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ABSTRACT

A team of experts examined eight representative examples of industrialized building systems in six countries to determine the origins of the system and the approach taken by its originators; the reasons that led school building agencies to adopt the system; the quality and other characteristics of the finished product; system costs compared with the costs of alternative methods; construction time compared with other methods; evaluation and development techniques; and building procurement practices. The report identifies the benefits and some of the criteria of the systems, and discusses building specification and purchase, as well as the arrangements made for systems development and components production. Also considered are the many decision-making elements and the preferable ways of interrelating them, considering the variations in governmental structure in participating countries. The final chapter summarizes the conclusions of the study. (Author/MLF)

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PROGRAMME ON EDUCATIONAL BUILDING

INDUSTRIALISED BUILDING FOR SCHOOLS

BY GUY ODDIE

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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The Organisation for Economic Co-operation and Development (OECD) was set up under a Convention signed in Paris on 14th December, 1960, which provides that the OECD shall promote policies designed :

- *to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;*
- *to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

The Members of OECD are Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The Programme on Educational Building (PEB) was established by the Council of the Organisation for Economic Co-operation and Development as from January 1972. Its present mandate expires at the end of 1976.

The main objectives of the Programme are:

- to facilitate the exchange of information and experience on aspects of educational building judged to be important by participating Member countries;
- to promote co-operation between such Member countries regarding the technical bases for improving the quality, speed and cost effectiveness of school construction.

The Programme functions within the Directorate for Social Affairs, Manpower and Education of the Organisation in accordance with the decisions of the Council of the Organisation, under the authority of the Secretary-General. It is directed by a Steering Committee of senior government officials, and financed by participating governments.

CONTENTS

PREFACE

The present report is concerned with one of the topics examined as part of the Programme on Educational Building (PEB) which was set up in 1972 by the OECD Council at the request of a number of Member countries. In most of these countries major changes have occurred over the past twenty years in both the structure and form of education and continue to occur as education necessarily adapts to new social, economic and demographic developments. As a result school building is always under pressure, not only to provide the right kind of buildings for evolving educational purposes, but to provide them where they are most needed (in the light of urban renewal and growth) and, in particular to provide enough buildings within limited budgets and within a limited time.

The principal objective of the Programme on Educational Building is to reinforce the efforts made by participating countries to surmount these pressures. One way by which this objective is pursued is through the analysis and evaluation of concrete country experience in specific and clearly identified areas of interest. Such analyses, of which the present report is typical, form the basis for future progress not by treating technical issues in isolation but by so relating them to educational, economic and institutional issues as to offer guidelines for the comprehensive policies which effective investment in school building demands.

Because industrialised production in general has been so successful in responding to pressures of cost and time it is natural to expect similar benefits from the industrialisation of building production. Many architects have shared this expectation from the earliest decades of this century. And many policy-makers, faced with an urgent need for building in quantity have likewise assumed that industrialised building would be the obvious answer to their problems. Others are more sceptical of the likely advantages. But to either, the potential increase in productivity which industrialisation can represent is not to be disregarded. Thus it is to policy-makers that this report is primarily addressed. But it is of importance also to all who may be concerned to see that educational interests and functions are not submerged in the requirements of modern mass production and mass marketing. Through its analysis of the lessons to be learned from the detailed study of a series of specific examples, the report documents the advantages and limitations of the various alternatives which policy-makers will need to balance in making choices best suited to their national circumstances. More than that it indicates the conditions which policies need to provide if industrialised building is to contribute successfully to overall educational objectives.

The report is published under the responsibility of the Secretariat which wishes to express its particular appreciation to the author of the report, Professor Guy Oddie, Senior Advisor to the Programme.

Chapter I

ORIGINS, OBJECTIVES AND WORKING METHOD

ORIGINS AND OBJECTIVES

1. Dangers from pollution, forecasts that important energy and mineral resources may soon be exhausted, warnings against the destruction of ecological balance, together with a troubled conscience concerning the Third World have recently led many people to fear industrialisation and to feel uneasy about the benefits they continue to enjoy from it. But the material benefits from industrialisation, by which the expectation and quality of life have so much been improved, are not be lightly undervalued; and because industrialisation has been slower and less marked in building than in other forms of production, the prospect of benefits from the greater use of industrialised methods remains tempting. Since the most important benefit that industrialisation has conferred is that a greater demand for goods can be satisfied, it is natural that the universal increase in demand for education with its consequent demand for building, should particularly look to industrialised building methods for its satisfaction.

2. What, however, is meant by industrialised building, what are its characteristics? What is the real nature of the benefits it can bring and what the imagined? What are the particular needs, if any, of school building as opposed to those of building in general? What are the quantitative implications of educational demand? What kind of policies and administrative arrangements are needed if such potential as industrialised building may offer is to be realised? The investigation which has culminated in the present report was originated as an attempt to discover what answers can be given to these questions.

3. Neither the investigation nor the report were expected to provide a comprehensive review of all alternative forms of industrialised building, still less an evaluation to establish some order of merit - such objectives would have been inconsistent with known differences in national circumstances, as well as with the resources available for the investigation. The principal objective was to clarify for policy-makers the considerations involved in using industrialised building methods to best advantage with respect to educational needs and to national, financial and administrative circumstances.

INDUSTRIALISED SYSTEMS THE BASIS OF STUDY

4. The investigation started from an assumption - which was afterwards confirmed - that degrees of industrialisation varied widely from one sector of building to another, but that, while the precise meaning of "industrialised" was open to dispute; a number of self-contained "kits of parts" existed which were commonly acknowledged to merit the title of "industrialised building systems". The OECD therefore gathered together a small team of consultants, including architects, an educationist and a building economist, to look at representative examples of such systems and the circumstances of their use, with a remit to look more widely if the need arose.

SELECTION OF SYSTEMS FOR STUDY

5. The selection of examples took account of three considerations. One was to study industrialised building in as many countries as were necessary to reveal the effects of different national circumstances - to which end systems were examined in Denmark, France, Italy, Switzerland, the United Kingdom and, beyond Europe, in Canada and the United States. Secondly, examples should be drawn from the private as well as the public sectors, in both of which systems were known to have originated. Finally, it was expected that the characteristics of systems and their application might vary according to the approach taken by their originators. In the private

sector the approach would naturally be dominated by commercial interests which might or might not conflict with the objectives of educational building. Public originators, with no commercial interest, would probably differ nevertheless in what they perceived as the key to success.

6. Across both sectors the various approaches might in turn be dominated by factors which included the following:

a) an interest in expanding sales of a key product - for example steel or concrete in the form of structural components;

b) commercial exploitation of the originator's design, management, fabrication or construction skills;

c) a conviction that the key to success lay in the maximum use of prefabrication.

d) confidence in the value of capital-intensive site assembly methods;

e) belief that educational purposes demand the use of heavy construction for acoustic or other reasons;

f) recognition that the system must be capable of assembly by small-scale construction firms;

g) a policy of placing maximum responsibility for design in the hands of manufacturers so that production techniques may be used to best advantage.

7. With all these considerations in mind members of the PEB Steering Committee (consisting of official representatives of the sixteen countries then participating in the Programme - Australia and New Zealand having joined later) advised the Secretariat on the systems which should be taken as examples. In the event, these systems did not correspond precisely with all the variations of approach which have just been described. Indeed they revealed different approaches from those that had been tentatively assumed; and in addition they formed, so to speak, observation platforms from which other systems, with other approaches, came to be discerned, as well as attempts to improve the effectiveness of school construction which proved worth attention, but which in the end seemed to lie outside a supportable definition of "industrialised building". All in all, the examples can be regarded as broadly representative of the range of institutional arrangements, procurement procedures and technical solutions which are typical of industrialised building.

SELECTED SYSTEMS

8. The following examples were selected for study.

a) FYNSPLAN (Denmark)

This system was promoted jointly by municipal and county education authorities on the island of Fyn in response to incentives provided by the central Ministry of Education to encourage the use of industrialised building. These incentives were offered in order to remedy the failure of the "traditional" building industry to meet the demand for more school accommodation; as a subsidiary element there was also a desire for improved educational standards. The system was designed by a group of private architectural and engineering firms. The principal features of the system (see note at end of this paragraph) are a heavy pre-cast concrete frame on a module of 3.60m spanning up to 10.80m with floor-to-floor height of 3.50m and capable of three-storey construction. Upper floors and roofs (either flat or pitched) are of pre-cast concrete slabs, and several alternatives may be used for external walls. Stabilising cores are used for every 400m2 of floor area.

b) COIGNET (France)

This system, like the BALLOT system outlined below, is characteristic of those used in France for school building. During the 1960s educational re-structuring and an increasing school population led to a demand for new construction which traditional building methods could not satisfy. The Ministry of Education therefore instituted its Concours Conception/Construction (Design/Build Competitions) in order to encourage builders to collaborate with architects and engineers in devising alternative constructional methods. The COIGNET system, one of many which either resulted from or were modified to suit the Concours, is of heavy concrete construction, with a planning module of 1.80m and a normal span of 7.20m between load-bearing internal walls, but with a maximum span of 9.00m. Upper floors, roofs and external walling are all of reinforced concrete.

c) BALLOT (France)

With origins similar to those of COIGNET, the BALLOT system is also of heavy reinforced concrete but with a structural frame of columns at 7.20m in both directions. Prefabricated timber panels can be used as an alternative to concrete for external walls. Lightweight partitions on a planning grid of 0.90m may be demountable and combine with the structural frame to offer some flexibility in the arrangement of teaching space. The system can be used to build the maximum number of storeys permissible for French school buildings.

d) FEAL (Italy)

This system was designed by a private company which was originally - as its name FEAL implies - concerned with making ferrous and aluminium products such as windows and modular partitions. The company saw in the promotion of a building system a means of widening the outlet for its products and diversifying its commercial activities. Based on the principle of steel-framed construction and the co-ordination of other components on modular dimensions, the details of components and materials used and the extent to which they are pre-fabricated vary considerably according to the class of building required by a particular customer and the locality where it is required. The company has marketed the system for hospitals and offices as well as for schools and for use in, for example, Germany and Czechoslovakia as well as in Italy. The company's interest in school construction was stimulated by the Italian government which, in support of the 1960 educational reform and the national need to speed school construction, allocated large funds for experimental projects in this field.

e) CROCS (Switzerland)

The name of this system derives from the Centre de Réalisation et d'Organisation des Constructions Scolaires - in essence a group of private architects commissioned by the municipality ~~of Lausanne~~ in order to study the municipality's school building needs and how best to meet them over the decade following 1965. After a detailed study of local educational requirements the Centre concluded that the needs would best be met by a standard industrialised system developed for use in all the schools required - which, in fact, numbered only ten (containing 175 classrooms) - but which could be used elsewhere in Switzerland. The system itself has a steel-framed structure dimensioned in bays of 7.80m x 7.80m, 7.80m x 5.40m and 5.40m x 5.40m. Pre-cast concrete slabs are used for upper floors and corrugated steel panels for roofs, while pre-cast concrete panels and aluminium windows form the external cladding. Internal partitions are independent of the structural columns and include lightweight demountable versions.

f) CLASP (United Kingdom)

This system takes its name from the initials of the Consortium of Local Authorities Special Programme. The Consortium was formed in 1957 to exploit the potential for attracting the co-operation of component manufacturers and for obtaining more favourable prices by means of bulk purchase which was thought to be offered by the industrialised building system designed originally by one of the authorities, Nottinghamshire County Council. This original system was one of a number which had been developed in the United Kingdom as an alternative to "traditional" building methods and organisation, which were unable to keep pace with the demand for school construction occasioned by a rising school population and the demands of nationally instituted reforms in education; but its particular attraction to other local authorities lay in its unique advantages in overcoming problems of mining subsidence. Subject since its inception to continuous technological development it remains a lightweight system based on a cold-rolled steel frame. In its latest version (1972) steel decks are used for roof construction and pre-cast concrete panels for upper floors and, as one alternative of several, for the external walls. Columns may be located anywhere on a 0.90m x 0.90m grid with a maximum span of 18.00m for roofs and 9.00m for upper floors. Maximum number of stories is six, except on sites liable to mining subsidence, where it is four. Designed originally for school buildings, the system has been further developed for use in multi-storey university laboratories, and has been used also for hospital, residential and community buildings. Using the same underlying principles, the system has been applied in a number of other European countries - France, Germany, Hungary and Portugal - but usually with substantial modification to suit local requirements.

g) METHOD (United Kingdom)

Developed by another consortium of local authorities, mainly in the Southwest of England, this system is described by its sponsors as a "rationalised traditional" system which concentrates on the dimensional co-ordination of a wide range of alternative components rather than on prefabrication or dry assembly, as does CLASP. There are three types of load-bearing structure; load-bearing brick walling, steel frame, and reinforced concrete. The consortium has standardised the frame, upper floors, roof and roof-lights, staircases, external walls, windows and suspended ceilings. The roof is a steel deck, upper floors are concrete, and external walls may be either brickwork or panels of timber or concrete. As with CLASP, the system is widely used for a variety of buildings.

h) SEF (Canada)

Late in 1965 the Metropolitan Toronto School Board instituted a project entitled Study of Educational Facilities. With financial and moral support from the Ontario Department of Education and the Educational Facilities Laboratories in New York City, this study set out to "estimate the nature and direction of the changes facing the public educational system in Metropolitan Toronto... to recommend the kinds of school building facilities required to accommodate educational needs in the present and future, and to develop a building system which would satisfy these requirements." The building system eventually developed, the SEF system, was intended "to apply more effectively the principles of modular construction in the achievement of greater flexibility of interior design" and "to reduce the cost of school building construction to provide better value for expenditure in terms of function, initial cost, environment, and maintenance." The system is of interest principally because of the novel relationships established between the designers of the system (in the Technical Directorate of SEF) and designers of the components (in producing organisations), and because of innovations in tendering procedures. The major technological features of the system result from the emphasis on provision for future change: demountable and relocatable internal partitions, a method of artificial lighting which is integrated with a suspended ceiling uniform throughout the resulting buildings, and an air-conditioning system the inlets and outlets of which can be repositioned as changes are made in the internal space arrangements. Associated with the system is also a co-ordinated range of mobile equipment and furniture.

One aim of the SEF system was that each element or sub-system, such as the lighting-ceiling should be capable of use in applications outside the SEF system itself. In the United States the consultant team visited three school building authorities (Detroit, Albany and Boston) where such sub-system had been incorporated into derivations from the SEF system.

Note : All the examples outlined in this paragraph were examined by the consultant team in the course of the year 1972. Further technical development has continued in most of the systems since then, but the essential characteristics which led to their selection have not materially changed.

MAIN STUDY

9. Examples having been selected, the consultant team embarked on studies of each case which were based on available documentation (which sometimes included evaluation reports), on visits to buildings (not invariably schools) constructed in the system, and on interviews and meetings. Interviews and meetings were held with system agencies (that is to say, the agencies, private or public, responsible for initiating and designing the system, financing or otherwise managing its development, and for selling it or for otherwise encouraging its use); with school building agencies (that is, the authorities with direct responsibility for letting building contracts) and, where appropriate, with other units of government, national or regional, associated with school construction; and with the architects, building firms and educationists concerned with the design, construction and use of buildings where the system in question had been applied.

10. The purpose of these studies was to examine:

a) the origins of the system and the approach taken by its originators;

b) the reasons that led school building agencies to adopt the system;

c) the quality and other characteristics of the finished product - in other words, of buildings constructed in the system;

d) the costs of using the system and how they compared with the costs of using alternative methods;

e) the consequences for construction time and the possibility of time-saving by comparison with other methods;

f) experience of evaluation and development techniques;

g) building procurement practices associated with using the system. In the event, the studies also brought to light the effect on industrialised building resulting from the relationships between economic, industrial and financial circumstances and the procurement considerations consequent on them.

FOLLOW-UP STUDIES

11. At the conclusion of the main study of selected examples a preliminary report was drafted by an architect consultant in the team, Mr. Francesco Gnecchi-Ruscone, and circulated as a basis for wider discussion at the OECD Symposium on School Building and Educational Change held at Buxton, England, in October 1973 (1). This revealed the need for further study and consideration of complexities which had not been fully appreciated at the outset of the activity and a follow-up investigation was then conducted by another consultant architect, Mr. J. Maxwell Anderson, now Dean of Architecture at the University of Manitoba, Canada. Reports from the latter shed further useful light on the topic which was then examined once again by the original consultant team, by permanent members of the Secretariat and by the Senior Adviser to the Programme.

PRESENT REPORT AND AUTHORSHIP

12. The present report is largely the outcome of this re-examination. However, while every attempt has been made throughout to weigh the accumulated evidence as objectively as possible, some degree of subjective judgement has been unavoidable. This is partly due to the presence of qualitative aspects, partly to the difficulty, in some cases, of tracing clear records of costs and construction times, and partly to problems of comparison which are explained in the chapters which follow. As a consequence, individuals in the team may differ in the emphasis each would give to the many issues dealt with, just as each differs in the expertise and personal experience he has contributed. Furthermore, the study has overlapped with others included in the Programme on Educational Building, one concerned with The Building Implications of the Multi-Option School (2), another with Providing for Future Change (3), and a third with Institutional Arrangements (4); and evidence emerging from these other activities as they progressed has been noticed by the Secretariat as pertinent to the conclusions which can be drawn. It is therefore the Senior Adviser to the Programme, Professor Guy Oddie, who has had the responsibility of interpreting the findings of the investigation in the light of this wider evidence and who is the author of the present report.

PATTERN OF REPORT

13. Reference was made in paragraph 4 to the initial assumption that, whatever alternative meanings might be attached to "industrialised building", "industrialised building systems" were commonly acknowledged to merit the epithet. Chapter II examines the characteristics of industrialisation in general, and of industrialised building in particular. These characteristics, it is argued, not only justify the assumption but, more than that, suggest that industrialisation is so much a feature of all modern building methods that only in the existence of systems can industrialised building be distinguished from building in general.

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1) Eric Pearson, School Building and Educational Change, OECD, Paris, 1975.

2) Jean Ader, Building Implications of the Multi-Option School, OECD, Paris, 1975.

3) Providing for Future Change: Adaptability and Flexibility in School Building, OECD, Paris (to be published).

4) Information Leaflet N°6, "Institutional Arrangements for School Building", by Noel Lindsay, Programme on Educational Building, OECD, July 1975.

14. Chapter II also points out that, by its nature, any industrialised building system imposes some limitations on the form and character of the buildings for which it is used. Such limitations would be unacceptable without offsetting compensations; so in Chapter III an account is given of the benefits which have in practice been obtained. At the same time, the studies suggest that the trend towards industrialisation in search of such benefits could in fact represent a danger unless a conscious and positive effort is made to ensure that the particular needs of education are properly met.

15. The first of these needs is clearly for buildings of the kind and quality which makes them effective instruments in educational practice. Chapter IV therefore analyses trends in educational practice with respect to their building implications and so identifies some of the criteria which industrialised building systems should meet.

16. In Chapter V further criteria for building systems are indicated by consideration of the strategic needs of education. These are the needs which demand not only the right kind and quality of building but demand buildings in sufficient quantity within limits of time and cost consistent with planned expansion or renewal of the stock of school building.

17. If industrialised building systems are to meet the criteria identified and their potential benefits realised, a number of conditions have to be met in the processes by which school buildings are specified and purchased and in the arrangements made for the development of systems and the production of their components. Chapter VI deals with these conditions and the steps taken to meet them in the examples studied.

18. The nature of industrialised building systems is such that their successful use has depended on satisfactory relationships between the many decision-making elements concerned with educational building. Chapter VII identifies these elements and examines preferable ways of inter-relating them, taking due account of variations of governmental structure encountered in participating countries. Chapter VIII summarises the conclusions reached as a result of the activity as a whole.

Chapter II

THE CHARACTERISTICS OF INDUSTRIALISED BUILDING

STANDARD PRODUCTS AND PREFABRICATION

19. Industrialisation connotes production by means that use machines in preference to manpower, and which concentrate both machines and such manpower as remains essential (usually in factories) so that they can be constantly employed in an even flow of production. Industrialisation also connotes a product which is produced in quantity rather than singly and which conforms to a repeatable standard of both form and quality.

20. If these are accepted as its connotations, industrialisation has occurred in the production of building components ever since machinery replaced manpower in the manufacture of bricks and tiles, and increasingly since then in the production of doors, windows, floor beams, wall panels, structural components and so on. For decades in the course of this development such components were incorporated into buildings which were otherwise site fabricated and this was no more than an extension of "traditional" building methods. The initiative for designing and making such components lay with the producers themselves, who had only two criteria in mind: the widest market appeal and economy of production. But as the trend proceeded a threshold was reached where the initiative was taken up by those building designers (either associated with producers or with purchasing clients) who believed that the building (as opposed to the manufacturing) process might be improved by the use of products not yet available on the general market, and who sought to maximise the use of standard products in order to maximise the efficiency of the building assembly process. At this point "industrialised building" began to emerge as a separately identifiable concept and as a distinct alternative to the "traditional".

21. Even in the assembly process itself, powered machinery like cranes and hoists, as well as labour-saving powered tools, have increasingly been used from the introduction of steam power onwards. But site use of labour-saving power is no more than the extension of principles of leverage and gearing that have so characterised assembly over the centuries as to blur rather than define the concept of industrialised building if the use of power is to be its sole distinguishing feature.

22. Some builders, however, have sought to make site operations even more capital-intensive by using powered machinery not only for assembly or for the bulk mixing and placing of concrete, but also for the site production of components. They have done so particularly in order to replace slow and labour-intensive bricklaying by casting large concrete components in what are effectively factories, but located on site. Again the result has come to be recognised as sufficiently distinct from traditional building to merit the term "industrialised".

23. As with industrial production in general, the components resulting from this extension of it are standardised in both form and quality. In addition, like those made in off-site factories, these components are fabricated in their final form before being placed in position - in short they are prefabricated even though they are site produced. Thus industrialised building is closely associated with prefabrication, even if prefabrication need not be synonymous with off-site production.

STANDARDISED SYSTEMS

24. The use of components which in this sense are prefabricated is not in itself sufficient to constitute what is commonly recognised as "industrialised building" unless they are used on a scale distinguishably larger than in the "traditional" case. When standardised components are, in fact, used

on a scale large enough to make the distinction perceptible they meet a requirement which further characterises industrialised building. Each component must be not only effective for its own particular functions, it must also be designed to fit in (or interface) with other standard components performing other functions. In other words all components must be mutually compatible, although in some cases the interfacing may be made easier by interposing special (i.e. non-standard) components between the standard ones. Whole walls (including windows and doorways), roofs, floors and supporting structure, and sometimes internal partitions, ceilings and other elements thus come to be composed of components which, by virtue of their compatibility, form part of a system. Likewise whole walls, roofs, supporting structure and other elements are made to interface and so constitute sub-systems of a larger system.

25. Where the word "system" is more than a synonym for "method" it means "a relationship of interdependent parts". In this sense any completed building may be regarded as a system. In "traditional" building the relationship of the parts is determined as the design of the building as a whole proceeds, so that the relationship is unique and particular to the building in question. But since industrialised building demands the use of standard repetitive and mutually compatible components the relationship by which they interface with each other must also be standardised and repetitive. The system as a whole, not just its components, is standard. Thus, a further distinguishing feature of industrialised building is that the range of constituent parts and the manner of inter-relating them remain constant for all buildings constructed in the system, and each such building must conform to the discipline of inter-relationships which has been determined before the building itself is designed.

26. Apart from mobile homes, caravans, or very small hut-scale buildings, we can find no example which consists exclusively of standardised components or of a standard system. The most compelling reason is that every site is unique in some respect or other, and therefore those components which interface with the ground, with site services or other site features are bound to be particular to the site in question. Additionally, either for ease of fit or for economic reasons, the disadvantages of standardisation may outweigh the advantages. Nevertheless, any building recognisable as "industrialised" will be constructed to a dominant extent by means of standard systems or sub-systems, that is to say to an extent where the systems or sub-systems constitute the major limitation on the alternative forms that buildings incorporating them can take.

DEFINITION OF INDUSTRIALISED BUILDING

27. We can now see that industrialised and traditional building have so many features in common - standardisation, prefabrication, the use of powered tools - that the features which distinguish them are hard to identify, subtle and partly a question of degree. Nevertheless if all the issues which have been analysed are taken together it seems possible to hazard the following definition:

> "Industrialised building (as opposed to alternate methods) means the construction of buildings by the use of pre-determined standard systems or sub-systems of mutually compatible pre-fabricated standard components to an extent where they impose the major limitation on the range of alternative forms that any single building may take."

LIMITATIONS IMPOSED

28. Bad buildings can result whatever system - industrialised or otherwise - is used. Some standard systems are so limiting that they can produce nothing but crude and inadequate buildings; and even sophisticated systems, if mishandled by inept designers, can result in buildings which fall far short of the desirable. Nevertheless, we have found many schools built from standard systems which, either functionally or aesthetically, are in no way inferior to the most sophisticated of those built by alternative methods. Thus while systems vary widely in the limitations they impose, there is no reason why a particular system can not be so designed that it in no way restricts the production of buildings of a desirable kind or quality.

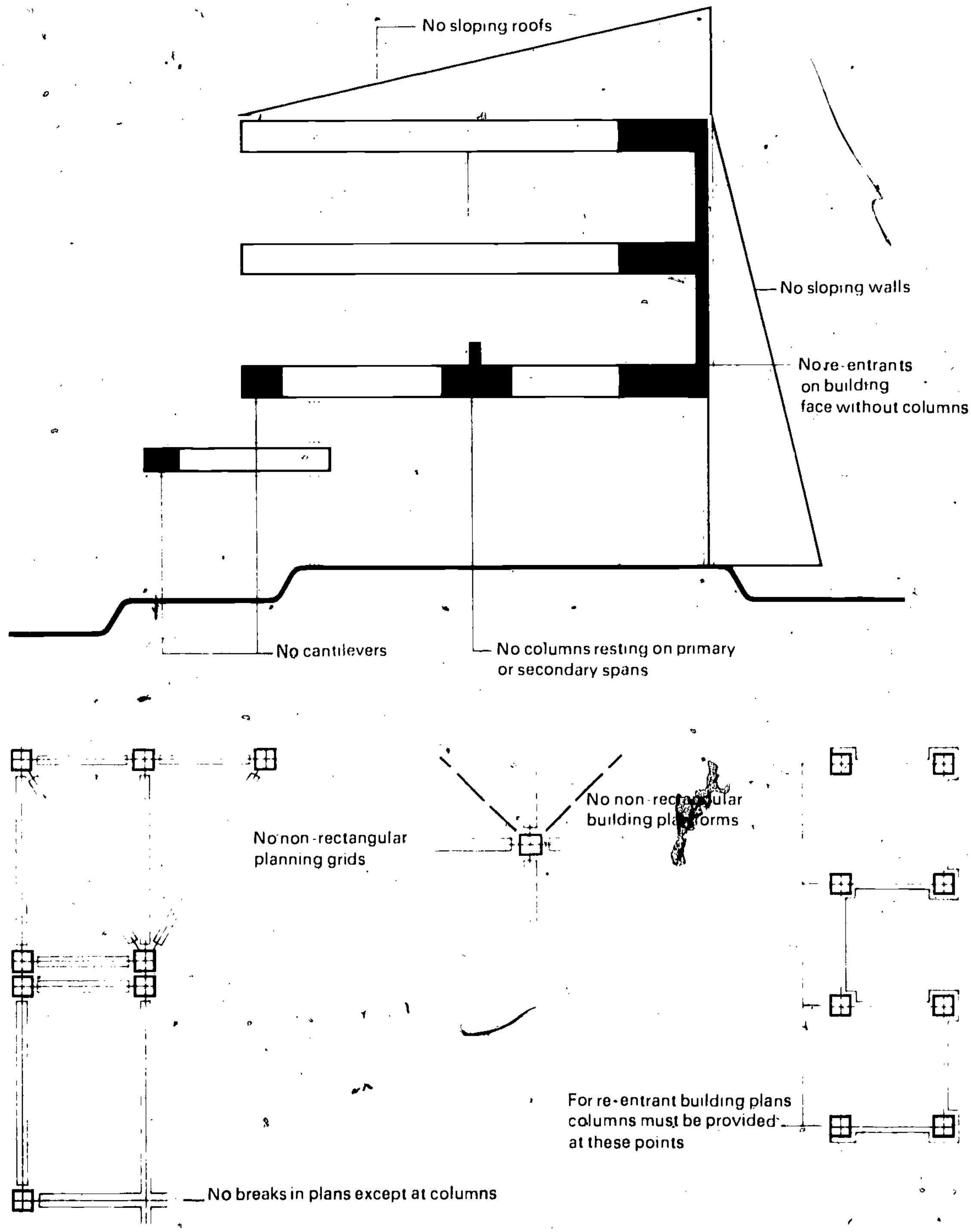

Figure 1. Limitations of choice imposed by one of the systems studied

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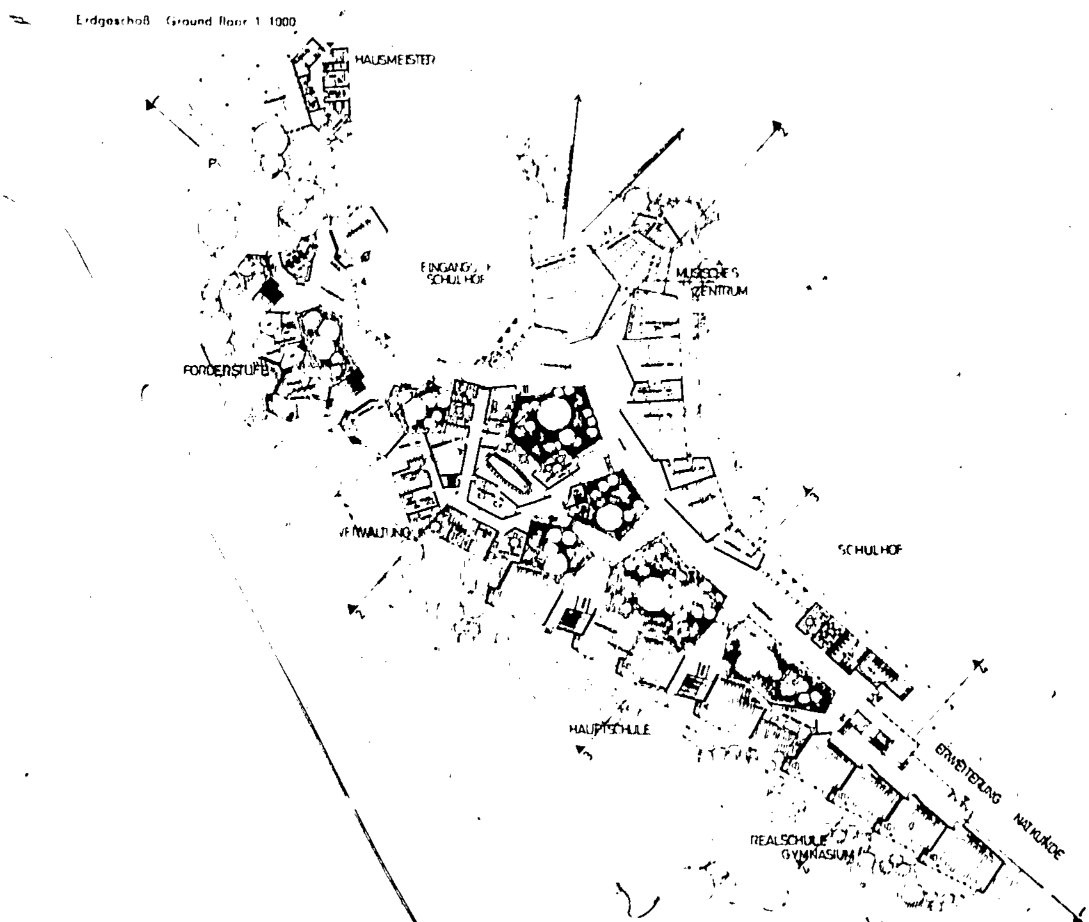
Figure 2. The polygonal space arrangements of this German school could not be provided by any of the systems studied; but this need not constitute an educational disadvantage.



29. Since the main work leading to this report was undertaken, a number of serious fires have occurred in buildings constructed in industrialised building systems. The number has not been large but lives have been lost. As a result public anxiety has been aroused over the possibility that using industrialised building systems increases fire dangers. Although individual buildings using standard systems have been criticised for defects contributing to fire dangers, no evidence has come to light which in any way suggests that industrialised building systems, as such, need be inferior, as concerns fire, to more conventional alternatives.

30. While it is conceivable that an exceptionally talented architect, given sufficient time, money and other favourable circumstances, may yet produce a better school by alternative methods, nothing inherent in industrialised building need prevent the same architect from developing a standard system by which equal results could be obtained. At the same time, it can not be denied that by their nature standard systems limit the choices open to designers of individual buildings in terms of dimensions and in terms of the components available in the standard range.

31. This inherent limitation on choice may be seen as a disadvantage of industrialised building. Indeed, that it has been seen as such is evident from the resistance to it displayed by many architects which we have noticed in our investigations. This resistance and, whether imagined or real, this disadvantage, have terminated several ventures in industrialised building. Nevertheless, many ventures have flourished, and some, particularly in England, have flourished to an extent that in many localities they have for more than a decade entirely replaced non-industrialised methods in the field of school building. The starting point for our investigation was therefore to examine the benefits accruing from industrialised building which have made its limitations acceptable, and which furthermore, may have stemmed from the limitations themselves.

Chapter III

BENEFITS, DANGERS AND OPPORTUNITIES

32. At first sight it might seem reasonable to expect that the use of industrialised building systems for school building is cheaper and quicker than the use of alternative methods. To this expectation no general or direct confirmation can be given. Confirmation will reflect what is meant by "cheaper and quicker". It will depend partly on the system itself but also on the arrangements which school building agencies can make for obtaining the buildings they need and above all on prevailing conditions of supply and demand within the building industry concerned.

CAPACITY OF THE BUILDING INDUSTRY

33. Only in two countries of the OECD, France and the United Kingdom, can industrialised building systems be discerned as at all dominant in school construction, although the FEAL system, originating in Italy (1), has been widely used in that country and in others. In each of these countries industrialised building systems owe their origin and development mainly to the inability of the conventional industry to meet all the demands placed upon it.

34. The United Kingdom was the first of these countries where such over-stretching of the industry became evident. In the late 1940's the need for a rapid increase in housing to make good the back-log of war, for new factories, and for schools both to serve new housing areas and to accommodate the extra numbers occasioned by a raised school-leaving age, all imposed a heavy demand. At the same time the building industry was suffering from a shortage of skilled bricklayers and plasterers after a war in which few had been trained and those already trained had been diverted, as had carpenters and joiners, if not into military service, then into areas of production more important in wartime than building. Since then, wages and working conditions in building have become progressively less attractive compared with those elsewhere, so that the original post-war impetus has been maintained. Although France and Italy did not feel the strain immediately after the war their rapid economic expansion eventually produced a similar effect. In all cases the industrialised building systems have significantly alleviated the consequent problems, but they have done so less as a substitute for conventional building than as an addition to the potential of the building industry.

35. In this sense, of course, industrialised building can be said to increase the total rate of output beyond what would be possible without it. But what can not be established from direct evidence is whether, for any individual building, industrialised systems offer advantages in construction time over conventional alternatives when the latter are unhandicapped by labour shortages or other consequences of overload. The reason is that in such a situation there is no incentive to develop or use industrialised building systems, on grounds of speed, since if school construction is fast enough there is no need for it to be faster. This may be one reason, although others will be apparent from paragraph 42 below, why despite well-publicised initiatives, industrialised building systems do not dominate school construction in the United States or Canada, where high building wages are a powerful incentive to efficient management with high capital investment behind each site workman. Admittedly, even in the United Kingdom, there are some regions where conventional building, rationalised and well-managed, continues to maintain the required output, side by side with other regions where industrialised building systems have been in sole use for many years. But this can be attributed to a number of causes, including the possibility that the continued success of conventional building is largely attributable to the relief afforded to the construction industry by the use of systems in the adjoining regions.

1) FEAL is only one of a number of systems used in Italy, where industrialised building, if not dominant, at least contributes substantially to school construction.

Nevertheless, we have no evidence that advantages of speed have ever led industrialised building systems to replace alternative methods where these have remained within the industry's capacity. We are thus led to conclude that the prime justification for the use of industrialised building systems is the inability of the building industry to meet demand without them. Thus the first benefit from the use of industrialised building systems is the extension of the building industry's potential.

36. For school building or for any other sector of demand which the industry can not otherwise satisfy this is justification enough. But bearing in mind that industrialisation in general is so much identified with cost reduction, we must ask why the prospect of such a benefit has not been convincing enough for industrialised building systems to displace all alternatives as the conventional mode for meeting all sectors of demand.

PROBLEMS OF COMPARISON

37. Reflection will quickly show that to speak of the cost of a system, industrialised or otherwise, is meaningless. Comparisons can only be made in terms of buildings constructed in the systems concerned, and for such comparisons to be at all reliable, account needs to be taken of variables which interact with each other in complex ways.

38. Broadly speaking the total cost of a building equals the total floor area multiplied by the cost per unit of floor area (square metre or square foot). It is in terms of cost per unit of floor area that comparisons of system costs can best be made. But of the total range of facilities provided within a school, some are significantly more expensive (e.g. laboratories, or other heavily serviced facilities) than others, and the mix is an important determinant of the cost per square metre. In part, this mix represents an educational choice, in part it reflects the skill with which the architect concerned has interrelated each facility to the others in order to avoid waste of floor area or to shorten lengths of service distribution or to optimise the total volume within which the facilities are contained - and architectural skill inevitably varies. Some systems may ease more than others the application of this skill; but any attempt to compare the costs of alternative systems must either be based on buildings in which the mix is the same, or otherwise make adjustments to take account of differences.

39. Then there is the difficulty of differences in quality or performance - liability for future maintenance, levels of thermal insulation, noise control, or artificial illumination, or the even more indefinable but not less important consideration of aesthetic acceptability.

40. Finally, we have the fact that of the total building cost only a variable proportion can be attributed to the system used. The proportion not only varies between systems but even between buildings in the same system, since it is affected by the unique features of the building site.

41. The difficulty which arises in allowing for all these variables is not lessened by the fact that official records do not break down the total cost of buildings in sufficient detail. Consequently, we can offer no firm evidence based on measurable data. Nevertheless, we can report on a number of indications which have considerable significance.

SOME INDICATIONS OF COST

42. The wide publicity given to the Southern California Systems Development (SCSD), particularly by the Educational Facilities Laboratories, New York City, persuaded the Metropolitan Toronto School Board that an industrialised system be developed by its Study of Educational Facilities (SEF) group. Almost alone among system designers this group included cost reduction as one of its two primary objectives, the other being the provision of greater adaptability of artificial lighting, services and partitions to meet future change in education. The first series of schools built in this system proved in the event to be more expensive than others being built at the same time and exceeded the standard limit of expenditure then in force. The advocates of the SEF system believe, although others do not agree, that this was the worth-while price for the extra adaptability achieved under the second objective. They also say that the higher comparative cost was the result, not of the system as such, but of the fixed price contracts made with suppliers and builders for the whole series. Contrary to expectation, prices in the building industry as a whole fell over the construction period, as a result of falling demand, to levels lower than the fixed prices

of the SEF series. We were also told by SEF representatives that the designers of individual schools had not used the system in the most economically advantageous way and that in the second series, then in the design stage, this would be remedied. It appeared, however, that if this were done, the limitation on choice which characterised this system as it does all standard systems, would be increased by economic considerations beyond the limitation inherent in the standard components and the requirements of mutual compatibility.

43. From the SEF experiment we can only conclude that industrialisation per se implies no guarantee of cost-savings. On the other hand, every system-built school completed in the United Kingdom since 1945 had been contained within the standard limits of expenditure imposed by the Ministry of Education (1). By the time the first 20 SEF schools had been evaluated, about 1,000 schools had been built in only one of the United Kingdom systems - CLASP. So there is even stronger evidence that industrialisation does not imply in any way that cost will increase as a result. Indeed the CLASP report for 1974, written in a period of rapid inflation, shows that in the fifteen months up to 1 July 1974, when the Royal Institution of Chartered Surveyors Index of general building costs rose by 30 per cent, the cost of CLASP components rose by only 18.87 per cent. For the year 1972/73 the equivalent figures were 25 per cent and 9.89 per cent. This evidence suggests that, whether or not cost benefits can be expected of all systems, they can certainly be expected of some. But the British evidence is particularly subject to the variables we have mentioned. Since the system of standard limits of expenditure allow all school buildings to reach that limit the designers of system-built schools tend to use the cost benefits to maintain standards of quality and performance and it has not yet proved possible to quantify the fall-off in such standards resulting from the inflationary effect on alternative construction. It is important to remember, also, that while costs are an important consideration and failure to build satisfactory schools within the United Kingdom limits would kill a system, cost-reduction has never been the primary objective of British systems. The prime objective has been to maintain school building output despite limitations on the capacity of the building industry to meet demand. This objective has certainly been met; and there is no indication that any industrialised system is yet threatened for lack of cost-competitiveness.

44. We must also take account of undeniable evidence that in one case studied, that of the Italian FEAL system, contracts for school-building, both in Italy and elsewhere, have been won by the promoting company entirely as the result of more competitive bids. Nothing suggests that this has resulted in buildings of any lower standard. We can therefore conclude that in some cases circumstantial evidence points to cost benefits when industrialised building systems are used. We shall examine in a later chapter the conditions which must be met if these and other benefits are to result.

COST HANDICAPS

45. In considering cost savings it is as well to make some reference to disadvantages which industrialised building systems must overcome if a net benefit is to result. The attempt to save scarce labour on site leads naturally to the use of standard components which are large, bulky, difficult to store and which, by comparison with bricks and tiles, are needed in much more limited quantities. For this reason industrialised building components can benefit much less from mass production or stockpiling as a means of sustaining production in periods of slack demand than can so many products of industrialisation in general. Since systems depend for their effect on the mutual compatibility of prefabricated components, mainly assembled by dry techniques, the components must be made to finer tolerances to ensure

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1) The same may be said of "non-industrialised" schools subject to the same limits. Despite rising costs government policy has been to raise the limit of expenditure only when an intolerably large number of tenders exceeded it. This has meant that schools built at times when pressures from the limit were particularly acute (that is on the threshold of a high limit) sometimes suffered from lower quality specification, lower ceiling heights and even reduction of educational floor area. However, there is no evidence that schools built in industrialised systems were at any greater disadvantage in this respect than those built by alternative methods. See also Chapter V, paragraph 111.

a proper fit; and higher dimensional accuracy can cost more. This is especially so if it demands, as it sometimes does, the use of more expensive basic material. Prefabricated partitions are an example of these symptoms, their first costs being in many cases so much higher than labour-intensive blockwork alternatives that their use may be preferred only if the labour needed for the latter is unavailable. Finally, because the range of components which are mutually compatible is inevitably less than the range where compatibility does not need to be considered, conventional building enjoys greater freedom to substitute one component for another to meet variations in cost and availability.

NEED FOR DEVELOPMENT

46. In cases where the development of industrialised building systems has been sustained by the continued inability of alternative methods to meet demand, ways have been devised of overcoming all these disadvantages. But they have not all been overcome at first attempt but only progressively over a period of years, so that in practice systems which are currently "successful" differ considerably from their original form and their continued success demands continuous development to meet changing circumstances.

47. The opportunity for this is absent in most sectors of building. Housing is the exception and here, as with schools, industrialised building has also flourished in many countries (although in forms modified to take account of the fact that housing consists of large numbers of smaller but highly repetitive units). But the absence of opportunity for sustained development in all other sectors is probably the main reason why industrialised systems have not yet become the dominant mode throughout building as a whole.

SAVINGS IN CONSTRUCTION TIME

48. Speed of construction is often seen by school building agencies as one of the benefits they have gained, is advanced as a claim by advocates of industrialised building systems, and is a constant goal in front of system designers. What therefore are the factors that must be considered here?

49. First, as we have said, no industrialised building system, however much it may dominate, accounts for the whole construction of any building, so that time-saving potential over the building as a whole reflects the ratio of industrialised building to the total. This is certainly the assumption made by designers who have attempted and are attempting to increase the ratio. But those industrialised components which cost more than non-industrialised alternatives may yet bring no compensating gains in time. We have found, for example, cases where traditional blockwork was significantly cheaper for internal partitions than any industrialised alternative but where the extra time needed for its construction was not, in fact, significant. The blockwork construction could be timed to coincide with other operations, and it was these other operations, not the blockwork itself, which were critical for total completion time. Thus real time savings are not dependent solely on the use of industrialised building systems, they are dependent also on how the industrialised system affects the critical path through the whole operational network.

50. To this is linked a second consideration in which building differs from so many other kinds of industrial production. Because of the tendency for every building to be unique, there is no opportunity, except for repetitive housing, for site operatives to become as familiar with assembly sequences and operations as workers on an assembly line. In this respect building systems do, in fact, offer an advantage over alternatives because the standardised interfacing of components increases the possibility of standardising assembly also. But this advantage can only be seized if the same assembly contractor can build a number of buildings in the same system.

51. Taking these two considerations together we find that not only do savings in construction time vary from one system to another, they vary even when the same system is being used, and depend on variations in building management and on the extent to which assembly contractors can gain familiarity with the system. Thus while evidence exists that savings in construction time have been made, there is also evidence that the savings can not be relied upon unless a number of other conditions are met. In cases such as CLASP, where they are met, the savings in construction time are considerable.

52. Just as the standardisation of interfaces gives industrialised building an advantage over alternative methods for familiarity

with assembly, so the extent to which prefabrication reduces "wet" operations (in which materials like cement and sand have to be stored on site, mixed wet for use and the surplus subsequently cleared away) offers a further inherent advantage. This advantage is particularly beneficial when it is used to speed assembly of the enclosing roof and walls so that as many operations as possible, even including some "wet" foundation work, can be independent of weather conditions. But with the much more detailed knowledge of the components and interfacing to be used than is normal with other methods, all site operations can be more confidently planned to interlock and overlap without the risk of one operation interfering with another. Thus "speed of assembly", mainly perceived until recently in terms of saving in total man-hours (i.e. productivity), can also be seen in terms of shortening the total construction period. The importance of productivity will increase as wages rise. Provided school construction can be planned far enough ahead of need, length of construction period is of little consequence. But this is a giant proviso, seldom met; and if high interest rates and inflation continue, shortening the construction period will become an increasingly important objective.

SAVINGS IN DECISION TIME

53. Important though the shortness of construction time may be it is often of less pressing importance than the period which elapses between the initial decision to build and the date on which construction commences. During this period many decisions have to be taken, including design decisions, approval of the design both by the school building agency itself and by authorities such as those responsible for urban planning, public health and safety, including safeguards against structural collapse or fire risk; following these approvals bids for construction have to be sought, the successful bidder must ascertain possible sources of labour and materials and then assemble what is needed from those sources for the project to be constructed. All these decisions take time. With conventional methods every one of them has to be taken on each occasion that an individual building is constructed. Using industrialised building systems many of these decisions need to be taken once only, no matter how many buildings are produced by the system. This time-saving on decisions constitutes a major benefit and is the benefit least disputed by school building agencies, by designers, suppliers and builders.

54. In many cases indeed the decision-saving benefit has been the chief attraction leading school building agencies to adopt standard systems. They can see immediately that the design period can be shortened by the fact that the designer of the individual building is relieved of the need to design every detail afresh each time, or to search an unlimited field for cost-effective components - a fact equally appreciated and widely agreed upon by designers under pressure to complete a volume of work in limited time. That a system is available for use also implies that manufacturers and suppliers are available and in a position to deliver, if not immediately then at least with a "lead-time" which is predictable, a fact equally appealing to builders who are then more assured that assembly can be more certainly related to deliveries, with minimum risk of losing time.

CONSISTENCY OF PRODUCT

55. Then, in addition, quality-and-cost control is easier to assure, with the knowledge that for a given expenditure quality of product will remain constant wherever the system is used, whereas with conventional building it is more subject to the greater variability of site supervision. In offering this benefit industrialised building systems come nearest to offering one of the major benefits which consumers in general enjoy from the industrialisation of product. This is the benefit that goods are not only in ready supply but are also of a quality which is not only acceptable but also reliable and consistent and can, furthermore, be sampled and evaluated before being purchased at firm prices declared beforehand.

56. A similar consistency applied in respect of those aspects of building, such as structural performance or methods of fire protection, which are subject to approval by authority: the standards of the system can be approved once for all, no matter how many buildings are constructed. The popularity of the FEAL system in Italy, we were told, was only partly due to its price competitiveness: it was also because the use of a standard system enabled short cuts to be taken through otherwise lengthy approval procedures.

57. Finally, where standard systems have proved durable, decision time has been saved by avoiding the necessity, as it were, of always re-inventing the wheel. By learning the lessons of each application, as well as by taking account of changing economic or technological conditions, designers have been able steadily to improve the quality of the system and increase the benefits it offers.

SCOPE FOR BULK PURCHASE

58. An early assumption made by developers of industrialised systems was that component producers would incur high capital costs which their prices would have to cover, and that a high volume of sales would be needed to make prices competitive. Not unnaturally, they assumed also that the incentive to produce a standard component would increase with the volume of sales it was expected to attract. Acting on these assumptions they formed two objectives. The first was to minimise the number of variants in any range of components (e.g. in a range of beams, to limit the different standard lengths and depths or in a range of wall panels to restrict the standard heights, widths and finishes available) and to exclude wherever possible the use of special components (i.e. specially made for a particular individual building). The second was to attract as many purchasers as possible to combine in placing large orders.

59. Research, to which our own study has added some further confirmation, has indicated that both assumptions and the objectives based on them, are open to question. The CROCS system in Lausanne was limited to only 10 buildings, yet its economic viability was not endangered. The reason appears to be that the system was designed for production by means that were already in active use - any extra tooling or capital investment needed for the CROCS components being insignificant. This is perhaps a reflection of the character, diversity and scale of Swiss industrial enterprises and can not therefore point to a generally valid conclusion. But it does seem true that such capital costs as are incurred are mainly in the form of tooling and that, given the tooling, a wide range of variants can be made without extra cost. Furthermore, in contrast to the capital investment needed for many industrial products, that for building components is comparatively low. Thus a comparatively small volume of production is needed for the capital-recovery element to be significant in the total production cost. This being so, it is true that a minimum level of sales is needed, but that little can be expected from economies of scale in the strict meaning of the phrase. More important to the producer, especially in an era of cash shortage and high interest rates, is the prospect of sustained levels of sale.

60. To question these early assumptions is not however to cast doubt on the advantages of bulk purchasing arrangements but rather to emphasise what they really are. Bulk purchase attracts keen prices and better performance (in terms of quality of product and promptness of delivery) for fear of losing a large order from an important customer. That these advantages are so briefly stated does not lessen their considerable importance.

61. If school building agencies have powers to combine their several requirements to purchase in bulk they can clearly gain these advantages, whatever mode of construction is used, in negotiating favourably for all kinds of building product. To do so, however, they need to reach agreement on what products to purchase, or, in other words, what products shall be standard for all the individual buildings to be built. Thus agreement to use a standard system clearly provides a ready framework to which bulk purchasing arrangements can be related.

DANGERS

62. From all the foregoing it can be seen that, subject to certain conditions, the use of industrialised building systems can go a long way, if not all the way, to providing the benefits which society has enjoyed from industrialised production outside and beyond the field of building. Because the "certain conditions" have only rarely been met, the potential benefits from industrialised building have not yet been easily enough obtained to establish it as the major mode of building. Yet pressures to secure the benefits remain strong and at times appear inexorable. Nothing suggests that the drift of skilled craftsmen away from the building industry is being halted, still less reversed, so there is an increasingly strong incentive to use systems which diminish reliance on them. For so long as economic activity is subject to sharp and sudden fluctuations all building agencies, school building agencies among them, will seek to reduce

construction time and will be pressed even harder to take pre-construction decisions with least possible delay. All these pressures expose school building to a number of dangers.

63. The first danger arises from the pressure to minimise decision time. Such pressure naturally inclines a school building agency towards a system which is already available in adequate quantity on the market and to see urgency as more important than any limitations such a system may impose on the kind of school which can be built. Urgency may even outweigh considerations of cost-effectiveness. In short, the danger is that the system used may provide too many bad schools.

64. The second danger lies in the temptation to design systems with no other aims than to maximise ease of production and to minimise the incidence of pressures on the building industry, again with too little regard for the limitations which may result.

NATURE OF LIMITATIONS

65. Using "conventional" modes of building the designer can, in theory, have recourse to any component available on the market, or even have components specially made to suit his purpose, so that, with the further freedom to use brickwork or masonry, he enjoys a theoretically unlimited choice by which any functional or dimensional requirement can be met. In practice, economic and technological conditions always restrict his choice, but the choice is still wider than is available from a standard system. This is not to say that a standard system will inevitably offer, for example, only one kind of walling or roofing sub-system, but the need for mutual compatibility tends to restrict the choice available in terms of the materials used, of the profile of components where they interface, and of their dimensions in thickness, length and width. Thus the more limited the range of alternatives which a standard system provides, the more it restricts the freedom of the designer to determine appearance (for which he is rightly concerned) to position walls, columns and beams where they will least obstruct space, to determine the position, size and shape of openings, such as doors and windows, or to determine the overall shape of the building and its relationship to the site. In short, the designer finds a standard system harder to manipulate, and the difficulty of manipulation varies inversely with the range of alternatives offered by the system.

66. The wider the range of alternatives on offer, the less will be the demand for any one alternative. This leads in conventional building to a process of "natural selection" which eliminates alternatives for which demand disappears. Thus if standard systems are produced, as are most saleable products, by suppliers seeking to profit from meeting a demand, pressures are automatically exerted to develop systems (or sub-systems) for which the widest possible demand can be discerned. However, when all classes of building are considered together, each class is found to have many requirements peculiar to itself and only a few which are common to the other classes. Thus housing has special requirements which differ from those of offices or factories, or of course from those of schools. The danger then is that initiators or promoters of systems will orient their systems either to the largest class (which is certainly not school building) or towards those requirements most common to several classes. This, in fact, is what has happened in many countries: systems have been developed for housing, for offices and factories - especially where they are needed in a hurry; and sub-systems have been developed, to provide, for example, walling which will serve equally well for offices, factories and, in some cases, housing also.

OPPORTUNITIES

67. Now if as the result of all the pressures we have noted, industrialised building systems increasingly replace less limiting alternative modes of building, there is the further danger that school construction, being a relatively small class of building, may find its own special requirements increasingly difficult to meet. Like what has happened in areas other than building, the tendency could be for "consumer interests" to be sacrificed to "production interests".

68. However, despite the automatic pressures to produce systems meeting the widest discernible demand, producers are ready enough to cater for a particular market if sales can be assured, and the study has shown that, in contrast to many products outside building, the volume of such sales does not need to be very large. We have al-

ready touched on the evidence from the CROCS experience (see paragraph 59). What is important, indeed essential, is that the special needs of the particular market - in this case school building - should be made articulate and communicated to interested producers.

69. We have mentioned also (in paragraph 58) the objective of reducing variants but have indicated (paragraph 59) that as far as building components are concerned this is not a prime objective of production. The need to limit variants arises much more from the need to limit the range of standardised dimensions to which components must be produced if they are to be mutually compatible. But neither production nor component compatibility demand that the variety of alternatives within a system need be minimised, only that they be controlled. And industrialised building is no less capable than other forms of industrialisation of enriching the variety of components available to the consumer.

70. Clearly, none of the dangers can be averted by relying on conventional alternatives where these are patently inadequate for the building industry to meet demand. They can only be averted by the development of standard systems which secure the advantages identified earlier in this chapter while reducing the restrictions placed on the designer to a degree where they do not militate against the production of satisfactory school buildings. Cases that have been noted in the present study show that not only is this possible but that such restrictions as remain can even be an aid rather than a hindrance, in that they save effort on the design of building detail and allow it to be transferred to a closer study of the user requirements which school buildings must meet. Thus if the industrialisation of building exposes school building to certain dangers it also offers opportunities. But the investigation has shown that these opportunities can only be fully seized if a number of important conditions are met. However, before exploring these conditions (in Chapters VI and VII) it is necessary to discuss in some detail the nature of the requirements particular to schools which industrialised building systems must meet.

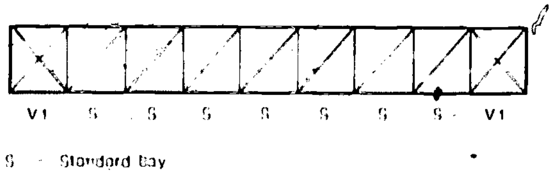
Chapter IV

RIGHT KING OF BUILDING

"SINGLE-CHAIN" SYSTEMS

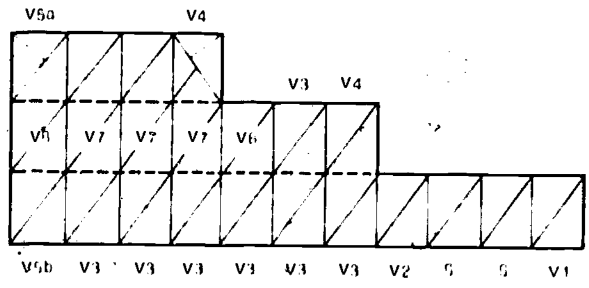
71. Many building systems have been conceived mainly to meet emergencies. This is especially true of those which set out to satisfy a general market demand rather than that of a special sector. Their appeal and their success lies primarily in savings of decision time, although provided siteworks or service installations are simple they can also offer savings in construction time. When emergencies occur and speed of decision and supply is the most compelling consideration, buildings which meet the emergency frequently appear to offer cost savings also, but these usually result from lower standards of performance and durability, which are acceptable in a temporary stop-gap but not over a long term.

72. Such systems are able to offer time-savings because of their simplicity. In essence they are based on a standard uniform bay, with an end bay variant. The only building form which can result is a straight "chain" of standard bays with an end bay at each end. If the building has to be formed of two or more bays laid side by side further variants have to be included in the system, and the more variants the more the time-saving benefits tend to be reduced. The diagram below illustrates in a simplified form the principle involved.



S Standard bay
V1 Variant to standard bay

73. In practice, even a "single-chain" system needs more than two variants unless the only doors are in the end-bay variant and all standard bays contain a uniform window. If bays are required without windows or if more than one window size is needed, so the number of variants will need to be increased. The greater the need to save decision time, the fewer the variants that are acceptable and the more severe the limitations on possible building form.



S standard bay
V variants needed (V1, V2, V3, etc.)
Note: V5 differs from V4 because both its external walls adjoin bays whose external walls lie in the same plane, whereas one of V4's external walls lies in a different plane from the one it adjoins. The same reason accounts for the difference between V2 and S.

74. "Single-chain" systems are broadly of two kinds: short-span and long-span. The short-span provides a building depth of about 7 to 9 metres and effective room heights up to about 2.80 metres. If space is the only consideration they will thus accommodate traditional classrooms for expository teaching, as well as laboratories, craft rooms or workshops, provided, of course, that all classrooms, etc. are related to each other as multiples of links in the chain. But, to mention only two examples of the effect of the lower performance standards common in many of these systems, the sound insulation will usually be inadequate to prevent disturbance between adjoining rooms, and if services, particularly water and drainage, are needed, their installation will require cutting and fixing to the prefabricated components, which will offset much of their inherent savings of construction time and probably produce an unsightly and inconvenient result.

75. The long-span systems, developed mainly for industrial premises, span from perhaps 15 to 24 metres and provide a clear internal height of 4.50 to 6.00m. Again, leaving aside considerations other than space, they are suitable for any educational activity which requires more space free of obstruction than a classroom for 30 or 40 pupils - such as indoor physical education and games, and, to a lesser extent, drama-tic activity. But as with the short-span sys-tems, environmental requirements other than space requirements - thermal and acoustic, for example - can only be met by considerable addition or modification, which offsets any advantages there may be in time and cost. Long-span systems are usually single-storey, whereas short-span systems often take a multi-storey form.

76. Unfortunately, when emergencies arise, the pressure to take decisions quickly is so strong that only the spatial character-istics of single-chain systems (of either kind) are taken into account, whereas other environmental characteristics (and short-comings) are overlooked, especially since they are so much less evident from drawings and brochures. Nevertheless, emergencies can sometimes be so demanding that the shortcomings must be tolerated. However, the use of such systems can only be recom-mended if no alternative standard system is immediately available, and even then only if the accommodation is necessary to supple-ment the resources of an existing school or to provide for a very limited first phase in the growth of a new one.

77. From this general recommendation we must except the case of a very small school of perhaps only one or two classes of 30 or 40 pupils each where the mode of teaching is still purely expository. But such cases are increasingly rare, both because of widespread urbanisation, with its demand for larger schools and the advantages they bring, and because purely expository teach-ing is no longer the sole mode of teaching in use and the general trend is away from it.

78. Many of the systems we have exam-ined, specifically designed for school rather than general purposes, have sought to over-come the environmental disadvantages of emergency buildings which have been men-tioned. But some of these systems have still retained the principle of the single-chain. Thus, while they are capable of pro-viding classrooms, laboratories, workshops, gymnasia, etc., which in themselves are satisfactory, they are not capable of pro-viding the kind of spaces which many modern educational methods require.

79. Two notable features characterise these methods as far as building is con-cerned. The first is the reduced impor-tance of the "class" as the teaching unit, so that, whereas formerly every pupil was taught for almost the whole time as part of a class of 30 or 40 in number, he now spends much of his time as part of a much smaller group or working individually on his own, or a hundred or so pupils may join temporarily together for instruction as part of a very large group. The second feature is the wide variety of activities which may occur either in rapid succession or even simultaneously. Some of these activities may occur in the same undivided space, while some, which would disturb or be disturbed by other activ-ities, or which demand a special environ-ment, occur in spaces exclusively reserved for them.

80. Modern education is subject to so much experiment and to such rapidly chang-ing developments that no suggestion can be made as to the best way of providing for these two major features, but one example which has resulted from detailed study of modern methods will serve to illustrate them.

IMPLICATIONS FOR FORM OF PLAN AND SECTION

81. Figure 3 shows the block plan of an English secondary school which has been recently extended in order to increase the number of pupils accommodated and to cater for the wide range of educational activities associated with comprehensive education for the 11 to 18 year age group. The ex-tended building consists of the original building and a number of additional separate blocks, each tailor-made to a different set of requirements.

Figure 4 shows the detailed plan of one of these blocks which is intended to serve as the headquarters of the 11 to 13 year olds. This age group will use other parts of the total complex but will spend the greater part of the school day in their head-quarters.

82. Only three of the spaces in this block (accounting for only about 12.5 per cent of the floor area) in any way resemble or can be used as traditional classrooms. Yet the number of pupils which the block may accom-modate at any one time can be the equiva-lent of about eight or nine classes. This means that at any given moment some two-thirds of the pupils are engaged on activities

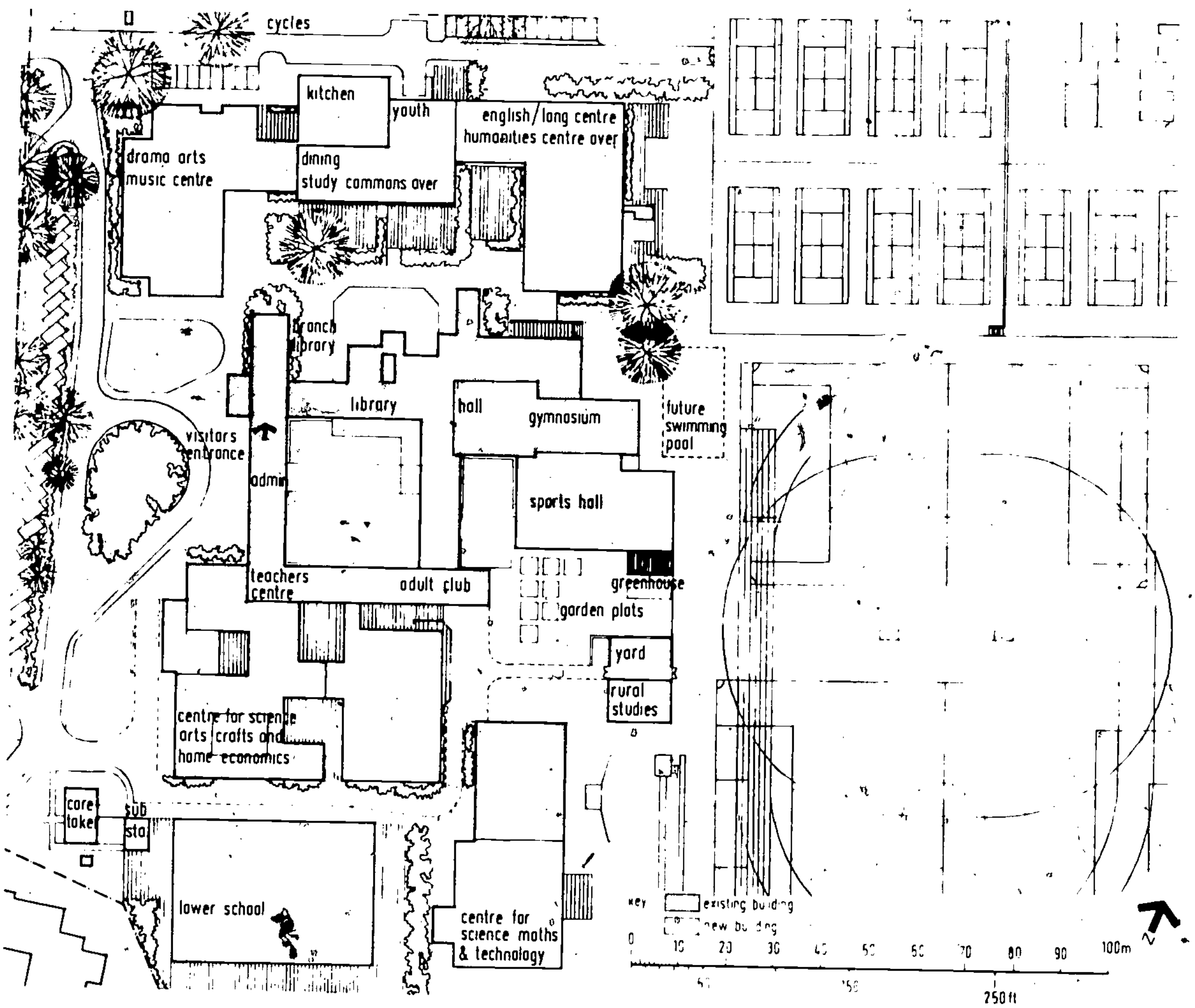
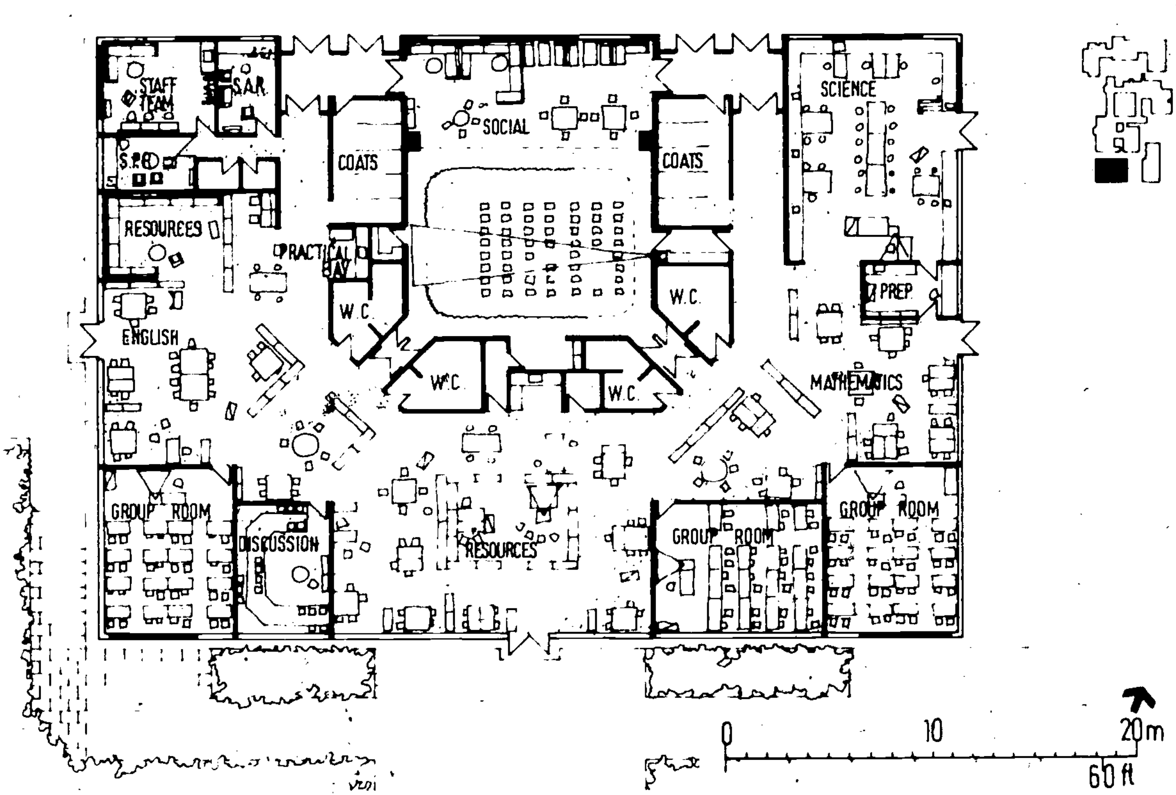


Figure 3. Block plan of a secondary school

outside the traditional classroom, with perhaps two classes grouped together in the auditorium in the middle of the north side of the block, another class in the science laboratory, and the remaining third disposed in the free-flowing spaces surrounding the southern half of the auditorium. All the pupils in this remaining third will be working either individually or in groups of two or three. Each may have a place at one of the tables as his working base, but will move frequently and freely over to one of the resource areas to consult a book, to project a film strip, or perhaps to work at a computer terminal; or, he may go to get help from one of the several teachers who will be working in the same general space. From time to time one of these teachers may gather a small group of pupils together and go with them into the discussion room to talk over the results of their work.

83. Not all the activities pursued by the 11 to 12 year olds in this particular school will take place in this particular block which is their headquarters or base. They will move to another part of the building for music and drama, for example, or for arts and crafts, or for physical education. But it will be noted that in this one block alone quite a variety of accommodation is provided. Some of the accommodation has special environmental requirements, like the auditorium, or needs special servicing like the science laboratory. Other parts like the group rooms or the discussion room need aural and visual privacy so that class and teacher can be undisturbed and will not

Figure 4. Headquarters of the 11 to 13 age group in the school shown in Figure 3



disturb the individual work going on in the general space; and each of these reserved spaces needs particular dimensions to suit the size of group which occupies it.

84. As important as variable size of teaching unit and as environmental differentiation, and inextricably linked with both, is the fact that the duration of any particular activity is also variable. Where the class remains as the principal teaching unit the teaching day tends to be subdivided into periods of equal length, with any particular activity lasting for only one period at a time or at the most for a double period. But in the kind of modern teaching for which the example is intended an activity may last from only ten or twenty minutes to a whole morning. Thus one group of pupils may spend only ten or twenty minutes in a group room while it is "briefed" for individual work in the "general" area which may continue for several hours, or which, for some of the pupils, may be interrupted by a session in the laboratory. Another group may start the day in the general area and then join another in the auditorium to watch a film for perhaps 35 or 40 minutes. A third may spend two conventional 40-minute periods consecutively in the group room on the type of question-and-answer learning which typifies older methods (1).

85. The main consequence of such a range of learning situations is increased movement by both individuals and groups. This in turn makes desirable the minimisation of travel distances between one kind of accommodation and another which is a major determinant of the "deep" plan illustrated.

86. Now it may be thought that a simple rectangular block of this kind could perfectly well be provided by means of a long-span single chain system. This would indeed be so if the system were able to span the 29m.

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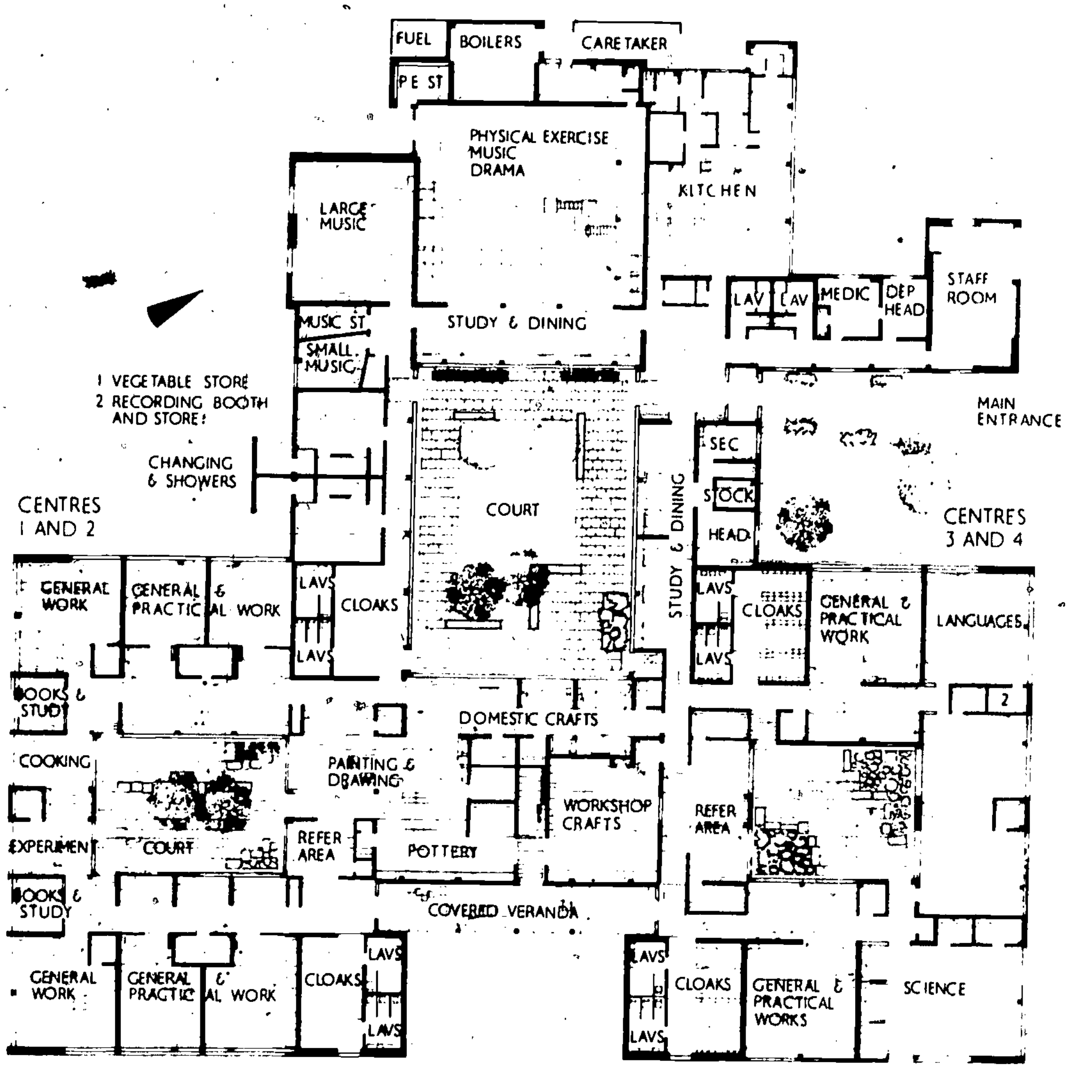
1) In practice not all the working stations are occupied at the same time, some are always free; otherwise such flexibility in activity duration would be impossible. Roughly 280 working stations are provided in this example for a nominal 240 pupils based in the block.

(97 ft.) represented by the shortest overall dimension of the block. But such a span could only be obtained by means of very deep and expensive beams. To avoid this an arrangement of intermediate supporting columns is needed, and a system is needed which provides for them. Furthermore, a deep plan of this kind poses problems of illumination; for adequate natural lighting of space remote from the windows roof lights are needed and the system must provide for these also.

87. Figure 4 illustrates only one block of a complete building. Figure 5 illustrates a complete building intended for 240 children of the 9 to 13 age group (4 year cycle). Designed for a somewhat different mode of teaching, the general and practical areas are sub-divided into spaces suitable for class-unit teaching, but nevertheless, outside each "classroom" are bays of varying length in which individuals or small groups may work on their own. And, just as in the previous example, these general areas need to be closely related to the "reserved" areas for more specialised purposes such as cooking, painting, pottery, workshop crafts and so on. Because teaching space is always at such a premium, advantage has been taken of what in this case is a favourable outdoor climate to provide three internal open-air courts and an external verandah into which activities can overflow or which can be used

Figure 5. A self-contained school building for 240 children aged 9 to 13



for the study of plants, small animals and birds. Note also that the space for physical education, music and drama (roof-lit as well as side-lit) is about four times the size of any of the class work rooms, with the consequence that it also needs to be higher.

To provide a building of this kind a system not only needs to provide various spans, it also needs to provide various roof or ceiling heights and to provide for internal as well as external corners.

88. Both examples so far shown are of single-storey forms. If sites are large enough much of the accommodation needed for modern primary and secondary education will preferably be at ground floor level. The reason lies in the need for easy inter-communication between the various kinds of accommodation which tends towards the deep plan (even the second example, with its internal courtyards is "deep" compared with a single or double-banked corridor plan) and the consequent need for roof lighting if natural lighting is desirable; and if natural lighting is dispensed with then other problems of both artificial lighting and artificial ventilation militate against such plans in multi-storey form. Nevertheless cases occur, and in secondary education they occur frequently, where to confine the whole of the building to single-storey construction would not only be wasteful of land but would extend the building beyond the limits where horizontal inter-communication was easier than vertical.

89. Thus for some cases systems need to be capable of providing for multi-storey as well as single-storey constructions. At the same time, the need for easy inter-communication between the various parts of the school demands that the multi-storey part should not have to be confined to a separate isolated block or blocks. The kind of interfacing which may be needed between multi-storey and single-storey accommodation of different heights is exemplified in Figure 6. And not only may storey heights and numbers need to vary but, except where flat sites are general, the system may need to be able to provide for changes in ground floor level also.

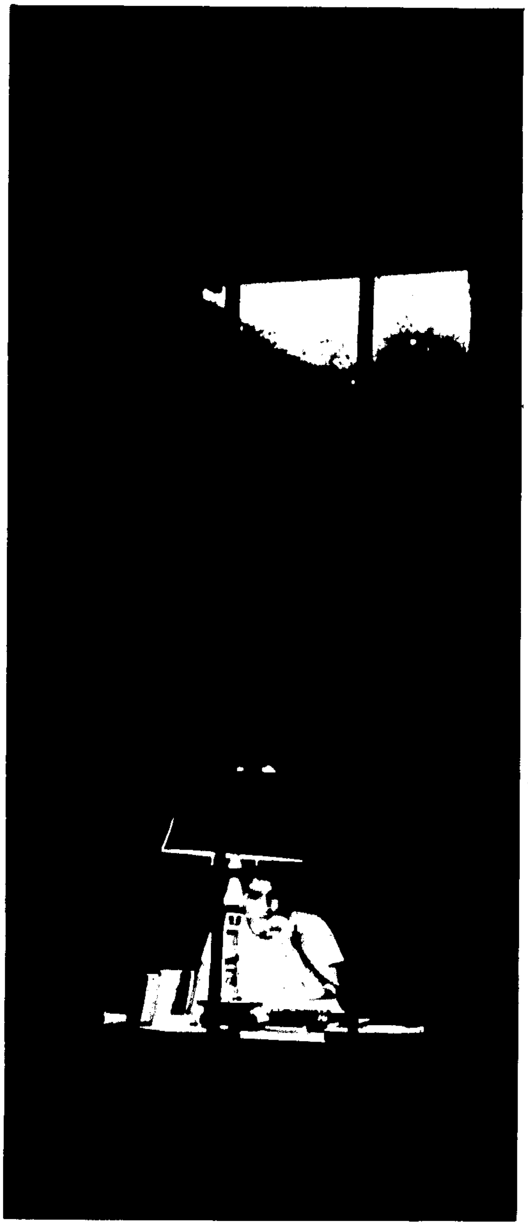
Figure 6. Interfacing between multi-storey and single-storey accomodation of different heights

Figure 7. Another example which allows for change in floor and roof levels

IMPLICATIONS FOR INTERNAL ENVIRONMENT

90. So far we have mainly been discussing the implications of modern educational methods for the forms that a system may have to provide for in the plan and sections of a building. We have mentioned in passing, however, (paragraphs 79 and 83) the needs these methods impose for a range of different environments suited to different activities. Painting, clay modelling or pottery, for example, clearly demand a different environment from, say, a group discussion room. The latter needs a floor finish which is warm and comfortable, and artificial or natural lighting which is domestic in character. The craft space on the other hand needs a floor finish which will not simply be easy to clean but which will not inhibit activities which are necessarily messy. (We have noticed many examples where carpeting has been provided in such spaces, the

architects claiming that it was no more expensive and just as easily cleaned as any alternative, but the teachers feeling constrained to cover it with untidy polythene sheeting). And it needs a form of lighting which not only provides sufficient illumination, but the right kind - both for the painting and for revealing and modelling the three-dimensional form of pottery or sculpture. Uniformity of environment throughout a school restricts the range of educational opportunity, yet some building systems we have seen go to great lengths to provide it. And what applies to floor finishes or lighting applies equally to acoustics or the thermal environment - the acoustics of a music room need to be different from those of a general work space, just as the heating and ventilation requirements of a sedentary activity differ from those of an activity like craft or dramatic work.



Figures 8 and 9. The range of school activity spans from the solitary pursuit of scholarship - outdoors as well as in - to boisterous group competition or group co-operation

IMPLICATIONS FOR SERVICES

91. Services fall broadly into two categories: those such as heating, ventilation and lighting which are usually needed for any kind of building and secondly those which distribute the electrical power or water needed for specifically educational purposes. Modern education increasingly relies on devices such as audio-visual aids and has introduced practical work into subjects like history, geography and mathematics which once were learned almost solely from books. As a consequence power and water supplies (and the drainage associated with the latter) are needed to a much greater degree than formerly and, moreover, need to be widely dispersed throughout the building rather than concentrated in one or two highly serviced areas, although, of course, some areas, like those for science or craft work, may still be more highly serviced than others. Unless the building system is designed to permit the easy installation of these services it is likely that construction time saved by the system will be offset by extra time needed for the services and the finished result will be cumbersome and unsightly.

APPEARANCE

92. Sometimes ugliness is excused on the grounds that it results from economic exigencies or the function the building has to serve. But the cultivation of visual awareness and aesthetic sensibility is as much an objective of education as the provision of knowledge and skills. So a school building which is ugly can not be excused on economic or functional grounds since it is not functioning as well as it should. We have seen some schools built in industrial systems to which this stricture certainly can not be applied, and where indeed the visual environment provided by the school is perhaps the first aid to aesthetic education that the children attending it have ever enjoyed. But we have seen too many school buildings where, internally as well as externally, the need for visual quality has been forgotten in the search for technical solutions to utilitarian problems.

93. Whether a building is visually pleasing is often dependent on how well it "fits in" with its surroundings. Unless, of course, the surroundings are themselves ugly, it needs to be sympathetic to the genius loci. Failure in this respect is common with modern building, industrialised or not. But in recent years the concern to remedy it has rapidly increased. It is particularly important, however, in the case of industrialised building systems, since buildings constructed in them may be built in a number of different localities each of which has a special architectural character of its own. To the extent that this is so, a system may need to include a number of alternatives in those components which affect external appearance.

PROVISION FOR FUTURE CHANGE

94. The characteristics of modern education outlined above are representative of a growing trend, but the manner in which they are interpreted or practised varies from one country to another, or even from one locality to another according to teachers' preferences and their perception of educational objectives and how best to meet them. Furthermore, in each case they have developed over the years according to different patterns. In all cases they are developments away from a starting point represented by book-learning and class-unit expository teaching. Some countries, because of prevalent attitudes to teacher-training and other aspects of the management of education, have moved much less far than others from the common starting point. And in all countries some individual teachers remain closer to the starting point than others and may tend to resist change and innovation to a degree where they could not be expected to work effectively or at ease in buildings designed for teaching methods which lie outside their experience. On the other hand, there is no evidence that the pace of educational change is slackening. On the contrary, since effective education must respond to social and economic change, the almost violent changes now occurring in industrialised societies suggest that the educational change in the next decade or so may be even more marked than in the last. From these considerations emerge two points significant for school buildings and building systems. These two points are in a sense two horns of a dilemma.

95. First is the recognition that to be effective a school building must suit the educational methods prevalent when it is brought into use. Secondly, we have the inconvenient but incontrovertible prospect that such a building will outlive the methods for which it was originally conceived and may then

handicap and certainly inhibit subsequent developments.

96. Another activity in the OECD Programme on Educational Building is devoted to this critical problem of providing for future change, and for an account of the investigations which have been conducted readers will need to refer to the report on that activity (1). All that is possible in the present context is to draw attention to those of its conclusions which are relevant to industrialised building systems.

97. The activity has shown that a distinction can usefully be made between the adaptability of a building on the one hand and, on the other, its flexibility. Adaptability is the capacity for physical alteration by relocation, replacement and removal of components or by the addition of further components. Flexibility is the quality of a building as it exists at any point in time which allows for change in the pattern of activities it accommodates without recourse to physical adaptation. Thus the greater the flexibility the longer the need for adaptation can be postponed.

98. Flexibility depends on three factors: the diversity of accommodation included in the building; the balance between general work spaces and the specialised work spaces - which themselves constitute the diversity; and the spatial inter-relationships between the general and the specialised. In other words it is a function of content and planning, not of the manner of construction or of the building sy em. Despite this flexibility has implications for building systems. Buildings planned on corridor lines for educational modes near to the expository starting point are unlikely to provide for the diversity, balance and inter-relationship of accommodation needed for a high level of flexibility. Thus if future change is to be provided for, systems intended for these educational modes need to provide for adaptability even more than those intended for more "modern" modes.

99. The most striking fact that has emerged from studying developments directed towards increased adaptability is that they almost invariably regard the relocatability of partitions as a prime objective. Very little attention has been paid to adaptability of external walls or roofs or upper floors. The assumption has been accepted without question that the demand for physical alteration arises from a need to alter the pattern of internal spaces which partitions demarcate and separate, and that the occupants of school buildings frequently want to change the size and shape of rooms. But this importance placed on partitioning is based on an almost total misconception of the real educational need.

100. Certainly, the study has revealed real cases of adaptation where partitions in an existing building have been pulled down to make a larger space, or where new ones have been inserted for sub-division. But substantial evidence shows that the size and shape of spaces is for most teachers a very minor inhibition when they seek to change their educational methods or introduce new activities. The only notable exception is where classrooms designed for expository teaching prove too small for the more active learning processes which increasingly characterise modern education, particularly for the younger children. This exception apart, the demand is usually first for extra services, especially water supply and drainage serving additional sinks for purposes of painting or clay-modelling or for scientific "experiments"; or for electricity supply, to illustrate aspects of science again, or to facilitate the use of audio-visual aids. The same desire to extend the range of educational activity creates a demand for different kinds of floor finish - which for example will not inhibit "dirty" activities or conversely which will encourage children to sit on the floor as they might sit on a fireside rug to listen to a story told at home - some are fortunate enough to have that kind of home, and the facility is even more important for the less fortunate. The demand may equally be for new light sources or for darkening a naturally lit room in order to see slide or film projections, or for extra sound absorption to reduce the noise level resulting from the active learning processes referred to. These are the demands which adaptability if it is to be useful must turn to satisfying.

101. Misplaced emphasis on the relocation of partitions has tended to cost money which would have been better directed towards other objectives. The partitions themselves have cost more, and costs have also been increased by using much larger beam spans than would otherwise be necessary in order to allow maximum latitude for future partition location. Furthermore, to facilitate relocation, uniform floor to ceiling heights and uniform floor and ceiling finishes have been used throughout the buildings concerned, directly contrary to the need for diversity

1) Providing for Future Change: Adaptability and Flexibility in School Building, op. cit.

which modern education demands and to the flexibility needed to facilitate change of activities.

102. The study has suggested a strategy for maximising adaptability without higher first costs or sacrifice of diversity for present needs. In essence this strategy may be summarised as resting on a policy of "pay-as-you-go" rather than of "pay-in-advance". To spend money on maximising the relocatability of any component in the building is to pay in advance. To defer any expenditure until adaptation is actually needed is to pay as you go. The strategy to be adopted is to design what is needed in the present in such a way that, without incurring additional first cost, expenditure on subsequent adaptation will not be increased by the nature of the initial provision. Relocation is less important to adaptation than replacement, removal, or addition. As a consequence, the evidence points to the need for buildings in which some elements are permanent and unchanging and to which other elements can be added, removed or replaced as and when the need arises. Here the common technology of structural frame rather than load-bearing wall is an obvious starting point. But above all, efforts to facilitate adaptability need to be directed mainly towards additions to service installations and towards the removal and replacement of finishes and fittings.

CONCLUSIONS

103. Taking account of the wide range of educational buildings for which any industrialised building system may need to cater, we can now draw a number of conclusions concerning the selection or design of such systems if they are to meet the criteria implicit in educational needs now and in the future.

a) A building system is only as good as the buildings which its limitations allow to be built. So the most thorough investigation of its capabilities is needed before a system is chosen: or if a new system is to be designed an equally thorough investigation is needed of all the educational requirements it will have to meet.

b) The simpler the educational requirements the greater the limitations which can be accepted and provided all sites are flat or nearly so, this simplicity may even allow for some form of "standard plan" which will in turn allow the system to be simplified still further.

c) Even where current educational requirements demand no more than a very limiting system or even a "standard plan", great caution is needed before accepting such limitations since they are likely to militate against meeting the needs of future change.

d) A capacity to meet the needs of future change is an important criterion in all school buildings. But in meeting these future needs, diversity of educational environment in the original building is more important than large spans or relocatable partitioning or similar devices that facilitate rearrangement of internal spaces. Second to this diversity the most important criterion for future adaptation is a building's capacity to accept additional services for ventilation, electricity and water supply and drainage.

e) The design of a system must take into account the extent to which educational circumstances demand that it shall allow for a wide range of:

   i) horizontal and vertical dimensions of individual spaces ranging from those of the scale found in housing (staff rooms, seminar rooms) to those of the scale more usual in industrial premises (e.g. for physical education or sports) and including many intermediate scales not found in either housing or industrial premises, nor in office-type accommodation;

   ii) overall plan form - in order to integrate outdoor as well as indoor educational spaces, in order to maximise the "fit" between building and site and in order to ensure the right interrelationship between individual spaces;

   iii) possible storey heights and interfaces between blocks of differing storey height;

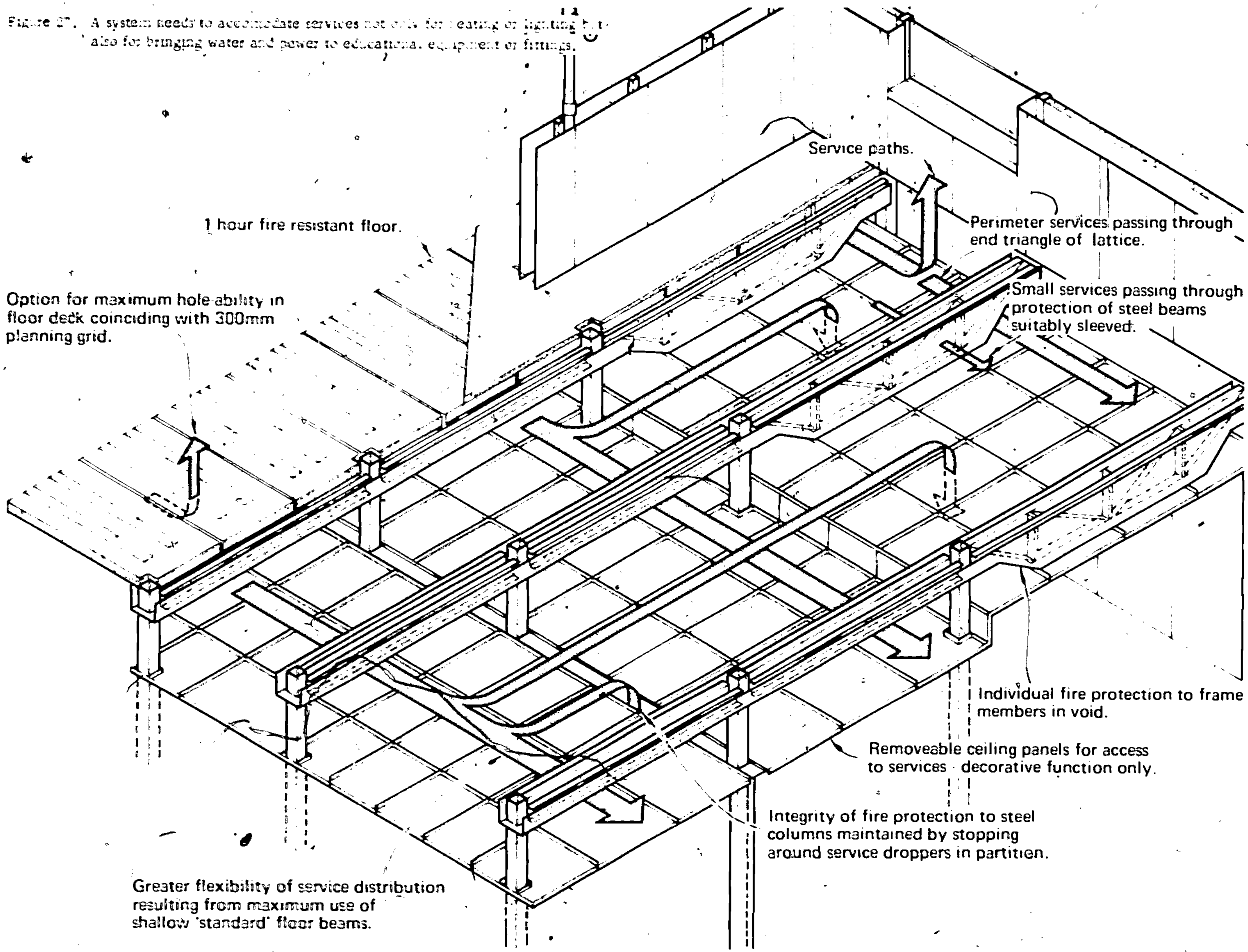
   iv) lighting (artificial and natural), acoustics and thermal environment to suit each educational activity, all of which may have several different requirements;

v) servicing provision, especially in respect of electricity, water supply and drainage which need to be more widely dispersed than in either housing or offices and which pose greater problems of integration with the structure than in the case of industrial premises;

vi) finishes and fittings, with due regard to subsequent replacement;

vii) alternatives for satisfactory visual appearance.

Figure 2?. A system needs to accommodate services not only for heating or lighting but also for bringing water and power to educational equipment or fittings.



Chapter V

NEEDS OF PLANNED EXPENDITURE AND OUTPUT

CONFLICTS OF COST, QUALITY AND TIME

104. Where educational building is the only need that a society feels obliged to meet, and if the need is sufficiently compelling, the tendency is for political pressure to insist that the considerations of cost are secondary to those of quality and output. While no case has been encountered where such a tendency has led to complete disregard of costs, cases have certainly been found where school building represented far the major local need and where the determination of a community to provide the "best possible" school for its young people outweighed any anxiety over cost. The tendency is most marked where school building is solely a local responsibility and where for the community concerned a new school building is an isolated historical event occurring only once or twice in a lifetime. Such communities also tend to be prepared not only to spend money but also to wait patiently for the desired result. For such communities expenditure-and-output-planning is of little significance, and any advantages they gain from industrialised building will have no connection with it. But such cases are comparatively rare.

105. By far the majority of cases, even where school building is a local responsibility, are those where educational building competes with other needs, where financial resources are limited, and where the needs must be met within a limited time if existing schools are not to be intolerably overcrowded. The larger the school population to be housed the more acute the twin pressures of cost and time. And for all such cases expenditure-and-output planning is highly significant.

106. Where this is so it is not enough that building systems should produce buildings of the right kind: they must provide such buildings at a cost and at a rate of output predetermined by an expenditure plan. Before identifying the criteria for systems which this implies, it is necessary to consider two alternative strategies for resolving the conflicts between cost, quality and rate of output.

QUALITY/COST BALANCE

107. What should be the limit of expenditure, what constitutes acceptable quality, and what represents sufficiency of number (or in other words, tolerable overcrowding) are all matters for political decision - however political decisions may be reached in any particular instance. But whereas budget limitation is capable of precise definition, quality is much more difficult to define, and overcrowding so politically delicate that how much is tolerable can never be predicted but only tested by the event. Thus the natural pressures on any school building agency are to put budget limitation as the priority and then to keep quality to the politically acceptable minimum, so that the maximum quantity can be obtained within the budget, if not within the period to which the budget relates.

108. To submit to these natural pressures is, however, to neglect certain important considerations. First, the level of quality which is politically acceptable probably reflects a misunderstanding of the real requirements of educations, which if adequately defined might persuade financial policy-makers to raise the budget limit. Secondly, the number of schools obtainable for a given expenditure is not solely a function of their quality. For any level of quality the number can be increased if architects make a determined effort to plan each building as economically as possible, and if educationists make equal and continuous efforts to ensure that habit does not retain redundant accommodation in the schools which are planned, especially when education is demanding new kinds of accommodation to meet new needs.

STANDARD PRODUCT STRATEGY

109. A number of countries have been mindful of the two considerations just mentioned and have therefore attempted to define real educational requirements and the most economical way of meeting them as precisely as possible. To this end they have prescribed in the utmost detail the accommodation to be provided in schools of standard sizes, the number and kind of rooms or spaces, their dimensions, the size of windows and sometimes the type of construction and finish. Other countries have not gone so far but at least have proceeded down the same road, stopping only at a less precise stage of detail. They have then said in effect "This, no more no less, is the kind of school we want. What it costs depends on current prices and, according to market fluctuations, we will thus get as many schools as the global budget will allow. If at the end of the day we are left with overcrowding at least we shall have satisfied both taxpayer and educationist." With this strategy the buildings produced are as nearly as possible of a uniform standard, but the number and cost of each is allowed to vary. We can dub it the standard product strategy.

110. Such a strategy is not only unsatisfactory in leaving overcrowding as a function of market conditions, it also overlooks further important considerations. The first is that no definition of quality (i.e. of "the right kind of building") can be absolute, and that educationists, who are as hampered in their activities as much by overcrowding as by shortcomings of the physical environment, are willing to consider alternative ways of meeting their requirements if, by doing so, they can lessen the risk that too few schools will be built. And, in practice, because the variables in providing an educationally acceptable environment are so numerous, a wide range of alternative solutions are possible. If, therefore, a limit of cost is set for each individual school, educationists can to a large extent trim their requirements accordingly. The same is true of architects for whom an equally wide range of alternatives is open, first in spatial arrangements which together with educational need, govern the total floor area needed; and secondly in the combinations of building components, some cheaper than others, which go together to form the total building. In short, there is no hard dividing line between the acceptable and the unacceptable but, rather, a wedge of opportunities which increase and decrease according to how sharply costs constrain them.

STANDARD COST STRATEGY

111. Now no country has found any incentive powerful enough to persuade educationists to reduce their demands to a minimum or to persuade architects to meet them at minimum possible cost. Some countries, however - notably England - have found that both educationists and architects respond well if given the opportunity to get the best building they can within a given limit of cost. Knowing that they will get no building at all if they exceed this limit, they have every incentive to keep within it. Knowing that they cannot, so to speak, "keep the change" if they spend below the limit, they have every incentive to get maximum value for the money allowed. This psychology has enabled the countries concerned to adopt an alternative strategy which recognises that standards of quality may vary from the thick end to the thin end of the "opportunity wedge" but that costs for individual schools can conform to a single standard. If a majority of schools approach too closely to the thin end of the wedge consideration can be given to raising the cost standard. We shall style this strategy the Standard Cost strategy (1).

1) The successful application of this strategy depends not only on the skill of the designer in limiting the size of the building and in ensuring that all components are used as cost-effectively as possible, but also on how accurately costs can be predicted for the supply and erection of the components which are used. With rapid and excessive inflation experience has been that the necessary degree of accuracy has no longer been possible to attain. Thus the British Department of Education and Science has now (1974) been obliged to put its standard cost strategy into temporary abeyance. Nevertheless, the fact that such a strategy had been operated with success for more than twenty preceding years has created a climate of cost-consciousness among educationists and designers alike which seems to ensure that school building remains broadly cost-effective without the need to fall back on the alternative of a standard product strategy.

EFFECT ON RATE OF OUTPUT

112. Of course, with the standard product strategy consideration can be given to increasing global budgets if rising prices result in a shortfall in the quantity of standard products. But the standard cost strategy, by relating the quantity rather than the quality to the global budget, reduces the risk of shortfall and is more useful, therefore, in reconciling the conflicts which exist, not only between financial restraint and educational desiderata, but between these and the need to meet a planned rate of output. In short it is a strategy which goes further towards ensuring that planned expenditure gives the planned return, in quantity related to time as well as in quality. It enables the strategists to say "We have satisfied the taxpayer, we have satisfied all educationists (even if some are more satisfied than others), and we have also minimised overcrowding." And it has the further advantage that educationists are obliged to order their preferences more carefully and to re-order them as educational change and experience suggest.

COST CONTROL CRITERIA FOR SYSTEMS

113. The standard product strategy, taken to its logical conclusion, results in buildings conforming to a series of standard designs. It thus tends to be more appropriate to that stage of educational development where educational activities are still limited in scope. If it is adopted, the criteria systems must meet are obviously dictated by the standard designs and nothing more need be said of them. A standard cost strategy, on the other hand, encouraging as it does a carefully considered ordering of preferences, is more appropriate where educational practice has become widely diversified in its activities, and where political and managerial circumstances permit such a strategy to be adopted. Application of the strategy depends on cost control at the design stage over varying individual buildings, and it is from the needs of cost control that further criteria for systems emerge.

114. The most powerful determinant of cost in any individual building is the total volume enclosed. Therefore in maximising value for money within a standard cost the more finely the volume can be adjusted the more firmly it can be adjusted to the cost requirement. Because wall and sometimes roof components tend to be standardised in larger sizes than in alternative methods, the increments by which the building volume can be enlarged or reduced are coarser. They range from cuboids of, say, 0.90m x 0.90m x 0.30m (CLASP) to as much as, or even more than, 7.20m x 7.20m x [illegible].00m (BALLOT and other French systems). No evidence exists to suggest that a smaller increment than the former is needed, nor that the smallest increment can not be larger. All that can be said is that the difficulties of meeting a standard cost tend to rise with increase in increment, and the contribution of a fine increment to cost control is even more important than its contribution to freedom of spatial planning. An important criterion is thus that the volumetric increment of a building system should be consistent with the cost control procedures which apply to buildings where it is to be used.

115. Reference has already been made to cost variations consequential on the mix of more and less expensive facilities in a school, a mix which is partly a reflection of educational choice, which of course is of prime importance in meeting a standard cost. But Chapter III (paragraph 38) has also mentioned the importance of architectural skill and suggested that some systems may hamper, others ease, its application in interrelating one facility to another in the most economical way. Thus a further criterion for a school building system is that it should facilitate the interlocking of facilities of different shape, dimension and environmental character.

116. The cost determinant of an individual building which is the most difficult to control is the cost per unit of floor area. [Total cost = cost per unit of floor area (square foot or square metre) x total floor area]. Despite the difficulty it is nevertheless susceptible to control by the architect. Because some building components are more expensive than others, the skilled architect can choose the most cost-effective mix available within the permissible limit allowed. His freedom to exercise this skill is however dependent on whether the system meets two further criteria.

117. These are:

a) that the system contain a range of alternatives each representing a different grade of cost-effectiveness - so that the mix of high quality/high cost and lower quality/lower cost can be adjusted across the "opportunity wedge" which divides the acceptable from the unacceptable - in terms of the building fabric as in terms of educational need. Here quality will embrace considerations of durability, appearance, ease of maintenance, environmental comfort and the balance between capital and running costs. The wider the range of alternatives contained in a system the greater the freedom to manipulate costs.

b) that the cost of the components, supplied and assembled be known at the design stage. Here the limitations of choice imposed by an industrialised building system offer an advantage over alternative methods. As Chapter III has implied, the familiarity which results from standardised repetition enables costs of both production and assembly to be more accurately predicted.

118. In defining industrialised building we have said that it is distinguished from alternative methods in that (among other things) it incorporates a dominant proportion of standardised and repetitive components, and that "dominant" implies some limitation on the forms that buildings may take. But what is dominant for the final form may be less significant for costs. In many buildings which by our definition are industrialised the industrialised proportion may still leave an unindustrialised proportion to which the predictability and consequent control of costs does not apply. Thus another important criterion relates to the extent to which the system governs the total building cost. Experience suggests, however, that to industrialise all elements can in some cases increase costs without any compensating increase in predictability. This can be true especially where the alternative method is well-tried, the basic materials are cheap and the required labour and skill are in adequate supply.

OUTPUT CONTROL CRITERIA

119. As with costs, so with rate of output: the extent to which an industrialised building system affects the completion time of whole buildings depends largely on the proportion of the whole it represents. However, Chapter III (paragraph 49) has referred to the fact that the use of a system will only affect total construction time insofar as its operations lie on the critical path through the whole operational network. Thus the final criterion related to planned output against which a system can be assessed is the extent to which it accounts for those operations in the assembly sequence on the progress of which other operations depend for their completion.

CRITERIA SUMMARISED

120. The criteria implied by the needs of expenditure/output planning can now be summarised as follows:

a) Where a standard product strategy applies, the system must be capable of providing schools to standard designs.

b) In all other cases where a standard cost strategy applies the following criteria must be met.

i) the volumetric increment of the system should be consistent with the cost control procedures which apply to buildings where it is used;

ii) the system should facilitate the interlocking of facilities [cf. Chapter IV, paragraph 103(e) (i), (ii), (iii)] of different shape, dimension and environmental character;

iii) the system should contain a range of alternatives each representing a different grade of cost-effectiveness;

iv) the cost of the components supplied and assembled be known at the design stage;

v) the system should be the dominant determinant of the total building cost;

vi) the system should be the dominant determinant in the completion time of the total building and should therefore account for the key operations on which other operations depend for their completion.

121. None of the systems which have been reviewed meets in full the criteria which have been identified in this chapter, but some come closer to meeting them than others. In fact, some of the criteria can not be met entirely by the characteristics of the system itself; some depend on the conditions which are provided by processes of purchasing or financing of school buildings - that is to say, by procurement processes, the implications of which form the subject of the following chapter.

Chapter VI

PROCUREMENT - PURCHASE AND SUPPLY

122. In discussing the potential benefits of industrialised building we have stated that for the potential to be realised certain conditions must be fulfilled. The same applies to ensuring that the system is capable of producing the right kind of building and that this capability is taken full advantage of in ways consistent with the requirements of planned production. Some of these conditions concern the working relationships between the numerous interests involved - educational and financial planners, educationists themselves, designers of systems and of individual buildings, component and system producers, and building contractors and sub-contractors. We shall deal with conditions affecting these relationships in Chapter VII. In the present chapter we are concerned with conditions which affect arrangements for the purchase and financing of industrialised buildings if standard systems are to meet the particular needs of educational building.

CONDITION 1: EDUCATIONAL REQUIREMENTS TO BE IDENTIFIED

123. In Chapter IV we have drawn attention to the widely varying characteristics which different educational methods may assume as they move away from the common starting point of expository teaching in the direction of more diversified learning activities. We have also pointed out that, at a given point in time, the methods prevalent in different countries will each be at different distances away from the starting line; and we have argued that while allowing for future change present needs must still be met. Thus no single form of building can be universally recommended: the right kind of building is that which at the moment it is occupied suits the requirements of the most advanced educational developments in the country concerned, according to the type and level of education to be served. Therefore the first condition to be met is that these requirements shall be identified in terms of the range mentioned under Conclusion (e) at the end of Chapter IV (paragraph 103).

124. For many of the systems we have examined, little effort has been spent on the identification of these requirements. The reason is that the educational modes for which the systems were intended were still close to what we have called the "starting point". Both the designers of the systems and the school building agencies concerned were able to assume that existing school buildings represented satisfactory models and it would be sufficient if the system could produce individual buildings conforming to those models. In some instances the mode is still unchanged so that the resulting buildings are satisfactory for it; but in other instances the mode has already moved away from the starting point to an extent where the resulting buildings are proving increasingly less satisfactory and modifications to the systems are being called for.

125. In the case of some systems - CROCS is an example - the architects responsible for their design have not been content to take existing schools as models but have preceded the design by a more fundamental study of educational practice, only to reach the same conclusion for the same reason. However, by virtue of studying other educational practices outside the locality for which the system was intended they have anticipated that the local practice would eventually undergo changes and have tried to provide a system capable of meeting them by adaptation of the resulting buildings. Somewhat ironically, in these instances too little change has yet been called for to provide evidence of either success or failure of the system in this respect.

126. In yet another class of systems - of which CLASP is an example - the architects responsible have again examined educational practice as it is carried on in existing schools but have found that the practice has indeed moved further from the starting point than it had when the schools were built, with consequent difficulties and obstacles to the conduct of educational activity. They have consequently looked at the implications for the design of individual buildings and from

these extrapolated the criteria which the system must meet. Where this has happened the resulting buildings have also been subjected to recurrent examination and subsequent improvements made to the system.

127. There is a final class of system where the system designers, without entirely ignoring any current practice, have taken the view that all current practice is inevitably ephemeral and that the ability of the system to meet future change should outweigh all its other characteristics - SEF is the prime example here. Unfortunately, however, they have seen this ability almost entirely in terms of changing spatial arrangements by the relocation of partitions rather than in terms of extending or varying the range of environmental opportunity. As will have been noted from Chapter IV (paragraphs 97 to 103), we regard emphasis on this aspect of adaptability as misplaced.

CONDITION 2: REVIEW OF COST CONTAINMENT POLICIES

128. As we have said in Chapter V, educational requirements can not, in practice, be stipulated without regard to the finance available for meeting them, and there is no hard line dividing the acceptable from the unacceptable, but rather a wedge of opportunities which increase or decrease according to the constraints of cost. Whether cost containment policy is based on a "standard product strategy" or on a "standard cost strategy" (see Chapter V, paragraphs 109 and 111), there is usually a measure of understanding on what constitutes an acceptable cost level, which may be relatively vague in some countries and relatively precise in others, but which is largely shared by all concerned. Usually it is an understanding based on precedent, that is, what schools have cost in the past is taken as an indication of what, with regard to current price levels, they should cost in the present. Carried too far a precedent-based policy can be as much a reductio ad absurdum as if the costs of education were conceived solely in terms of teachers' pay without regard to the cost of books, scientific and technical apparatus or any other teaching aids required as educational practice moves from its expository origins. As essential, therefore, as the recurrent modification of building systems are recurrent reviews of cost containment policy. In the course of these reviews evolving requirements of education and their consequences for "right kinds" of building need to receive as serious attention as changes in price levels; and the result of the reviews need to be such that educationists and the architects serving them can then cut their coats according to their cloth in the knowledge that all factors have been taken into account in striking a feasible balance between aspirations and resources.

129. What has just been said applies with equal force whether industrialised building systems are to be used or not. Nevertheless successful application of such systems can not be expected if the cost constraint policy is so harsh that the right kind of building can not be produced by any method at all. For this reason we draw attention to a second condition of success :

> Cost containment policies associated with the financing of educational building need to be recurrently reviewed in order to maintain an acceptable balance between cost, quantity and the qualities needed for the "right kinds of school".

130. The conclusion can not be avoided that in almost every country financial pressures tend to result in neglect of these quality considerations so that when reviews take place it is the change in price levels alone which receives consideration. This is particularly so where no adequate mechanism exists for articulating and expressing the claims of education, but it is suggested that in all cases it is worth asking whether cost restraint, undoubtedly necessary in itself, is not in conflict with the equal necessity for cost effectiveness.

CONDITION 3: PURCHASE ARRANGEMENTS TO FACILITATE SYSTEM DEVELOPMENT

131. As the foregoing paragraphs imply, the identification of education requirements can not be regarded as a once for all definitive process, it must be a recurrent process taking account of changes as they occur. Thus as C. W. Phillips has observed in PEB Leaflet No. 5"... the development of a building system is empirical; it does not spring fully developed, as it were, from the brow of Zeus, but evolves as the educationists and architects demand more from it in terms of educational objectives" (1). However, in

1) Information Leaflet No. 5,"Industrialised Building Systems: Educational Objectives and the Problem of Change", by C. W. Phillips, Programme on Educational Building, OECD, March 1974, page 11.

some of the cases we have noted, systems have been unable to fulfil their initial promise because their use has been confined to only a limited number of buildings all completed within a relatively brief time-span. By contrast, those industrialised building systems which have produced the greatest benefits have been used for successive annual building programmes over an extensive time-span during which new versions of the system have been introduced, in the light of the experience gained as educational requirements themselves have evolved, and, of course, as economic and technological circumstances change. Thus we can identify a third condition which must be met if the full potential of industrialised building is to be realised:

> Procurement arrangements must be such as will allow for the modification or development of an industrialised building system as educational, economic and technological circumstances change.

CONDITION 4: NEED FOR SUSTAINED PRODUCTION

132. We have already mentioned (paragraph 59) that the CROCS system incorporated components which could be produced by firms in the Lausanne region which were already making products so similar in their tooling requirements that no extra tooling would be needed, and for which the school building components (despite the small investment programme) constituted an order large enough as a proportion of their total output to stimulate keen competition. In many other of the systems studied this was not the case; although the school building components had, as it were, a family resemblance to the general run of products made by the firms concerned, they were sufficiently dissimilar to demand some measure of re-tooling or of production re-organisation. For such firms (and they are a majority because the structure of Swiss production is untypical) the size of order represented by the Lausanne programme would not have been sufficiently attractive. Indeed, several of the firms were of the kind who, unless the special requirements of school building has been drawn to their attention, would have confined their production to the needs of the general market, exposing school construction to the danger already mentioned in Chapter III, paragraph 67. Such firms need to have prospects that the orders to be met will be beyond the minimum needed to justify re-tooling and re-organisation of production.

133. It was also noted, however, that the amount of re-tooling and re-organisation needed was not simply a function of the product required, but was also proportional to the volume of production needed within a specified time. For this reason, manufacturers tended to be attracted by comparatively small orders, provided they had prospects that the orders would be repeated and demand for the product, or at least some variant of it, sustained.

134. The SEF project based its whole approach on the assumption that, having regard both to the structure of North American industry and to the degree to which Canadian and American school building agencies are localised, the size of order which an agency could place and the limited extent to which it could sustain demand were both insufficient to attract acceptable quotations from manufacturers. The SEF architects therefore attempted to collaborate with producers to ensure that all products intended for school building would be equally in demand for the general market, so that producers could rely on normal advertising methods to secure the outlets needed to justify the new line of product. The attempt appears to have succeeded in respect of the sub-system which integrates artificial lighting and ceilings, and in respect of the air-conditioning system, but in respect of other sub-systems the non-school demand appears to have been insignificant.

135. The systems whose success is least in dispute (relative to the educational needs they have sought to satisfy) are, CROCS apart, those where the volume of orders has been both substantial and sustained. Broadly speaking this has been made possible by various means typified by the following examples.

136. The kind of school buildings for which the FEAL system has been used are of the comparatively simple kind which are needed for educational methods still close to the "starting point" and therefore the system is suitable for other buildings, such as offices, accommodating activities which are not very different from those of desk work for expository teaching; and for requirements further removed from these the firm has been able to improvise acceptable ad hoc variants to the system. As a consequence, the firm has been able to sustain an optimum level of demand by the normal commercial devices of market research, enterprising

salesmanship and competitive bidding. Firms responsible for the systems used in France have likewise been able to extend their markets by similar measures.

137. Some English systems have been originated by private enterprise and have followed a similar pattern to those in France and Italy. All but a negligible amount of school buildings using industrialised methods have, however, been originated specifically for school purposes by school building agencies which contract with producers for the supply of components. Even here, while school buildings have absorbed the bulk of production, the outlet for components has been extended by using the system for other purposes including not only offices but also public libraries, housing, hospitals and laboratories.

138. Most of these extended uses are in buildings which are as much a public responsibility as schools. But in the case of CLASP the system is also marketed to the private sector through the firm which supplies the steel frame sub-system. The originating consortium of school building agencies also has an agreement which authorises the same firm to promote the principles and methods of the system outside the United Kingdom. This usually involves a complete redesign of the system to meet the particular requirements of the countries concerned, a fact which is also true of other systems when used in countries outside the country of origin. To this extent it can be argued that systems are not exportable. On the other hand, the principles and methods by which compatibility of components is assured remain unchanged as do the types of component included; the change which is needed is mainly in the form of extra variants within the range for each type of component.

139. Here then, we have an extension of the means by which, by diversification of the application of a system, the outlet for its products has been increased and sustained. At the same time, it is necessary to note that unless the external market is geographically close to the home-base, the majority (if not all) of the components will be made locally by local firms rather than by the firms who produce for the original system. This suggests that while export can offer some extension of the market it can not alone suffice to produce sustained demand of sufficient volume.

140. By far the most effective device for optimising the level of sustained production is that which has been used by the central ministry in France and by local authorities in England and Wales, namely a form of bulk ordering. In France, the central ministry, exercising powerful control over school construction, is able to ensure that virtually the total annual construction of schools is shared out among thirty or so system building contractors, so that each competing firm can make its bid in the expectation that a successful bid will result in a substantial order. In Britain, local school building agencies have grouped themselves voluntarily into consortia for bulk purchase and are thus able to offer similar assurances, whereas an individual agency on its own would be unable to do so. In both countries indicative planning (which in France concerns the economy in general as well as school construction) provides sufficient guide to the level at which demand is likely to be sustained in succeeding years, subject only to economic cycles by which building in general tends to be affected.

141. It will be realised that if the output of a system can be maintained by any of these means, either singly or in combination, the essential pre-requisite will also have been provided for meeting Condition 3. Condition 4 can be summarised as follows:

> Procurement arrangements need to offer producers prospects of sustained sales optimised at a level beyond the minimum needed to cover capital outlay.

CONDITION 5: NEED FOR STAGGERED BUILDING STARTS

142. Unless unacceptably severe limitations are to be imposed on building form or environment, a range of variants will be needed for each type of component in the system, and the less the limitations the greater the number of variants. The bulk and comparative cost of most components, coupled with uncertainty about the quantity in which any particular variant may eventually be needed, make producers reluctant to hold items in stock. Although, from time to time, they may stockpile in order to maintain production through a period of slack demand, they will stockpile only those variants most commonly in demand. If buildings were to use no other than the most common variants the effect would obviously be to increase the limitations imposed by the system. Thus while some variants may occasionally be stockpiled, some of those

that in practice are necessary will not be. They will only be made in response to a firm order.

143. Here we arrive at something of a paradox. Where immediate delivery from stock is normally associated with so many industrialised products in general, it is even less a feature of industrialised building systems than it is of "non-industrialised" methods, in which, despite shortages of bricklayers or carpenters, a temporary glut can make bricks or timber obtainable, if not immediately, at much shorter notice than some prefabricated elements. Delivery delays can, of course, completely negate the savings in construction time which are among the potential benefits of industrialised systems. To avoid them producers must have adequate notice.

144. It may be thought that indicative forward planning would in itself provide adequate notice, but this is by no means confirmed from experience. We have found that well before the beginning of an investment year both school building agencies and producers can be fully aware of the total volume of building that will be required in the year concerned, but neither can know what the total implies for variant production until the designs are ready for every individual building covered by the investment total. There is always a tendency to complete all designs at the same point in time and then to start the construction of each individual building equally simultaneously. If the construction of all buildings is then to proceed at the same pace and with due dispatch, each class of component needs to be delivered to every building site at the same point in time. But this need runs directly counter to the practical manufacturing necessity for component production to be evenly maintained and not subjected to sharply contrasting peaks and troughs. Thus, because practical necessity insists, some components arrive on site when they are needed, others perforce arrive late, with consequent disruption to construction schedules. The "bunching" of starts - usually the consequence of administrative procedures - is therefore more responsible for delays than any inherent defect of industrialised building systems as such, so that every attempt should be made to spread the starts of individual buildings throughout the year. Such an objective will be the more readily attainable the less the initial building operations are dependent on good weather.

145. Thus we have a fifth condition that procurement arrangements need meet :

> Procurement arrangements need to allow for individual building starts to be so staggered as to facilitate an even flow of component production with adequate "lead time" to allow for prompt deliveries.

CONDITION 6: DESIGN, PRODUCTION AND ASSEMBLY TO BE INTEGRATED

146. Marginal differences in the form of interfacing of system components may have little effect on ultimate performance but considerable effect on costs of production and assembly. Component and system development has invariably proved to benefit if the designers can be made aware of production problems which an earlier design has caused and which can be eradicated by design modifications. Furthermore, different producers may use different production methods so that a design which is economical for one may be less so for another. The same considerations apply equally to assembly. Thus we have as a final condition :

> Procurement processes need to promote the closest possible integration of design, production and assembly.

147. As we have said in Chapter II, paragraph 25, an industrialised building system is a relationship of interdependent parts, each of which is standardised, repeatable and mutually compatible. To borrow computer terminology, the relationship represents the software, the components the hardware. Production and assembly in the physical sense can therefore only apply to the latter. By the same token we risk confusion to speak of a "system producer" since in fact, while a single organisation may produce (in the sense of physically "making") an important range of components, no case has been found where a single organisation makes all the components of a system; so that it is better to think in terms of a "system agency" - whose essential function is to identify potential component producers and persuade them to manufacture and supply the components needed for the system. Nor has any case been found where the system agency has not also been responsible for the design of the system. The reason is not, as might be thought, that otherwise the agency would have no raison d'être, but rather that designers can not design a system without also performing the function of an agency. The design of the software can not be

independent of the availability of the hardware.

148. The software relationship which ensures mutual compatibility of the hardware components need not directly specify the materials they are made of, nor whether they must be homogeneous or heterogeneous. But, although it need not specify all of their dimensional or weight characteristics it must certainly specify some, and besides determining their permissible locations in space, it must also specify their functional performance, the form of their interfacing profiles and sometimes their appearance. As a consequence the design of the relationship is as inseparable from the design of the components as it is dependent on their availability. And as a further consequence the instances where the system designers have not also designed the components constitute no more than rare exceptions to a general rule.

149. Now bearing this last point in mind, together with the fact that for one system there may be a number of different component producers, how can the criterion of design/production integration be met? Or put another way, how can the system designer, obliged as he is to initiate and eventually approve, if not to monopolise, the design of components, make certain that he is taking full account of production considerations and the expertise of all the producers involved?

150. With the exception of CROCS (which in this as in other respects is untypical) the design of all but a very few components, in all the systems studied, has followed, to a greater or lesser extent, the practice common to most forms of industrial production. The initial design for a component is submitted for the manufacturer's comments and modified in the light of them, after which a trial production run may lead to further modification before the design is finalised for full production. In short, design is a mixed process of "desk-work" and practical development, in which the system designer and the producer are complementary participants aiming to strike a balance between ends and means.

151. Clearly the development design process just described is impractical if a large number of producers are competing to win an order for the same component; yet for the system designer to work with only one producer may put others at a disadvantage. The alternative is to give a single producer a monopoly, which is unacceptable to any school building agency which is accountable for public expenditure. Nowhere has this dilemma been entirely resolved, but in different cases studied different approaches to a resolution have been made, each with attendant advantages and disadvantages which are worth noting.

COMPETITION BETWEEN SYSTEM AGENCIES

152. The first approach (adopted in France and Italy) has been for the school building agency to put system agencies in competition with each other but to leave the latter free to make any arrangement they wish - monopolistic or otherwise - with component producers. In Italy, FEAL, as a system agency has won contracts in competition both with rival system agencies and with "non-system" building contractors. In France, thirty or so competing system agencies bid for a share of the annual building programme.

153. The advantages of this approach lie in its apparent simplicity and clarity. The disadvantage lies in the difficulty of comparing like with like, which arises from the fact, already noted, that the cost of systems can only be compared in terms of the cost of individual buildings for which they are used.

154. Some school building agencies have sought a way round this difficulty by basing the competition on typical designs drawn up by architects commissioned or employed by the school building agency itself. But because the dimensional relationships and other key characteristics differ from one system to another the building which each particular system can produce is unlikely to do more than approximate to the typical design. As a consequence the lowest bid may represent an unacceptably wide deviation from the typical results which are sought, or a bid only marginally higher than another may offer significantly better value for money. Thus in awarding the contract, an element of judgement has to be added to the apparent objectivity of the price alone.

155. A further difficulty of comparing like with like arises from the fact that the cost of a finished building is determined, not only by the price of components supplied, but also by the costs of assembly and by the extent to which the system leaves some of the total building to be constructed by non-system methods. As a consequence school building agencies have tended to see logic in requiring the system agency to act as assembly contractor also, competing not only for

the supply of components but for construction of the entire building. Then, because the design of school buildings is not only concerned with educational requirements but also with satisfying them in a manner which uses the system to best advantage, it is but a small step further in the logic to require the system agency to take yet more responsibility by designing the building as well as the system.

156. When this strategy is taken to its logical conclusion two consequences follow. First the apparent objectivity of price-based competition is even further confused by the necessity of extending the influence of qualitative judgement, so that the impartiality required by public accountability is not so clearly beyond dispute. Secondly, because the variables in providing an educationally acceptable environment are so complex, and because no definition of educationally acceptable can be absolute (see Chapters IV and V), the compromise between the desirable and the feasible is a matter for inter-active decision between educationist and designer. Yet it is clearly impractical to provide for such inter-active decision-making when educationists act on behalf of a single school building agency while numerous system agencies, each with its own designers, are competing with each other.

157. The disadvantages of placing system agencies in competition seem less acute the nearer the educational activity accommodated lies to what we have called the "starting point" of expository teaching. For such activity the functional requirements of school building are comparatively simple and easily defined. But for educational modes remote from the starting line this is not so, and the "strategy of competing agencies" then seems inappropriate. In this respect it parallels the "standard product strategy" discussed in Chapter V.

COMPETITION BETWEEN COMPONENT PRODUCERS

158. Effectively, the only discernible alternative to a strategy of competing system agencies is one where the school building agency itself assumes the role of system agency and places component producers in competition with each other. We shall style this alternative a "strategy of competing producers". Of the cases studied, those where this strategy has been adopted - with variations in detail which will be noted later - occur in Canada and the United Kingdom.

159. In paragraph 149 the question has already been asked of how the system designer can design components while taking full account of the production expertise of all the component producers involved. When for any single component and its variants a number of producers are in competition, the problem is analogous to that posed when a single educational voice must join in inter-active decision-making with a number of system agencies in competition. The system/component designer can not, in reality, take full account of all the idiosyncracies of every producer. A way has to be found of limiting the number of producers with which this interaction can take place.

160. All sub-systems of a system are, by the nature of systems, interdependent. In practice, however, it has been found that one key sub-system sets the tone, as it were, with which the other must keep in tune. This key sub-system is usually the one which governs the major dimensional characteristic of the system, the lowest common multiple by which the overall dimensions of a building are determined, or the permissible locations of individual components. In most cases the key sub-system has been the structural frame, although in the SEF system it can be argued that it was the ceiling/lighting sub-system, by which the prime objective of adaptability was expected to be met. It is in the design of the key sub-system that most system agencies have concentrated their efforts to collaborate with production expertise.

161. In the case of the CLASP system, so much importance was attached to collaboration with the key sub-system producer that the producer in question - the producer of the steel frame components - was given the privilege of what was tantamount to a monopoly. Nevertheless, selection of the producer was based in the first instance on a number of carefully specified criteria - industrial capacity to manufacture components of the type required, managerial ability and willingness to collaborate on development, engineering design expertise, financial reliability and general price levels and profit margins ascertained by preliminary investigation to be competitive if not the lowest invariably obtainable. By negotiation before any contract was placed the system agency agreed with the selected firm the level of profit acceptable to both parties for a given volume of production; and once production commenced the firm

made all its accounts available for inspection by the system agency.

162. During the initial stages of system development similar arrangements were made with a limited number of other sub-systems producers, where design/production interaction was considered more important than strictly competitive bidding. In subsequent development, however, competitive bidding was introduced even for these sub-systems, and although the original firms enjoyed some initial advantage this was regarded as fair compensation for their contribution to the development process and did not deter other firms from competing or prevent them from making successful bids. As further development progressed still other firms were occasionally offered a temporary monopoly until sufficient advantage had been gained from the design/production interaction. The steel frame key producer has maintained his monopolistic advantage but only in the face of periodic checks by the system agency that his prices can not be undercut by competitors, or at least undercut sufficiently to warrant breaking off an association which the agency regards as valuable for maintaining progress. Where competitive bidding has been used, a contract for two-thirds of the volume of required production has been awarded to the lowest bidder, and the other third to the second lowest, the next stage of collaborative development then being shared between the two firms.

163. It is important to recognise that the approach just described has occurred within a form of financial administration characterised by what in Chapter V has been called a "standard cost strategy". Thus there has been strong external pressure on the agency concerned to ensure that its resultant buildings provided the required quantity and quality of accommodation within a pre-determined limit of expenditure; so that the same external pressure constituted in itself some safeguard against possible abuse of monopolistic or quasi-monopolistic advantages. Where a "standard product strategy" applied this safeguard would be absent.

VARIATIONS OF PRODUCER COMPETITION

164. Limited attempts have been made to increase competition among producers by avoiding the need for the system designer to design the component and thus to engage so interactively with production expertise. These attempts have been based on the concept of performance specification.

165. For present purposes this concept is most easily explained by reference to the particular example of an internal partition. As far as the system is concerned the only important spatial characteristics of partitions which the system designer need specify are the increments of height and length in which they are needed, and their thickness. He need only specify their sectional profile in terms of the roofs or ceilings and floors with which they interface, say whether their vertical sides must be entirely flat or can be moulded. But he also needs to specify such characteristics as the sound reduction they must provide, their resistance to fire or mechanical damage, whether they need be transparent or translucent, and so on. This then is a performance specification. What material or materials are used, whether the partition is made of full height panels or built up from smaller units, or how they are joined and fixed, are of no concern provided the assembled partitions perform as specified. Thus many alternative ways may exist whereby producers can meet a performance specification, and responsibility for that element in component design which most interacts with production expertise can be transferred from the system agency to the producer firm.

166. Why no more than limited attempts have been made to secure producer competition on this basis is a matter for conjecture. One possibility is that in practice the interfacing complexities in the case of many elements are so great that they can not be considered separately from the profiles that can feasibly be produced.

SEF COMPETITIVE ARRANGEMENTS

167. The SEF system agency was in effect identifiable with the complex of Toronto school building agencies and, although attempting to produce school buildings at costs equal to or lower than those produced by conventional methods, was not in competition with any other system agency. Its system was conceived, however, in terms of a limited number of ten interfacing sub-systems (1). For each sub-system the SEF

1) The ten sub-systems were :

i) Structure: Including floor and roof-deck elements, spanning members, columns, etc., and provisions to designers produced a performance specification stipulating the functional requirements, what other sub-systems were to interface, and what interfacing conditions were to be met. Producer firms were then asked to offer sub-systems to their own design. Thus the systems agency placed sub-systems agencies in competition with each other and left it to them to arrange for design and production of the components needed. By this means the system designers concentrated on the "software" relationship, the component designers (integrated in a sub-system producer's organisation) concentrated on the "hardware".

168. Interfacing compatibility between sub-systems was also the responsibility of the sub-system producers. Each sub-system producer was therefore obliged to collaborate with at least one of the producers of every sub-system with which his own had to interface. Since three of the ten sub-systems each had to have interface compatibility with as many as five of the others, the burden of mutual co-ordination placed on competing firms was obviously formidable. The procedure also demanded that the names of every firm intending to bid had to be made known to the others.

169. That the procedure operated well enough for 20 schools to be built is itself a tribute to the remarkable managerial and technical competence of the SEF agency; but its complexities were such that a major effort would be necessary to apply it with equal success in a different technological or managerial context.

170. Implicit in the procurement issues which have now been discussed is the fact that what solutions are feasible in any particular circumstances depends on the relationships existing between school building agencies, systems agencies and component producers. In this respect the problem of monopoly is no different from the problems of designing systems to meet educational and economic criteria, or of meeting the six conditions set out in the first part of this chapter. The solution to any of these problems is bound up with the kind of working relationship which can be established between all parties to the procurement process which begins with identifying educational needs and ends by satisfying them.

Note 1) (cont'd)

accommodate the requirements of outside walls, lighting-ceiling and interior space division sub-systems.

ii) Atmosphere: Heating, cooling and ventilation systems.

iii) Lighting-Ceiling: Lighting fixtures and connections, acoustic installation, ceiling panels, and provision for the electric-electronic sub-system.

iv) Interior Space Division: Inside partitions, doors, panels, glass, chalkboards, tack panels.

v) Vertical Skin: Outside walls, windows, and doors.

vi) Plumbing: Plumbing fixtures, washrooms.

vii) Electric-Electronic: Lighting panels, interior wiring, integrated public address devices, fire alarm and other systems.

viii) Caseworks and Furniture: Cupboards, counters, lockers, storage facilities and loose furniture.

ix) Roofing: Roofing, insulation, skylights fascias and miscellaneous details.

x) Interior Finishing: Floor and wall finishes.

Chapter VII

WORKING RELATIONSHIPS

SEPARATION OF DECISION-MAKING MECHANISMS

171. As we have said, the educational objectives of school building - seen in the widest sense - are to provide the right kinds of building to suit both the diversity of schools which the current educational system needs, and the diversity of educational mode or method appropriate to each kind of school in the system; to provide these schools in the quantity and at the speed required; and yet at the same time to balance considerations of "kind", quantity and time against the equally important one of acceptable expenditure. But those who are responsible for financial planning (and determine global budgets) are different people with a different official role or status from the educational planners (concerned with the time, quantity and structural needs of the educational system), and similar differences exist between the educationists who teach or direct teaching in each type of school and the architects and others responsible for design. If all considerations are to be balanced, it is not sufficient for an element responsible for one of these functions to perform its function separately; all four elements - financial planners, educational planners, "classroom educationists" and designers - need to work together, to co-operate, with no other objective than to strike the balance required. In short they must have the right working relationship.

172. The official status of each element and how it relates with the others varies from one country to another according to the governmental structure within which it operates. In some countries all elements are predominantly central government mechanisms, (e.g. France), in others local (e.g. the United States) or some kind of mixture of the two (e.g. Sweden, the United Kingdom). In some the financial and educational planning are centralised while responsibility for educational briefing and design are local, or, as yet another alternative, national financial planning has to be reconciled with both local financial and local educational planning (England and Wales). Similarly educational briefing may be centralised while design is localised or both may be either central or local, while in some cases a middle regional element also intervenes. Thus the problems of establishing a satisfactory working relationship between the elements concerned can be of formidable dimensions.

173. A solution to these problems is needed whether industrialised building is used or not; but it is emphasised here for two reasons. First, ventures in industrialised building can fail for want of one, rather than because of disadvantages inherent in industrialised building itself. Secondly, in the case of industrialised building the links between all the decision-making elements are more complicated, since not only have the individual buildings to be designed, but the standard system also. Comment on failures of communication in any particular example would not be constructive unless made by nationals of the country in question, since only they can hope to be familiar enough with the institutional niceties, national legislation and practice which must be taken into account. Nevertheless, the study suggests that all countries need to look critically at how well the decision-making elements inter-relate co-operatively, since failures in communication between them are the chief obstacle when school building fails to meet the multiple objectives of quality, quantity and cost. The main purpose of this chapter is to provide a basis for such a critical review.

NEED FOR SYNTHESISING MECHANISMS

174. Central to the whole pattern of decision-making, and equally important as financial and educational planning, is the need to ensure that the buildings provided by an industrialised system are "right" for the educational purposes they are intended to serve. Yet hardly any country has instituted a

completely satisfactory mechanism for identifying and communicating the educational brief insofar as "classroom educationists" are concerned - that is to say, those who work in the schools themselves and for whom the building and the environment it provides are as much essential tools as books or other learning material.

175. Here the fact must be faced that for any one system there are many individual buildings, usually as many building designers, and even more educationists. Educationists, for their part, have particular difficulty in forming a collective view on their requirements respecting the built environment (1). This suggests the need for some kind of synthesising mechanism comprised of leading educationists, who may not necessarily themselves be engaged in teaching, but who have wide experience and familiarity with current educational practice and its needs, and who can discern what those needs imply for physical accommodation, with sufficient insight to be able to collaborate with designers in formulating a brief. Clearly, however, such collaborative brief-formulation is impractical where many individual buildings have to be designed, each of them by a different designer or design team. Thus there is an equal need for a counterpart synthesising mechanism comprised of designers able to give a similar lead by virtue of their own extensive experience of and familiarity with school building problems.

176. When these two mechanisms operate together they are able to formulate a brief for an individual building or for individual buildings, each of which can represent a new point of departure in educational building development and which can reveal the criteria which building systems must meet. When a number of buildings have been erected in the system, these two synthesising mechanisms can again work together in examining the results and in identifying new criteria or changed criteria which subsequent modifications or subsequent systems should meet. In combination they constitute in effect what can be called an "educational development group", because it is a group which sets new developments in train.

177. The design synthesisers are of course those who can by virtue of their experience as building designers best collaborate with the system designers. When they do so, they constitute, with the system designers, what might be described as a "system development group". But if they are properly to perform their function in this respect they must also maintain steady and clear communications with the individual designers who design the bulk of individual buildings produced.

SOME EXAMPLES OF SYNTHESISING MECHANISMS

178. No case has been noticed where educational synthesisers form a separate group operating wholly independently from a corresponding group of designers. This is hardly surprising, since educationists on their own are unaccustomed to thinking comprehensively about the total physical environment they need: they tend to see it in terms of piecemeal improvements over what they are already used to in existing schools. Such piecemeal improvement is certainly not worthless, indeed many advances in school building originate in improvements which practising teachers have introduced themselves into the buildings they occupy. But when teachers can be assisted by architects in a collaborative effort they recognise new possibilities which unaided they can not imagine, so that a dialogue then develops between educationist and architect and the proposals eventually made for building result from a continuing exchange of ideas in the course of this dialogue.

179. The clearest example of collaboration between synthesising educationists and designers is found in some of the English local authorities. The educational branch of these authorities includes a number of "educational advisers" whose main function is to keep in touch with educational developments originating in schools administered both by their own authority and by others, and to ensure that the practising teachers whom they advise are made aware of them as soon as possible. In performing this function they themselves harvest ideas from the teachers and are thus in an ideal position for knowing, or at least for recognising, any needs or problems relating to buildings and equipment.

180. In each of these authorities the educational branch has a counterpart in an

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1) See also:

Pearson, op. cit.

Ader, op. cit.

Information Leaflet No. 7, "Teachers and School Building", by Birgit Rodhe, Programme on Educational Building, OECD, Paris, December 1975.

architects branch responsible for the design of all school buildings and other buildings which the authority requires, including community facilities such as youth clubs, public libraries, sports halls, fire stations et al. The annual volume of work that an architects' branch of this kind will undertake is large enough to demand the effort of perhaps six to a dozen or more design groups, each of which would be the equivalent of what in many countries would be an individual private architectural practice. But whereas the latter works for a wide variety of clients on a wide variety of projects, these groups work for only one, and most of them work mainly on school buildings, with the result that they must, as it were, "live with their mistakes", and consequently can easily apply to subsequent designs the lessons learned by evaluating earlier ones.

181. In making these evaluations and applying the lessons learned each group can rely on the close collaboration of the educational advisers described in paragraph 179 above. However, when changing educational requirements point to the need for new developments in building, the extra design time needed means that these new developments can not be explored by all groups at once. One group must, with the educational advisers on hand, constitute the development group, setting a lead for the others to follow. But because all groups are part of the same organisation and communications flow easily and naturally between them, the development group can synthesise the view and test the reactions of the others and quickly pass on to them its own experience and conclusions.

182. The model just described, reflects, however, an institutional arrangement peculiar to the United Kingdom. In most Member countries public authorities do not enjoy the same service from highly qualified and skilled public architects. This need not, however, constitute an insuperable obstacle to successful educationist/architect collaboration as the example of SAMSKAP in Sweden has shown. In this example a group of innovating educationists of the Malmö education authority worked together in the same way with a corresponding group of private architects and this collaboration has been sustained throughout a period of systematic evaluation of the resulting schools and school buildings. FYNSPLAN and CROCS represent similar arrangements, but with less emphasis on educational innovation.

183. The example of SAMSKAP has not, however, been widely followed, if at all, by other Swedish educational authorities, probably because the majority are comparatively small and have no educational building programme sustained over an extended period of years. And as far as the United Kingdom is concerned care has been taken to speak only of some local authorities since not all follow the practice described, a practice which is entirely at the discretion of local autonomy and subject to no kind of legislative sanction. Thus neither of the examples so far quoted succeed in synthesising educational and design practice at more than a local level. To illustrate how the synthesis can be taken further, to a national level, an English example must again be cited.

CENTRAL/LOCAL LINKS

184. The local educational advisers of English education authorities have a counterpart in the so-called Inspectors of the national schools inspectorate. Originating in the 19th century as watchdogs charged with ensuring that local education authorities carried out the functions imposed on them by law, the inspectorate, while still playing the same nominal role, now plays much more the role of adviser, ensuring that practising teachers and their local authority advisers are aware of new educational thinking and emerging educational needs, and acting, as it were, as talent-scouts on the look-out for effective learning methods introduced by innovating practising teachers. From these Inspectors, of whom there are several hundred, a small number (never more than two or three) have been given the special responsibility of synthesising an educational view with respect to building needs.

185. Likewise, the "development groups" of some local authorities have their national counterpart in the Architects and Building Branch of the Central Department (i.e. Ministry) of Education and Science (DES). Whenever the Inspectors discern a new educational development which demands a corresponding building development they collaborate with their architectural colleagues to develop a new brief and to build a new school building which represents a new point of departure from which other developments can follow as the result of further initiatives by the local authorities themselves. And by means of written publications, personal contacts, and the example of the development project itself, the Inspectorate encourages these further local initiatives to be taken by both local educationists and local authority architects. Furthermore, the Inspectorate effort is parallelled by a similar effort on

the part of the DES Architects and Building Branch who has the duty of encouraging its local counterparts to undertake further developments which take the centrally-designed development project as the point of departure. The results are then continuously evaluated, fed back into the system of local central communication and lead eventually to further development projects. In this way the central government institution acts as the synthesising agent between many local authorities.

EDUCATIONAL DEVELOPMENT ESSENTIAL TO SYSTEM DEVELOPMENT

186. No example has come to attention of an agency other than central government for synthesising local initiatives in respect of educational development, but reference will later be made to an example where voluntary co-operation between autonomous local authorities occurs with respect to system development; and there seems no reason why such voluntary co-operation should not occur educationally, subject to one important provision. This is that either central (or regional) government or a specific local authority needs to take the initiative in persuading the other local authorities to join forces.

187. Clearly, if, as the evidence suggests, there is a justification for creating a mechanism to synthesise educational development in building, the justification exists whether industrialised construction is used or not. But since such mechanisms produce development projects as specific individual buildings, and since the value of a system can only be judged by the quality of the specific buildings it can provide, an educational development group is indispensible to system development. Indeed, as a matter of interesting historical fact, the first initiatives for "educational development" (in the connotation to it given here), were made not by educationists themselves, but by architects (of Hertfordshire County Council, England, in 1948/49) seeking to develop an industrialised alternative to by-pass the labour shortages in conventional building and who found themselves unable to design an industrialised system without first finding what kind of buildings education required it to produce. An educational development group is desirable even when no system development is needed. But satisfactory system development is inconceivable without the support of an educational development mechanism.

188. Perhaps because of the historical precedent just mentioned, subsequent initiatives have also been taken mainly by architects. It was a group of architects who first pointed out to the Lausanne education authority (Switzerland) that advantages could follow if a whole investment programme of ten new schools were to use an industrialised building system designed for the purpose. And it was the same group of architects who for want of an established educational development group were obliged themselves to double in that role also. Similarly, when the Danish Ministry of Education, believing that industrialised building would speed educational building, offered incentives to local authorities to develop industrialised building methods, it was a consortium of architects and engineers who undertook both the system development and the investigation of educational needs. The Study of Educational Facilities (SEF) on which an industrialised building system was eventually based was again the result of an initiative made by architects to the Metropolitan Toronto School Board.

189. However, there are dangers in leaving these initiatives entirely with architects. The risk is that the educationist, primarily interested, as he tends to be, in child development or curriculum content, may be conscious of handicaps he suffers from an inadequate building but is often wholly unaware of the wealth of opportunity that a good building can open up; and he will only awaken to these opportunities if he is prompted to observe the inter-action of people and buildings more attentively than he is normally expected to. He will only be prompted in this way if he is required to play a creative and active role in developing designs with architects. But too often he is only assigned a passive role at the receiving end of a questionnaire in which many mistaken assumptions underlie the questions posed by the architect.

190. In cases when the educationist has no more than this passive role, when no "educational development" has preceded the "system development", the resulting system tends to be at one of two extremes, which might be dubbed either "historical" or "futuristic". At the historical extreme the system is focused on the traditional concept of classroom-teaching by exposition, and as a consequence tends to confine the specific buildings to forms inimical to other learning modes. At the futuristic extreme the architect has found the educationist so vague and uncertain about his requirements that the resulting system maximises provision

for future change at the expense of the real needs of the present. When, however, the educationist has played a positive and creative role in the educational development, present needs are made precise without overlooking the implications of possible changes in the future. To elaborate further on the genuine need to take account of change would obscure the main argument of this chapter, and the subject is one which is dealt with in a forthcoming PEB report (1).

LINKS BETWEEN EDUCATIONAL AND SYSTEMS DEVELOPMENT

191. Because educational development work is so indispensible for satisfactory system development, there is an obvious need for the strongest possible links between the two. Both of the development groups concerned can, of course, contain the same designers, and indeed this was the case with the 1948 Hertfordshire system. In that case no linking mechanism is needed. This represents an ideal, and is an ideal which is attainable so long as educational development and system development can be discharged by the same mechanism either centrally or locally.

192. There is, however, a barrier to this ideal. Where a number of school building agencies use the same system in different local conditions, and when each enjoys a measure of autonomy there may be as many educational development groups as there are agencies, but only one system development group. Even where the main lines of educational development are undertaken centrally (either by central government as in England, or in the hypothetical case of a single educational development group set up on behalf of a number of agencies) some educational development will probably still occur locally to cater for local conditions. This is again the case in England, so that a description of the linking mechanisms there may have some value to other countries where local autonomy is a feature of the institutional structure.

193. As mentioned in Chapter VI (Procurement - Purchase and Supply) English local authorities using the same system constitute a consortium to manage the system. A single system development group serves the whole consortium. Local educational development work however is undertaken by the education branch of each authority, in collaboration with the architects' branch. The chief architects of each authority constitute a development steering committee, meeting the system development group at regular intervals and deciding with them what modifications are needed to the system to cater for newly-emerging requirements including educational requirements identified by the collaboration just referred to. Under this arrangement it is reasonable to assume that those local authorities who put most effort into their own educational development work are most able, as a result, to influence the system development. But the criticism can be made that educational influences on system development are exerted only obliquely, through the architects, rather than directly by educationists themselves.

194. In drawing attention to this example we must point out that, in the case of CLASP, which is the oldest of the consortia covered by our study, the system pre-dated the consortium. It was originated by one local authority, Nottinghamshire, which then invited other authorities to join it in order to offer more attractive orders to producers. As a result the system development group remains most closely associated with Nottingham. When, with central government encouragement, other consortia were formed, they tended to follow the CLASP precedent when one of the authorities assumed a central responsibility for developing the original system, albeit in consultation with its partners.

LINKS BETWEEN SYSTEM DESIGNERS AND BUILDING DESIGNERS

195. It is important to distinguish clearly between systems designers and building designers. Individuals or teams of designers may have the expertise to be both, but they are never both simultaneously and the objectives and emphasis of their work differ according to which role they are playing. The system designer is primarily concerned to design a system which maximises opportunities of production while minimising the limitations on built form which the system imposes. In the previous chapter we have emphasised the close relationship which the system designer must have with the producer in order to maximise production opportunities. But unless he is also responsible for

1) Providing for Future Change: Adaptability and Flexibility in School Building, op. cit.

the building design he must have an equally close relationship with the building designer. In the cases where building designers have resisted the use of industrialised building systems this close relationship has not been established. When the building designers are not responsible for the system design their reactions to the system need to be synthesised and communicated to the system designers.

196. The primary concern of the building designer is, or should be, to maximise the opportunities for education while working within the constraints of cost and the limitations of the system. He therefore needs to exert a pressure on the system designer to reduce those limitations by diversifying the system, just as he himself is under pressure from the educationist to maximise the educational opportunities. On the other hand he needs to be well aware of the cost disbenefits which will result from a demand for too many rarely used variants within the range of variants the system offers. So he must listen to the system designer as well as influence him.

197. In the cases of CROCS and FYNSPLAN this sympathy was assured since the same organisations performed both roles. The same applies to FEAL when the firm contracts on a design-and-build basis. When FEAL contracts to a design produced by another organisation it modifies the original design when the system so demands and when special variants within the system can not remove the need for modification. In short while the original design may be by another, the final design - which is the one determining cost - is FEAL; so that FEAL is not, in the end, different from the other two cases.

198. From this it may appear that close communications between system and specific building designers are not particularly a problem. However, in both CROCS and FYNSPLAN no more buildings were built in the respective system than the system design group itself could comfortably handle, whereas when a system is extensively used the reverse is the case. And with FEAL and the French examples none of the requirements have been complex enough to bring the limitations of the system into sharp conflict with the aims of the specific building designer. But where educational requirements are complex, when the pressures they create push hard against cost ceilings, and when the architect is struggling to conjure the best compromise from the variables at his disposal (see Chapter V, paragraphs 118 to 120) then a sharp conflict can arise. It then becomes even more important that system designers and building designers should be able to influence, and to listen to, each other.

199. That the SEF system of Toronto has not been widely used is due to several factors not all of which reflect shortcomings of the system or of the supply and contracting methods associated with it. But one of these factors is that so many specific building designers disliked the system and believed they could produce better results by alternative methods. A major English consortium MACE has also run into difficulties with similar symptoms. Some of the reaction of individual designers against systems is no doubt emotional and stems from a fear that systems will cramp their individual architectural style. While such fears may in some cases reflect an unjustifiable egotism we can see, nevertheless, that real dangers can arise if the designers of systems lose touch with the design of specific buildings to the extent that they concentrate too exclusively on meeting technological requirements of production, on means rather than on ends. There is some evidence that even the strongest advocates of system building are now complaining that systems which they admired in earlier versions are tending, in the latest stage of development, to suffer from this defect. This suggests that not only should the strongest links be maintained between system designers and specific building designers but that the former should periodically exchange roles with the latter.

200. Broadly speaking there are two main instances whereby system designers are unavoidably separate people, working in separate organisations, from the designers of individual buildings. The first is where system designers are incorporated into a private or commercial systems agency, while designers of individual buildings are answerable, either as public employees or as private practitioners, to a public sector school building agency. This, of course, is inevitable with private systems except where the systems agency operates a "package deal". The second instance is that of the English consortia, in which each of a number of school building agencies employs its own architects (and with them may combine its educational advisers in an "educational development group"), but where a single system development group serves the whole consortium. (Reference has been made to this in paragraph 193, which has shown how links are maintained with local educational

development groups through the medium of a committee containing the chief architects of each school building agency. Because each chief architect is also in close touch with individual architects on his staff, a link mechanism exists which is as strong as the individuals concerned care to make it.)

CONTINUITY OF EXPERIENCE AMONG PRIVATE ARCHITECTS

201. If, in the light of this report, any country seeks to promote a centrally-developed system, either nationally or regionally - as in the case of the English consortia or the Toronto SEF - then the English model may be one which is tempting to follow. But here a note of caution must be sounded. The public authority architects departments which are peculiar to the United Kingdom have acquired a long experience of educational building and already enjoyed the benefits of this long experience before delegating system development to separate development groups - themselves composed of architects very familiar with educational building needs. As a consequence, even though the personnel of these departments change employment from time to time, some moving into and others out of general private practice, each department as a collective sustains a well-informed attitude to educational building. Furthermore, in the English case, the central government Department of Education and Science has, since 1948, co-operated closely with local authorities in technical as well as in educational development and has therefore further strengthened continuity of development and co-ordination of effort.

202. The position is very different in countries where the bulk of architectural work is carried out by general private practice. If the English model were to be adapted to such countries it would seem desirable to ensure that :

a) selected general practices be given a sustained programme of school building commissions so that they can become familiar with the special requirements of education and also with the industrialised building system adopted;

b) arrangements be made to co-ordinate the selected practices and synthesise their collective view on matters relating to system development;

c) further arrangements be made to facilitate an exchange of personnel between the practices and the system development group.

LINKS BETWEEN SYSTEM AGENCIES, BUILDERS AND COMPONENT PRODUCERS

203. A further distinction must now be made, that between system agencies and system builders. Sometimes the same organisation doubles in the two roles but each role remains distinguishable. The first is to design the system and organise the production and supply of interrelated components, the second to organise the assembly of the components in specific individual buildings - the role, in fact, of the traditional building contractor. Now if these two functions are discharged, as they often are, by separate organisations, the building designer is again a link, since he must take account of the constraints imposed not only by the system on the design but also of the constraints of assembly, some of which are also imposed by the system. If the building contractor finds the latter too inconvenient the most natural means of communication to the system designer (who may be able to lighten them) is through the building designer. Unless a special effort is made by the system designer to secure feedback direct from the contractor, those building designers who work in an educational development group seem best placed to perform effectively in this linking role.

204. In saying that the role of a system agency is to organise the production of interrelated components we have recognised that an agency may not produce all components, nor indeed, even a single component. Among the examples studied are some where the system agency is simply a commercial enterprise which finds it profitable to persuade separate component producers to make their products conform to each other in accordance with the standard interrelationships of the agency's system; and which exercises this persuasion by marketing each component as part of a co-ordinated package. In many cases the system agency may have a staple product or range of products for which it can find a wider market outlet by organising the production by other enterprises of other components co-ordinated with its own. Alternatively the system may be produced by a building contractor wishing to minimise the use of site

labour and to whom component or sub-system contractors then sub-contract. And as a further alternative designers of individual buildings may see an advantage both to themselves and to their clients in designing a system and then find, like the commercial enterprise or the building contractor, that they must also assume the role of system agency. Finally examples have been found of combinations between, for example building designers and contractors, contractors and staple product producers, or staple producers and building designers.

205. In all these alternatives the system designer is, of course, indispensible, as is the component designer, so that again the inter-relation must be so close that the one designer may play a double role. But because the system designer is inevitably part of the system agency (see previous chapter) and the component designer - if a separate person - part of a production organisation, the essential decision-making mechanisms to be linked are those of the system agency and the component producers.

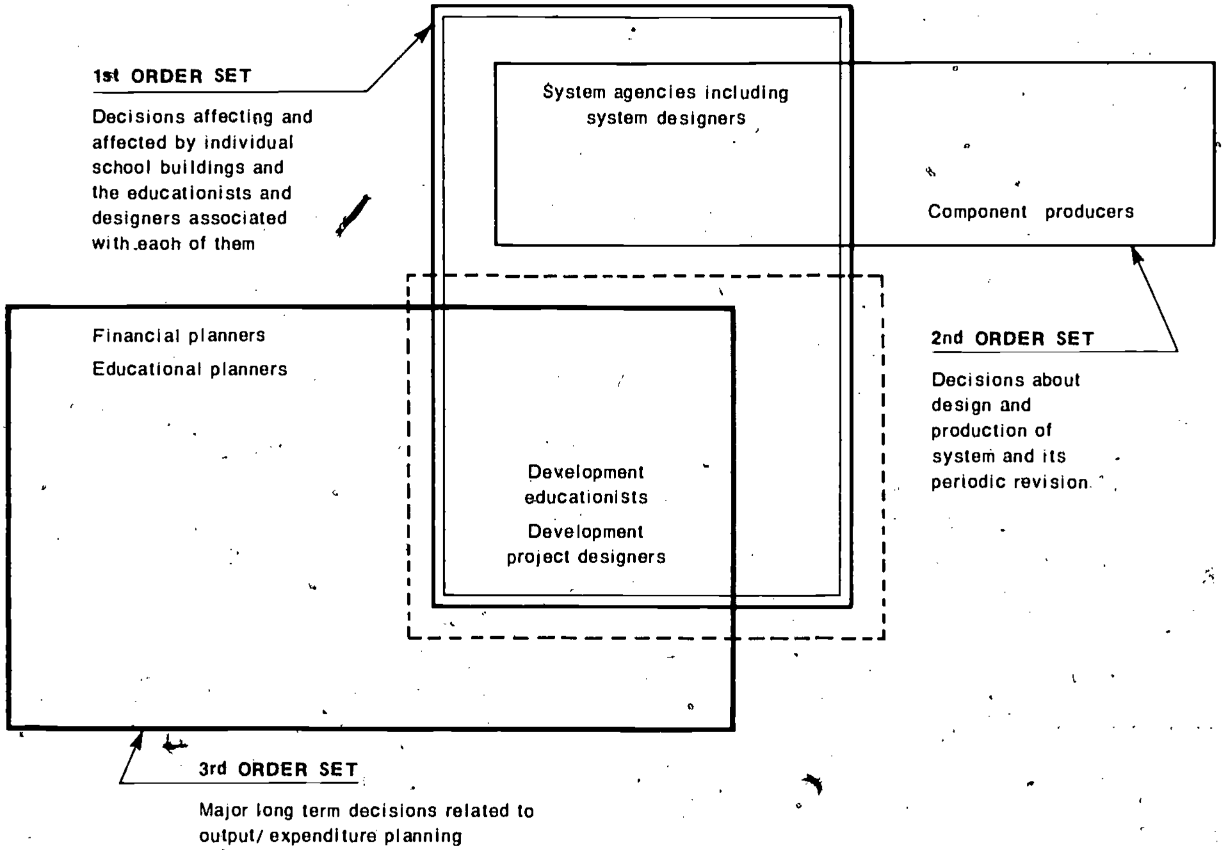
LOCATION OF DECISION-MAKING MECHANISMS

206. At the start of this chapter four kinds of decision-maker were mentioned - financial planners, educational planners, educationists and designers. It will now be apparent, however, that the multiplicity of educationists and designers points to a rather more complex categorisation:

- a) Financial planners
  - a) and b) co-operating on output/ expenditure planning (Chapter V).
- b) Educational planners
  - b) co-operating with c) and d) to determine overall educational needs and how to meet them in terms of school location and building.
- c) Development educationists
- d) Development project designers
  - c) and d) co-operating on development projects (paragraphs 174 to 177).
- e) System designers in system agencies
  - e) co-operating with d) to ensure compatibility with "right" kind cost and quality of individual buildings; and with f) to maximise use of production expertise.
- f) Component designers/producers.

207. It may at first sight appear that communications would flow most freely if all decision-making elements referred to belonged to the same organisation. But this is to overlook the fact that this would only be possible if the organisation were very large and that large organisations are compelled to break themselves down into sub-organisations. Furthermore in all real cases some decisions are taken by one mechanism and some by another according to the scale or magnitude of the decision which ranges from national or regional issues, such as those affecting the overall budget, to local issues affecting an individual school, the building provided for it and the activities of the teachers and pupils belonging to it. Scale of decision is also reflected in frequency of decision; for example over a given period of time only one national or regional educational plan has to be decided, whereas many individual schools, each in an individual location, have to be built. It is this frequency of decision-making which seems to point most clearly to the mechanisms with which each area of decision needs to be most closely identified. The following diagram therefore shows the six mechanisms grouped in three overlapping sets, in descending order from first to third according to the frequency of decision made.

208. The most frequent decisions are those that have to be taken on many individual schools, and it is these that are most affected by the building system. It is also the frequent evaluation of experience from such schools that should affect the development of the system itself. The development educationists and project designers are the synthesising mechanisms in the flow of communications between the system designers and the many educationists and designers associated with the individual schools. Thus these three underlined elements constitute the first order set. Since one system serves many buildings, system agencies (including their designers) and component producers are concerned with more far-reaching but less frequent decisions, and so are placed in the second order set. Financial and educational planners are concerned with decisions which are even more far-reaching in their importance, since they are likely to affect more than one system, but which, being by their nature long-term, are less frequent. But in reaching their decisions the planners need to take account of the practical ways and means by which plans can be carried out, ways and means which it is the function of the development educationists and designers to explore. Thus



they are grouped with the two latter elements in a third order set.

209. Now if it can be assumed that communications are easier within a single organisation (subject to the size limitation already mentioned) than between two or more organisations, it can be seen that if all three elements in the first order set can belong to a single organisation then not only do they enjoy a greater facility for communication with each other but the organisation itself belongs to the other two sets and can speak with a single voice to the elements they contain. Such an arrangement, however, is not always consistent with government structures, so that a second preference is to contain the development educationists and project designers is one organisation (indicated by a broken line in the set diagram) and the system agency and its designers in another. Variations on this second preference have already been referred to in the United Kingdom examples discussed in paragraphs 191 to 193. But if the second preference is the best of the options open then it is imperative between the two organisations; and wherever to maintain frequent and open consultation institutional necessity separates any of the six elements from another the consultation must remain equally open and as frequent as the periodicity of the relevant decisions demands.

210. The following table shows in simplified outline the relationships possible between decision elements and organisations depending on the governmental structure of the country concerned. An "O" shows the organisational situation possible for any element. For example, system agencies may be situated in either a Ministry of Education or a Ministry of Public Works, in a local school building agency or in a private enterprise. Educational or financial planning may be functions discharged in a central ministry or ministries or at local level and so on.

211. From the table it will appear that the first preference for containing in a single organisation the three elements of development educationists, development project designers and system designers, can be met

	Organisations / Decision-making mechanisms	Financial planners	Educational planners	Development educationists	Development project designers	System agencies and designers	Component producers	Notes
Central government or nearest equivalent	Ministry of Finance	●						(1)
	Ministry of Economic Planning	●	●					(1) & (3)
	Ministry of Education**	●	●	●	●	●		(2) & (3)
	Ministry of Public Works *	●			●	●		(3)
Local or regional government	Financial branch	●						(4)
	Education branch		●	●				(5)
	Building branch *				●	●		(6)
Private enterprises	Manufacturing enterprise					●	●	
	Building enterprise					●	●	
	Other firms					●	●	

* Whichever organisation enters into contracts with builders is the school building agency.

Regional organisations intermediate between central and local government are ignored for the sake of simplicity, but this does not affect the principles of communication under discussion.

Notes:

1) The Ministry of Finance and the Ministry of Economic Planning may often be combined in one.
2) Where local government spends funds provided by central government, the Ministry of Education may allocate to each local mechanism its portion of the total fund allocated for education by another ministry. To this extent it performs a financial planning function.
3) Where building is solely the responsibility of a central public building ministry, the Ministry of Finance usually determines the building budget. In this case it is essential that the Ministry of Education should have a voice in how the total is allocated to individual building projects. Both Building and Education Ministries then perform a financial planning function.
4) A local authority disposing of a total budget has a financial planning function in apportioning it to individual building projects. In discharging this financial planning function it may be either autonomous or subject to central government approval. At the scale on which local authorities operate little difficulty seems to arise in ensuring adequate communications between the financial, educational and building branches.
5) Even if not autonomous a local authority may need to make detailed local forecasts of educational requirements within the overall strategy of central educational planning.
6) It is, of course, quite possible that the development project designers may be professionals practising in the private sector; but to discharge the development function they will be commissioned by some government organisation, central or local.

by one organisation alone, namely a Ministry of Education. Unless the volume of school building undertaken by regional or local authorities is large enough to provide the minimum level of outlets to attract producers, there is little doubt that a Ministry of Education is the best situation for the three most important elements. But if the reverse applies, then a local government school building agency would be equally suitable, provided that the Education Branch in the table (containing the development educationists) and the Building Branch are both contained within the one school building agency.

212. If the second preference is the only option open, then the table shows that a system agency serving many local school building agencies could be located, either in one of the local organisations, or in a central Ministry of Education or Public Works, or in one of the private enterprises shown. But in these cases where would the development educationists and designers be situated if they are not to be organisationally separated from each other? The question is itself enough to show that the number of effective alternatives is very small. And if the systems agency is in a private enterprise it seems likely that communications will then be more difficult with the development project educationists and designers, who can only be brought together in one of the public organisations.

213. To conclude the main part of this report it may be observed that the issues of industrialised building are by no means confined to technological considerations of what building components can best be standardised in their form and inter-relationships. Important though these technological considerations are, they can not be separated from the educational requirements that each industrialised building must meet both now and in the future. Nor can they be separated from the requirements of planned production or from problems of demand forecasting, from financing and purchasing arrangements, or, as the present chapter has shown, from the flow of communications between all participants in the decision-making processes involved. In short, the economical production of good educational buildings in quantity demands that education itself, educational planning, building technology, procurement processes and institutional arrangements constitute together a network of interrelated issues which always need to be considered together as a totality - as a larger system within which building systems are contained. In this respect educational building need not be seen as more difficult to manage or more peculiar than building for other purposes. On the contrary, it represents a convenient and comparatively easily-handled model which deserves attention from anyone concerned with wider issues of providing a total built environment in response to social, economic and cultural needs.

Chapter VIII

SUMMARY AND CONCLUSIONS

CHARACTERISTICS OF INDUSTRIALISED BUILDING (CHAPTER II)

214. Virtually all modern building is industrialised in as much as many site processes are mechanised and many factory produced components and materials are used. If industrialised methods are to be separately distinguished from the generality of building practice it is in their use of predetermined standard systems or subsystems of mutually compatible prefabricated standard components to an extent where they impose the major limitation on alternative forms.

215. Systems vary widely in the limitations they impose. But many schools built in standard systems are at least as good, aesthetically and functionally, as those built by alternative methods. Thus the limitations of a well-conceived system need in no way restrict the production of buildings of desirable kind or quality.

BENEFITS AND DANGERS (CHAPTER III)

216. The prime justification for the use of industrialised building systems is the inability of the building industry to meet demand with them. Thus the first benefit from the use of industrialised building systems is the extension of the building industry's potential.

217. Cost comparisons of industrialised with alternative methods are made unreliable, partly by difficulties of comparing like with like, and by the fact that where the former have been widely used they have displaced the latter. Circumstantial evidence shows that the cost advantage varies from one system to another, but that if cost benefits are to result certain conditions must be met by the arrangements made for the purchase and supply of school buildings.

218. Savings in construction time over the use of alternative methods reflect the extent to which the building industry is overloaded; but taking due account of this the savings in construction time made by some systems are significant. Like cost savings they are dependent partly on the characteristics of the system and partly on purchase and supply arrangements.

219. Savings in the time needed for decision-making prior to the start of construction represent a major benefit obtainable from the use of standard systems.

220. The use of standard systems means that quality and cost control is easier to assure. In offering this benefit industrialised building systems come nearest to offering one of the major benefits which consumers in general enjoy from industrialised production: that goods are not only in ready supply but reliable and consistent and can be sampled and evaluated before being purchased at firm prices declared beforehand.

221. The effectiveness of standard systems may be increased by but is not dependent on bulk purchase. But the use of a standard building system facilitates the operation of bulk purchase arrangements which can lead to financial savings.

222. The pressures for industrialised building systems to replace alternative modes of building remain strong and possibly inexorable. In this lies the danger that school construction, being a relatively small section of the building market as a whole, may find its own special requirements increasingly difficult to meet. This danger can be averted if these special requirements are clearly identified and made known to interested producers.

RIGHT KIND OF SCHOOL BUILDING (CHAPTER IV)

223. The requirements special to school building vary according to the nature and

pattern of the educational activities which have to be accommodated. The range and diversity of these activities increase as education departs from the traditional starting point of simple expository instruction. As the diversity increases so does the diversity of environments which a standard system must be able to provide.

224. A building system is only as good as the buildings which its limitations allow to be built. So the most thorough investigation of its capabilities is needed before a system is chosen: or if a new system is to be designed an equally thorough investigation is needed of all the educational requirements it will have to meet.

225. The simpler the educational requirements the greater the limitations which can be accepted and provided all sites are flat, or nearly so, this simplicity may even allow for some form of "standard plan" which will in turn allow the system to be simplified still further.

226. Even where current educational requirements demand no more than a very limiting system or even a standard plan, great caution is needed before accepting such limitations since they are likely to militate against meeting the needs of future change.

227. A capacity to meet the needs of future change is an important criterion in all school buildings. But in meeting these future needs, diversity of educational environment in the original building is more important than large spans or relocatable partitioning or similar devices that facilitate rearrangement of internal spaces. Second to this diversity the most important criterion for future adaptation is a building's capacity to accept additional services for ventilation, electricity and water supply and drainage.

228. The design of a system must take into account the extent to which educational circumstances demand that it shall allow for a wide range of:

a) horizontal and vertical dimensions of individual spaces ranging from those of the scale found in housing (staff rooms, seminar rooms) to those of the scale more usual in industrial premises (e.g. for physical education or sports) and including many intermediate scales not found in either housing or industrial premises, nor in office-type accommodation;

b) overall plan form - in order to integrate outdoor as well as indoor educational spaces, in order to maximise the "fit" between building and site and in order to ensure the right inter-relationship between individual spaces;

c) possible storey heights and interfaces between blocks of differing storey height;

d) lighting (artificial and natural), acoustics and thermal environment to suit each educational activity, all of which may have several different requirements;

e) servicing provision, especially in respect of electricity, water supply and drainage which need to be more widely dispersed than in either housing or offices and which pose greater problems of integration with the structure than in the case of industrial premises;

f) finishes and fittings, with due regard to subsequent replacement;

g) alternatives for satisfactory visual appearance.

NEEDS OF PLANNED EXPENDITURE AND OUTPUT (CHAPTER V)

229. The design and selection of systems must take into account more than the need to provide the required kinds and quality of buildings: they need to have equal regard for ensuring that the required kind of buildings are produced quickly and cheaply enough to provide a planned quantity within a planned period of time and within a planned level of expenditure, in short, to meet the needs of output/expenditure planning.

230. In practice, output/expenditure planning rests on either of two alternative strategies, namely:

a) Standard Product Strategy, where the kind and quality of building is regarded as an immutable constant, but output and expenditure are accepted as variables in the output/expenditure plan; or

b) Standard Cost Strategy, which attempts to maintain a planned expenditure for a planned output, but within planned limits the quality is allowed to vary. This is the more appropriate strategy where educational practice has become so widely diversified in its activities that cost restraint demands a careful ordering of preferences.

231. According to which strategy is adopted, the criteria for building systems implied by the needs of output/expenditure planning must be added to those implied by the "right kind and quality of school building", as follows:

a) Where Standard Product Strategy applies, the system must be capable of providing schools to standard designs.

b) In all other cases where a Standard Cost Strategy applies the following criteria must be met:

i) the volumetric increment of the system should be consistent with the cost control procedures which apply to buildings where it is used;

ii) the system should facilitate the interlocking of facilities, /cf. Chapter IV, paragraph 103(e) (i), (ii), (iii)/, of different shape, dimension and environmental character;

iii) the system should contain a range of alternatives each representing a different grade of cost-effectiveness;

iv) the cost of the components supplied and assembled should be known at the design stage;

v) the system should be the dominant determinant of the total building cost;

vi) the system should be the dominant determinant in the completion time of the total building and should therefore account for the key operations on which other operations depend for their completion.

232. The potential benefits obtainable from industrialised building systems can only be realised and the criteria implied both by educational needs and by output/expenditure planning can only be met if certain conditions are fulfilled. Some of these conditions relate to the arrangements made for the financing and purchase and specification of school buildings, others to the working relationships which are established between the parties involved in these procurement arrangements.

PROCUREMENT ARRANGEMENTS (CHAPTER VI)

233. Procurement arrangements need to meet conditions which respectively allow for:

a) identification of current educational developments and the consequent range of requirements a building system must meet. (See paragraph 228);

b) recurrent review of any cost containment policy associated with the financing of educational building to ensure that cost restraint is not in conflict with cost-effectiveness. (No standard system can be successfully applied if cost restraint is so harsh that educationally acceptable buildings can not be produced by any method at all);

c) modification or development of the industrialised building system adopted, as educational, economic and technological circumstances change;

d) offering producers prospects of sustained sales optimised above the minimum level needed to cover capital outlay;

e) individual building starts to be so staggered as to facilitate an even flow of component production with adequate lead time to allow for prompt deliveries;

f) closest possible integration of design, production and assembly.

Examples have been found among the cases studied which show that all these conditions can be met.

234. No example can be found where all components of a system are produced by a single enterprise, so that it is useful to use the expression "system agency" to identify the organisation which designs the system and arranges for the necessary components to be produced and supplied by component producers. Integration of design and production under these circumstances demands collaborative discussion between designer and producer followed by product trials leading to modification of designs before they are finalised for full-scale production.

235. Designer/producer collaboration is impractical where many producers are in competition, yet raises difficulties for

public accountability if a single producer is granted a monopoly. Two different strategies have been developed for resolving this dilemma:

a) the school building agency puts systems agencies in competition with each other;

b) the school building agency assumes the role of systems agency and places component producers in competition.

236. The first of the last-mentioned alternatives lends itself to "standard product" cost restraint and thus tends to be limited in its usefulness to that stage of educational development where a standard product is less likely to inhibit educational practice. The second alternative is better where educational practice has become so widely diversified in its activities that a standard cost strategy is needed.

237. Varying degrees of monopoly, sometimes rotating among producers for limited periods, have been used by some school building agencies without risk to overall competitiveness, but only where "standard cost" has been the basis of cost restraint. Attempts to place component producers in competition to design and produce products satisfying performance specifications drafted by system agency designers have met with some success, but a major and complex effort is needed to apply this procedure to all components in a system.

WORKING RELATIONSHIPS (CHAPTER VII)

238. In order to strike a proper balance between quality, quantity, rate of production and acceptable expenditure, close working relationships need to be established between the financial planners, educational planners, educationists and architects involved directly or indirectly with school building agencies in the procurement process. All countries need to look critically at how well these decision-making elements interrelate co-operatively, since failures of communication between them are the chief cause when school construction fails to meet the multiple objectives of quality, quantity and cost.

239. Satisfactory working relationships, especially between educationists and architects, are important whatever the method of construction used; but their importance and their complexity are even greater when a standard system has to be designed (or selected) as well as individual buildings.

240. The common difficulty of educationists in synthesising their accommodation requirements is best overcome by collaborating with architects on the design of specific individual buildings. It is by generalised extrapolation from the latter that the criteria to be met by a standard system can be identified.

241. The activity has identified three overlapping sets of decision-making elements as follows:

a) for output/expenditure planning: financial planners, educational planners, educationists and designers of individual buildings;

b) for system design: system designer (as part of system agency) and component designer/producers;

c) for implementation of building programme: educationists, building designers, system designers, builders.

242. It can be assumed that, while a manageable organisation can not embrace all these decision-making elements, communications and collaboration are easiest between elements which are within a single organisation. Analysis of the scale and frequency of decisions taken by each element shows that, on this assumption, communications will be optimised if educationists, individual building designers and system designers can be contained within or closely associated with the same organisation. Within this organisation the individual building designers are the link between educationists and system designers. Building designers and educationists must then form the collaborative link with any separate organisation concerned with output/expenditure planning, while building designers link with builders and system designers with producers.

243. The relationship model just described can not, however, be strictly followed if the term "educationists" is held to include all those who will teach in the schools to be constructed, or if "individual building designers" includes all designers for all buildings. This leads to the conclusion that educationist/designer collaboration requires a synthesising mechanism containing leading educationists and educationally-specialised designers and described as an educational

development group. It is this group which should design the individual buildings which synthesise the needs of the educational development desired, and from which the criteria for systems can be extrapolated (cf. paragraph 240). This process of extrapolation can best be achieved by collaboration between designers concerned with educational development and those concerned with system design, the two kinds of designer thus constituting a technical or systems development group.

244. Institutional patterns may unavoidably require that the two groups are kept separate, even in separate organisations, and so prevent designers from playing a dual role in both kinds of development; in that event every effort is needed to maintain the strongest possible link between the two groups and the designers in each should periodically exchange roles. Where educational and technical development groups have approximated most closely to the model described in paragraph 242 above, the designers have been public employees, but there seems no reason why arrangements having the same effect should not be made where the bulk of architectural work is carried out by private practitioners.

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