of a building system that he is unlikely to make an attractive profit unless he can maintain his factory at 80% of design capacity over a long period".

Costs as Percentage of Sales Value.

Item	Percentage plant utilization		
	60%	80%	100%
Material	35	35	35
Direct labour	15	15	15
Indirect labour Plant depreciation & maintenance *	40	30	24
Overheads, design, selling etc.	13	10	8
Profit or loss	-3	+10	+18
Selling price	100%	100%	100%
Profit expressed as percentage of capital employed	-4.5%	+20%	+45%

* Based on average life over building & plant of 6 years.

Table 3
(Presented as table 2 in Mr. Woods paper in Canada, 1968.)

An Industrialized Country

The above formula illustrates the well-known results, when an European country embarks on a housing development programme:

The shortage of skilled labour results in high wages and insufficient output. The training of craftsmen, e.g. brick-layers, takes too much time, and the results are not in the long run an improvement, as the wages are constantly increasing together with the rising standards of living. Mechanization becomes inevitable. Mechanization is followed by better working conditions and by employment without seasonal fluctuations. Mechanization means a higher output. Therefore, the country goes for mechanization, often with the government in the role as a benevolent subsidiary character. The labour is recruited from the unskilled, and a new semi-skilled trade is established. By the way, the hourly pay in the building industry is almost the same for semi-skilled as for skilled labourers, a fact of minor importance in the cost analysis, partly due to a small α (mechanized plants are well-organized), partly due to a small $\alpha \cdot A$ (mechanization). The output increases rapidly, with two consequenses: Firstly, some craftsmen (probably brick-layers) become un-employed, and as retraining creates psychological difficulties, a social problem is created. Secondly, the output of a constantly improving industry is usually under-estimated, whereupon the plants are not utilized at full capacity (B increases). The more a factory is mechanized, the more "uneconomical" it becomes in a superficial analysis (the parliaments short-cut through piles of reports). Nobody considers now the fact that a high price is due only to an insufficient utilization of a costly plant. Thus, the most advanced factories are disliked in a depression period (possibly due to a foreign exchange crisis). These pioneers may go bankrupt, in itself not a positive addition to a national crisis. However, on a short-sighted basis, the results are good: The building-industry-output is indeed reduced, and as the most mechanized factories go bankrupt the increase in un-employment is small.

Whether a developing country can find a better pattern of decision-making leading to a reasonable long-term policy of a combined development- and export-, and housing-programme, foreseeing international financial tides, I don't know. None of the established industrial countries in East or West have so far found a system that could give politicians, economists, managers of heavy and light industries, housing-contractors, and the tax-payers a common and stable and long-termed programme of development. Usually, external or internal financial problems are solved by squeezing the housing programme rather than the production of consumer goods. Of course, the impact is great and fast, and the public shall not observe the meagre outcome before it is about time to elect a man on a new housing programme with a revolutionary technology. A daring investment.

Finally, housing is decidedly a long-term investment, probably over 100 years, whereas the seat in Parliament lasts 3-5 years in most countries. In many European countries the annual output in housing is 3 to 5 per cent of the total number of dwellings.

The housing shortage is not reduced, as the extra dwellings are occupied by tenants moving from rural to urban districts, by tenants from dwellings demolished as part of new traffic systems, and by new types of tenants (single persons live now in small flats rather than in rented rooms). The surplus is max. 1 per cent. Therefore, if a real expansion in housing shall take place, the surplus must be approx. 10 per cent, which indicates that the annual output should be raised from 3-5 per cent to 12-15 per cent. An expansion with an almost unpredictable impact on the national budget, taking all consequences into account. The supply and demand market - mechanism does not work at all.

Therefore, we must comprehend that innovation and expansion in housing take time. We may mechanize to speed up matters, but the more we mechanize, the worse if market conditions change. Therefore, long-term planning is a necessity, and it is important that the politicians stick to their decisions. All over the world good factories, erected as a follow-up on government development policies, have gone bankrupt when the policy was changed.

The danger is obvious in a capitalist system with a complete separation between the governments stop-go-policy and the private investments. In a socialist system the same problem arises, but due to the centralized decision-pattern, the sad results may camouflage themselves, at least for the public. Therefore, the socialist long-term-planning, 5-year-plans and the like, is a wise way out of the dilemma, provided of course that each new 5-year-plan is announced something like 4 years in advance.

Developing Countries/System Building

The above formulas are of limited value in a non-industrialized country, and a number of corrections must be considered, together with the reservations stated above.

Building policy and housing policy is of even greater importance here, not only in quality, price, and size, but also in relation to the general development policy, the resources etc.

The proportional share of present and future national budget to be spent on housing in relation to the expanding industry (and therefore the expanding cities and growing housing shortage) is the prime decision.

The need for housing and the building capacity must be analysed, and the quality-policy must be decided upon, e.g. whether many, small, not-too-good homes fast is better than a better, more slow production-rate, and how to ensure homes, cheap to-day. yet pre-planned for easy modernization simultaneously with an industrial development.

The materials must be very carefully analysed. Traditional methods may be ripe for rationalization (pleasing the politicians) and yet prove a cul-de-sac in the long run, barring the country from taking up the newest building methods later (frustrating the technicians).

Therefore, new materials, and methods must be checked as alternatives, even on a level theoretically too advanced for the country.

However, it is worse to accept an advanced process, if qualified personel is not available, or the country is unable to make full use of the process.

A cost-benefit-analysis may give a very misleading result, if the price of the machinery is extraordinarily low as part of an assistance-programme. Quite a number of free U.S.S.R. and U.S.A. plants have come to a standstill after a short period of mass-production of a product a bit different from what the local people anticipated.

I may add that some ecologists say that civilization cannot exist due to a lack of resources and energy if all countries should achieve the degree of industrialization we find in the U.S., Europe, the U.S.S.R., and Japan. If the developing countries are to be able to raise their food and housing level, the rich countries must stop their expansion and give up the economy of waste, with technical gadgets, and pollution as signs of technological welfare. If/as this is true, the above reasoning is partly wrong, and any industry becomes part of an international pattern of ecological problems.

Within the lifetime of a building, say 50-100 years, we shall certainly get some international supervision of the use of resources and the corresponding pollution by the industries. Therefore, the idea of making a flexible house, in order to facilitate innovation, is dubious unless the planning looks far ahead.

Anyway, I do not recommend evolution, but revolution in the housing field. I have stated that some of the best - the most industrialized - participants may be so vulnerable that they go bankrupt (some of the best will usually die during a revolution). The development in Denmark shows several technological revolutions, such as the direct shift from brickwork to precast concrete in 1950, the drastic reduction in manpower by the 1960 mechanization, and the reaction to monotony represented by Brøndby Strand in 1970 (a Danish "Habitat 67").

The lesson could be that a building industry should be innovated every now and then through technological forecasts of an almost demagogic nature, so that the innovator aims high even when his actual machinery takes a rather pragmatic shape.

In short, use the present technology, but in a way that may train you and your staff for an easy shift to a more mechanized production. That is why I prefer primitive cast in situ concrete or traditional timberconstruction to brickwork: You will never mechanize bricklaying but you could mecharize concrete- or timber-constructions.

The brickindustry may be rationalized, but probably not with an increase in output sufficiently high to solve the housing shortage. The skill required would mean training a number of men for many years. In the long run the process will be outdated.

Concrete-blocks (or blocks of similar materials, such as laterite) may look similar to bricks, yet they are easier to handle for a semi-skilled (or even a lay man, making his own home), and a carefully planned concrete-block production may develop into a precasting industry.

Timber-construction could follow a similar development pattern. Sweden, Finland, Canada, and the U.S. have highly mechanized timber-house industries. Swedish houses go through Denmark to Germany.

Precast concrete elements is a logical way to a faster and more rational production of homes. They will usually make their first appearance in blocks of 3-4 or more storeys. The low-rise, 1-2 storeys, often individual homes, are often mechanized later, partly because they can be made by the tenant himself, partly because of the more individualized home, one is accustomed to in low-rise.

The different kinds of structural systems for industrialized building are not equal in economy, flexibility, fulfilment of functional requirements etc:

Load-bearing crosswalls (simply supported floor-slabs) is a general West-European system. It is fast, easy to erect, solves the problem of sound-insulation between flats, leaves the architect considerable freedom in the facade (light or heavy), and it is rather cheap due to the simple, relatively similar components that form the structure.

A balcony is easily installed.

With a reasonable modular planning grid (see page 11), quite a number of different layouts are feasible.

There are strong limitations on the flexibility one can offer for a later modernization stage, although facades could be renewed easily - and bath-units could be substituted through the opening (?).

The system will survive with very long spans covering even the biggest flat.

Load-bearing facades, possibly with a spine-wall, have some virtues. This system is not very much different from that of load-bearing crosswalls, seen from the manufacturer's viewpoint. The planner will find new limitations in the layout, but also more freedom in the longitudinal direction. He may even install the possibility of a later adjustment of the flat area, or the accomodation of households spreading wider than the prevalent father, mother, children prototype, such as the group-family, the collective, etc.

The facades are limited in design. Light facades are out. Windows in concrete facades must be placed in compliance with statical requirements.

In cold climates, the balconies cannot be cantilevered from the floor-slabs, as this would form a cold-bridge with un-acceptable condensation. In cold climates balconies are an extra, attached to the structure. In warm climates, the load-bearing facade-system offers cheap balconies.

Mixed-systems are common, as the wind-bracing function must be fulfilled. Both systems have some walls perpendicular to the main-system. The load-bearing crosswall-system have at least one longitudinal wind-bracing wall per two flats, often at the stair-well. The load-bearing-facade-system have bracing walls across the building, usually between flats (sound-insulation).

The bracing function could have been dealt with by bath-units.

A flat can be divided up into a number of rooms by cheap, light walls with limited sound-insulation, by more expensive, heavy (concrete) walls with sound-insulation in accordance with the requirements between flats, or by very expensive, double, light walls.

From the above reasoning, based upon European legislation on sound-insulation, one may draw some conclusions on the structural systems, taking into account the running meters of walls between flats (and around the stair-well) in comparison with the running meters of other walls necessary to divide the flat up into rooms.

a) Flats with concrete walls in both directions are statically very simple, but are very unflexible, dead against the interests of the tenants.

   With modern technology they are rather expensive.

b) Flats with load-bearing crosswalls and light walls (see page 11) are the cheapest, are statically rather simple, and are not as flexible as the tenants would like them to be, even with long spans.

c) Flats with load-bearing facades are between a) and b) in price, and are rather flexible internally, but not in the facade. Between flats could be installed either double, light walls, or (bracing) heavy walls.

d) Column-beam- as well as column-slab-systems are the most expensive but also the most flexible. The structural system costs less than a wall system, but to this one must add the light walls, plus the double light walls between flats.

Flexibility, now and especially later, means more light, double walls and a more expensive bracing system. As a matter of fact, this applies to any variant of the above systems.

Box-systems seem logical in a country with an advanced technology as the home is almost completed at the factory.

However, the components require a huge factory volume, and the transport-organization is difficult. Many roads cannot be used by trucks above the max. width 2.5 meters - and the special permit up to 3.5 meters is limited to certain roads and certain hours.

The economy has not been proved, and the system is hopeless if a reasonable flexibility is required.

Just to plan an acceptable layout is a problem within a box-discipline. If the plan is good, some of the rooms will be made up of several boxes, and consequently the boxes and their joining become complicated. Of course, one can ignore the size of a human being, and if the housing-shortage leaves him no choice, he will accept too narrow rooms, as some existing box-systems prove.

Mobile homes has all the disadvantages in planning and transport stated under box-systems. They have - in the U.S. - a reasonable economy, but the idea cannot be transferred to other countries.

The product is highly mechanized, very well organized and detailed, with a good finish, a typical industrial product. However, the economy is based partly upon the unusual high ratio in the U.S. of the wages of the building craftsman and the industrial worker, partly upon the lack of town-plan-restrictions on mobile-homes settlements. Finally, there is no real estate tax on a mobile-home!

A town-planner has, with some malice, asked whether the mobile-homes idea is not just the capitalist way of offering the worker a glittering finish on a poor layout, an environment created by the industries, deliberately avoiding most of the building legislation that apply to a house but not to a box on wheels (whether the wheels are ever used or not).

However, sociologists have stated that many people prefer low rise, which they know in the form of an individual home, but that the old "village system" probably is advantageous in offering the combination of variation, low-rise, privacy, and contact with other people, so often missing in single-house-areas as well as in high-rise.

This may indicate that the low-rise-high-density communities experimented with in many European countries is the (old) new, human way of building homes. If so, mobile homes is probably a part of the experiment as well. They are popular in the U.S., contradicting the malicious criticism, at least on the surface. In western Europe experimental low-rise-high-density-environments are usually inhabitated by people very much aware of the value of close relations between people, in general also the most politically active groups, as opposing the industrialized monotony in the precast blocks.

The low-rise-high-density-townships are possibly also more suited than any other environment for the acceptance of groups with different or new family patterns (the Turkisk labourer in Denmark, the group-family, the collective). Therefore, this "building system" must be extremely flexible.

Flexibility has been used (too) much above. It may deserve some definitions.

External flexibility is a virtue, not only from an aestethic point of view, but also from a sociological, environmental viewpoint. Too much of the industrialized housing has been monotonous, in-human in appearance, neither offering the tenant the feeling of being an individual in his identitiable home, nor offering him pleasant surroundings for contacting his neighbours.

Hence, short and long blocks, variations in orientation, the mixing of different numbers of storeys, terrace-houses blending with blocks of flats, shopping centres, kindergardens, etc., etc., within the same system is one side of the external flexibility. The other side is the "sculptural" facade, with all the variants of facades, cantilevers, columns joints, balconies, etc., etc., that may create the pleasing facade.

Internal planning flexibility means that the client can get the variation in layouts he wants. It might also mean that the tenant could influence the layout of his flat.

True internal flexibility is a rather costly extra, but gives several advantages: The client can get any layout he may want, now and later. He may modernize the house, as an example by revising the florage or number of rooms, or by installing new sanitary-units.

However, another advantage is probably of growing importance: The tenant can influence the layout of his own florage, and revise it according to the change in family size. He may add new areas, or leave some areas to his neighbour. He may feel that this is his home, not a shelter pressed upon him.

Experiments in Sweden with flats virtually just one huge area with a few columns, a bath, part of a kitchen, a pile of light walls and doors per family have shown that in some cases the most "outrageous" layouts satisfied the family that created the chaos more than the floor-plans recommended by the architect.

Finally, a true internal flexibility could create the background for a reasonable long-term-housing-policy in a country of expanding economy. The flat may just comprise a sheltered area with the absolutely necessary sanitary installations and no more.

If the tenant should feel inclined to install light walls himself, the investment in materials and labour is his own problem, possibly regarded as a saving seen from the government's viewpoint.

Alternatively, the completion could be added when public funds become available and/or when the tenants' wages can pay - in any case when the country can afford the additional quality.

A spacious flat with the quality added later is a better housing investment than the good, but too small flat.

The individual 1-storey home, based partly upon the tenants own labour is not necessarily the cheapest way for the government. The system requires huge road- and sewer-systems, and creates transport problems. On the other hand, the home may comprise a piece of land, sewerage, water, electricity, and a prefab sanitary unit.

A building system based upon available, simple components might be left to the initiative of the tenant/owner of the lot. Some checking would be needed to ensure, that fire - and sanitary - regulations are followed.

I may finally quote from the Report of the Jury on the Nordic Idea Competition on "Housing in the Developing Countries", with first-prize winner "Scanplan":"No new design, form of production, or combination of materials can in itself solve the housing problem of the developing countries"........."Low-cost housing is only part of the problem. The problem proper is low-cost urbanization"........."Those projects that view housing as dependant on elementary, urban infra-structure, such as roads, water, and sewerage bear the mark of careful consideration with regard to the scale of the problems"........."If the elementary needs only are to be complied with, e.g. protection against the weather, safety during sleep, and hygiene, the maximum economical effort is practically reached"........."a relatively simple, professional assembly of a stable frame-work, the detailed filling of which can be more free, maybe even left to the local inhabitants. A building process of this kind can form the first basis for an industrialization and a training of specialized workers"........

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