DEVELOPMENT OF OBJECTIVE METHODS FOR MEASURING FLEXIBILITY OF SCHOOL BUILDINGS

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ABSTRACT. This research investigates many problems related to the design for change and flexibility of school buildings. The problem of change proves to be highly complex due to the unpredictability and the difficulty of measuring change. Many deficiencies have been identified in the previous methods concerning lack of indicators for measuring flexibility, reliability and insufficiency of data for indicating change in buildings over time. In the light of the above problems, two main objectives have been established: (i) to propose operational measures of the extent of incorporation of design variables in school designs, and (ii) to propose operational measures of the extent of flexibility of school buildings in use. However, due to the limitations this paper is bound to, the investigation will focus on the second objective. It is anticipated that such operational measures might provide a framework for both architects and researchers, during the early design stage, to ensure that their conjectures about the potential of flexibility might be enhanced during use; hence, improving their predictions of buildings performance over time. This might assist in developing a more coherent objective body of knowledge, which could be fruitfully manipulated during the early design stage to enhance the effectiveness of flexibility in use.

1. Problems of Measuring Flexibility

It has generally been recognised that the need for change and flexibility arises from the increasing rate of change in activity organisation, particularly its spatial and services aspects, which characterises particular building types, such as hospitals, laboratories, universities, housing and school buildings. In these buildings, the interface between space and technical services has evoked much controversy about how change can be accommodated cost-effectively during use, and to what extent the provision for change may improve the operational efficiency of buildings in use. The search for an optimum approach to flexibility has become a significant aspect in building design and the focus of many studies in the past. Several design ideas for optimising flexibility can be distinguished, which however differ in their scope and the aspects of change that have been investigated. The basic assumption underpinning these studies is that the extent of incorporation of particular design variables in building designs might enhance and optimise their flexibility in use. Only a few proposals concern us here: (i) the adaptability of design layout to accommodate change in the organisation and activities housed in them (Fawcett 1976a, 1976b; Stedman 1983) with particular emphasis on whether a prediction could be made about changes in activities to match their own spaces in the future (Fawcett 1978; Mavor 1979; Vickery 1979), and (ii) the flexibility of buildings in relation to different design variables, such as uniformity of the spatial organisation and structure, and patterns of circulation and access systems (Weeks 1964, 1969; Habraken et al. 1976; Oxman 1978; Oddie 1974; Moharram 1980; Al-Nijjeld 1985).

The above studies could be criticised as being parametrical rather than comprehensive, since they concentrated on particular facets of flexibility as related to certain variables of the design layout, which in turn detracts from applicability to other building types. These studies have in common the lack of operational definitions and measures of design variables and flexibility, the
inadequacy of the previous methods for measuring flexibility, and the insufficiency of empirical data for measuring flexibility. Only a few attempts have been made in the above studies to assess the extent of flexibility advocated in buildings. These could be categorised as largely subjective; such studies tend to be descriptive, based on a morphological analysis of flexible design (Oxson 1978; Moharram 1980). Alternatively, they could be categorised as objective. The latter fall into four main types: purely theoretical, without any empirical evidence (Aylward 1968; Aylward et al. 1974); theoretical, based on hypothetical models with some empirical evidence (Cowen and Nicholson 1965; Llewelyn Davies et al. 1973); theoretical framework, supported by empirical evidence (Al-Nijadi 1985); and theoretical, based on mathematical models and predictive formula for measurement (Fawcett 1976a, 1976b, 1978; Vickery 1979).

The methods adopted in the subjective studies were based on arbitrary weighting scores for indicating flexibility (Moharram 1980); hence their findings can be considered to have a lower degree of reliability. Most of the quantitative methods suffer from a number of deficiencies, particularly a lack of objective criteria and lack of indicators for assessing flexibility; hence there is a genuine lack of data for indicating change in buildings. Though some indicators have been developed in the latter empirical studies, these are shown to be selective concerning certain types of flexibility related to certain parts, or aspects, of the building and organisation, which makes them unreliable for measuring flexibility.

For example, the method proposed by Fawcett can be criticised as highly probabilistic in tackling the issue of matching activity to space in the future from a purely abstract point of view (Fawcett 1978), as it measures future flexibility rather than past real flexibility. Moreover, the probability of being able to allocate teaching activities to their units of accommodation is highly dubious since the activities are themselves changeable. On the other hand, it hardly considered or presented any operational technique for measuring change in activities. It fell short of explaining the complexity of the nature of activities, particularly about how change has been carried out in other characteristics of the activities. It did not classify aspects of change, nor did it identify types of change or quantify their magnitude, which brings it beyond the scope of this study.

By the same token, the same problems can be identified in the Markov simulation model adopted by Vickery (1979). In this model, flexibility of design was measured according to a lower average of communication cost penalty over time, concentrating on organisational flexibility, and many operational problems can be detected in this respect. Therefore, a comprehensive method for assessing and measuring flexibility is needed to enable data about change to be obtained and applied. In the following, an attempt will be made to develop some operational definition and indicators for measuring flexibility of school buildings.

2. The Meaning of Flexibility

In the literature, several definitions of flexibility have been proposed. These differ according to the type of building and the emphasis that has been given in each study. This is particularly clear in cases where certain attributes or parts of these buildings were investigated. The controversy in describing flexibility in buildings could be envisaged through a diversity of terminologies, such as flexibility, adaptability, variability (Dhahouche 1973), expansion, versatility, convertibility and so on (Aylward and Lapthorne 1974; Pena 1977). Most of these definitions have described flexibility as the potential to accommodate change, indicating why flexibility is needed and how it was advocated in design.

Fawcett (1978) considered flexibility to take into account the uncertainty and changeability of the relationship between activities and space. He defined flexibility as “the probability that a building will not become obsolete, and it is a subjective probability based on state of knowledge about the activities that might occur in the building”. Oddie (1974 p 115) distinguished between
three aspects of flexibility in school buildings: the ‘modular coarseness’ or ‘refinement’ which responds to the diversity of accommodating activities; ‘adaptability’, which refers to capacity for physical alteration to meet changing circumstances; and ‘versatility’ or ‘polyvalence’. He defined versatility as "the quality of building as planned and fitted out which allows for variation in patterns of activities, without the need for physical adaptation". He added that the greater the versatility, the longer the adaptation can be postponed (Oddle 1974 pp. 114-115).

The above distinction contradicts the definitions suggested by Dishonsh (1973 p.13), who distinguished between flexibility and variability. He defined flexibility as the ability to achieve a change of condition, which he claimed to be synonymous with adaptation and modification, whereas variability was defined as the ability to change the condition without recourse to modification.

Thus, it seems that flexibility is a multi-faceted concept and that there is a diversity of definitions that describe these facets, which are mostly concerned with the accommodation of change or adaptation or both. In some definitions flexibility was distinguished from adaptability, and both were considered to be extremes on one continuum, where the accommodation of change can be made with, or without, adaptation. In other definitions (Fawcett 1978) flexibility was mentioned interchangeably with adaptability and in relation to change only.

Despite the diversity of definitions, there seems to be a shared agreement that flexibility could be described according to attributes of both change and adaptation, in any part of a building or a building as a whole. Although such a statement was not explicitly formulated in the literature, it could be stated that the flexibility of buildings could be described along one continuum, depending on the type and the amount of change, in relation to the amount of adaptation that may occur over time. This will be the starting point for measuring flexibility in school buildings. Two operational definitions can be explored and refined in order to arrive at a system of measurement. First, “Flexibility is the quality of building, as it exists at any point in time, which allows for change in patterns of activities that can be accommodated, without recourse to physical change i.e. adaptation” (Oddle 1975 p.33). Secondly, “Flexibility denotes the potential of school building which permits change and variations in activities, time-tabling and class-size group without need for adaptation” (Pearson 1975 p.25).

It appears that flexibility refers to the accommodation for change of activities pursued at a particular point in time. Pearson (1975 p.26) argued that flexibility could be facilitated by a continuum of space and a well-designed system of portable and adaptable furniture, equipment and storage units, allowing teachers and pupils to rearrange their accommodation whenever needed. On the other hand, adaptability was defined as “the capacity of physical alteration by relocation, replacement and removal of components in respect to either the constructional elements or services of the buildings or by addition of further components towards increased adaptability” (Oddle 1975 p.35).

Most of the previous ideas dealt with relocation of partitions as a prime objective of adaptation. Very little attention was paid to other parts of the building. The demand for physical alteration arises from a need to alter the pattern of internal spaces, which partitions demarcate and separate. Nonetheless, it is evident that, in real cases, adaptation was made by pulling down partitions, to make a larger space, or inserted for subdivision. Two main assumptions can be pointed out: (i) both notions are inversely related and opposite in their objective, and (ii) the demand for flexibility of teaching space necessitates certain flexible provisions - the higher the degree of change, the lower the demand for redesigning or adapting the space to the new requirements.

During the course of this study, the term flexibility will be considered comprehensively and it will encompass attributes of both change and adaptation. Meanwhile, the overlap between the classes of flexibility which catered for change, with or without adaptation, can be clarified by further empirical evidence.
3. Development of Objective Methods for Measuring Flexibility

To measure flexibility, some criteria need to be developed and established. Such criteria must be reliable, valid and sensitive enough to allow an objective comparison of the flexibility between different school buildings. Two main measurement criteria can be distinguished in the literature: the objective and the comparative. The former should be based on a yardstick of shared understanding. The latter has to permit teaching spaces belonging to different samples to be assessed comparatively. In this case, the comparison can be carried out according to what was originally proposed so that any deviation or mismatch in use can be detected. This is exemplified when change in the activity patterns and in area/size of teaching spaces are examined. Both criteria will be deployed in this study to develop some indicators related to both change and adaptation.

3.1. Indicators of Organisational Change

Several indicators can be proposed in this study for the purpose of investigation. Though these indicators are interrelated and most likely associated with particular design aspects, they will be dealt with and examined separately in this study. However, it is of primary importance to pull out only few indicators: change in activity types, the use and function of the space, the size of learning group and the area of teaching spaces. These represent various interwoven aspects of change of activity requirements, in terms of their allocation in the space and their interrelationship as a whole. An attempt will be made to examine their reliability and the criterion for measuring each of them will be outlined separately.

3.2. Change in Activity Characteristics

A major emphasis has been given in past studies of activities to investigate the change in activity patterns in buildings. It could be defined as a description of the typical makeup or flow of activities for a population group, a class or an organisation over time (Faberstein 1974 p.19). Most of the past studies of activity are selective in the properties of activities which are incorporated. They lack comprehensiveness since they emphasize parts of the institution rather than the whole. However, measuring change in activities was found to be constrained by many problems in the procedures of collecting data about activity requirements (Al-Nijad 1985 p.120). The availability of data will enable an objective assessment to be made during any limited period of time.

Only two approaches concern us here. The first emphasises activity as related to group size, percentage of meeting time and room sizes (DES 1972, Rawlinson 1978). The second focuses on the activities space interface (Markus et al. 1972, Mavec 1979). It appears that the first is highly relevant to real flexibility of school buildings as it provides an insight into how the organisation of activities housed in the building can fruitfully be manipulated over time to achieve improved use of space. A time-table and space allocation system has been developed and three important interdependent functions of activity were distinguished: (i) the nature of the activity, (ii) the type of facilities and environmental requirements, and (iii) the number of participants in the activities (i.e. size of groups related to areas of rooms).

The second approach was developed by the Building Performance Research Unit (BPRU) and centred around the temporal variations in the functional requirements of comprehensive schools (Markus et al. 1972). The degree of the mismatch between the need and the provision of both activity and space was measured. This was thought to start during the use of the building and to increase as time passes (Mavec 1979 p.12). It was attributed to the change in the timetable of activities which may normally have a duration of one week or longer, and the change in the
teaching methods and curriculum (Maver 1979; Davies and Thng 1972, 1975). A few beneficial
points for measuring change in activities can be distinguished from the above: (i) describing how
the initial schedule of accommodation in school organisation has been transformed and changed
into another during use, (ii) revealing the behaviour setting of different group size and the way of
performing activities, and (iii) indicating how different subjects within the curriculum could affect
the size of learning groups and their distribution as time passes, particularly when different
groups can perform the same types of activities (Maver 1979 pp. 13-14).
A few operational deficiencies could be envisaged: most of them were bound by the lack of
information about activities and their time-tableing in the past as well as the existing patterns; this
might affect the reliability of measurements. Even if some observational techniques are adopted
for data collection, there are still some difficulties in achieving a desirable level of accuracy
through continuous observations. Such difficulties could emerge, for instance, when detailed
observation of teaching spaces is required, which makes it very laborious and time-consuming.
An exploratory approach through questionnaire, observation and discussion with users can be
proposed. This would be more flexible and allow points of significance to emerge, but this may
require more time as the sample becomes larger. Despite the usefulness of the questionnaire in
some situations, detailed observation of an exploratory nature would be a much more adaptable
method. This may enable a cross-checking of the layouts of the teaching spaces to be
investigated. It would also allow observation of the users at work to take place, discussing with
them the nature of their activities and change in their requirements. Such informal discussions
with users may highlight several points about user problems and areas of dissatisfaction.

4. Proposal for Measuring Change in Activity

This study argues that change in activity can be measured in relation to teaching space, in terms of
the degree of mismatch between the requirements of activities and the space, and how frequently
that may occur over time. The availability of records of activities is very important. But when
these records are not obtainable for whatever reason and for any of the school sample under
investigation, this might result in unprecedented consequences. It could affect the
representativeness of the sample and hence lower the number of comparable samples.

From the pilot study of selected schools, some clues about approaching the survey by
reducing the number of schools were revealed, so that a higher degree of accuracy can be
ensured. This implies assessing change of a selected teaching department rather than school
buildings. It seems that the whole school flexibility in use would be very difficult to achieve. It
would be very time-consuming and necessitate expensive resources, which are not available.
There are considerable problems concerning the lack of criteria by which such flexibility can be
assessed. These are ascribed to the variation of size of schools and diversity of their functions
which have to be considered. On the other hand, though the criteria were identified and used in
the investigation, flexibility of school buildings in use is a dynamic and changeable phenomenon,
which would hardly allow such criteria to be adequate.

These arguments would be applicable to the teaching department as well, but to lesser extent
than to the whole school. Although teaching departments are not totally representative of schools,
they can be considered a satisfactory indicator of the overall flexibility of school buildings. Their
significance could be envisaged throughout. First, they are the main organisational and teaching
units of a school building. Secondly, they vary in their design characteristics, such as the shape
of the layout, types of activities they house and their technical requirements; hence, teaching
departments may enable us to compare their extent of flexibility in relation to these variations.
Thirdly, they represent a basis for comparing different constructional methods and building
systems.
Only two types of teaching departments will be chosen for the purpose of comparison in the empirical study. Both differ in terms of activities and their requirements. They fall into the generalised (e.g. Humanities/Languages departments) and the specialised (e.g. CDT/Science departments). Three main characteristics will be assessed:

(i) The type of activities performed. It is evident that teaching activities can be categorised according to four main types: theoretical, light-practical, heavy-practical, and movement and physical education (P.E.) activities. Although this is very useful in indicating change in the level of services of teaching spaces, it would be of lower validity in transforming any detailed information about the nature of activities. Thus, an alternative categorisation can be proposed depending on broad types of activities, or clusters of activities which are most likely occurring and commonly in use. These include, for instance, general teaching, individualised activities, discussion and seminar, experimenting, project work activities, and so on. Such categorisation includes an implicit assumption about the size of learning groups. Nonetheless, the choice of learning group size is an arbitrary measure, which can be varied to suit specific requirements, but it is a more reliable criterion than others for indicating types of activities. By measuring change in type and number of activities, the extent of change in the characteristics of activities could be obtained for each space, which could then be averaged for all teaching spaces in the teaching department.

(ii) The size of learning groups. It is very important to identify whether any change in the size of the learning groups has occurred. By measuring the mismatch in the size of learning groups - comparing the actual size with those originally proposed by the timetable - a new indicator can be obtained. Such a mismatch could be examined in relation to room areas, which may indicate any inadequacy or inappropriateness of the size of areas in regard to their users.

(iii) The time spent on performing activities. This indicator measures the amount of change in the average period of time spent on performing each activity, or sets of activities, and the average number of daily and weekly periods of time-tabled activities. Some complementary information regarding change in teaching methods, curriculum and teaching-aids is needed in relation to change in the level of services of teaching activities.

5. Indicators of Adaptation

Previous studies of flexibility pointed to some manageable procedures for measuring adaptation in buildings in terms of their operational cost of adaptation (Bottle and Piper 1970; Bottle 1971). By indicating all expenditures on conversion and adaptation, it would be possible to arrive at a reliable measure of adaptation. This too would depend on the availability of records about cost for each particular part of the building. Even when these records are available, they often include the total adaptation cost of a school building as a whole rather than the departments, and hence fall short in measuring adaptation. An attempt was made to identify these relevant indicators of adaptation by an examination of the available records and drawings concerning school buildings and accounts of past situations, so a comparison could be made on a chronological sequence, and detailed observations and description of school buildings, which aimed to quantify the type and the amount of adaptation undergone during a fixed period of time. This will be supported by a questionnaire to gather information about the status quo of these buildings in use. That information will enable many changes in building elements which have not been annotated on the plans or on other records to be checked.

Two main indicators can be proposed. The first is adaptation in the area and size of teaching
spaces, which might indicate the pattern of change in the spatial organisation of teaching departments as a whole. The second is internal adaptation in teaching space, which might indicate the types of adaptation in the technical/environmental services and facilities within the teaching spaces. It is evident that adaptation in areas could be made by addition of adjacent teaching spaces, contraction, subdivision and addition of completely new teaching spaces. The overall extent of adaptation in any particular department could be measured in terms of the average percentage scores for each space. However, the data about adaptation could be manipulated to enable development of a hypothetical model of cost of adaptation.

6. Alternative Measure of Cost of Adaptation

A hypothetical model for assessing flexibility in terms of cost of adaptation can be developed in this study as an alternative measure of adaptation. This model is based on extrapolation of percentages of adaptation of areas and internal adaptation into more meaningful cost indicators. It incorporates the parameter of cost of adaptation, as a variable, in allocating scores for adaptation rather than percentages. By allocating scores for each teaching space, a more reliable measure of adaptation may be arrived at. This will be a very difficult task to achieve, due to many interwoven aspects that might influence the estimation of such scores relating to: a) aspects and types of adaptation (e.g. constructional, services and contents characteristics); b) the amount and frequency of adaptation; c) the area and size of the space that underwent such adaptation; and d) the level of services provision of that particular space. Two main indicators of cost of adaptation can be identified as follows: (i) cost of adaptation of area, resulting from inserting or removing walls and/or partitions, according to one or more of the possible ways of adaptation, and (ii) cost of internal adaptation in the teaching space, which incorporates those aspects of adaptation in the contents and facilities within the space. However, this study argues that these indicators could be aggregated into spatial and services characteristics.

6.1. Assumptions on Measuring Cost of Adaptation

The following assumptions have been made for measuring cost of adaptation: first, a system of weighting of different indicators of adaptation was established by deploying previous records about the cost of construction of superstructure, including different building elements and excluding preliminaries. This system has been based on bills of quantities prepared and deployed in the construction of some comprehensive schools which were indicated by cost per sq m of area for each basic element. The analysis proceeds to obtain the average percentage contributed by each element to the overall cost; later on, the relative cost per element can be identified as shown in Table 1. Secondly, a weighting of indicators was accomplished by creating an association matrix to determine which of the elemental costs were affected by any single indicator of adaptation examined, as indicated in Table 2. Thirdly, indicators of adaptation were summed and the resulting scores were normalised to the lowest weighting scores. Hence, relative weighting scores for each single indicator of adaptation could be identified, as shown in Table 3, so that a comparison and assessment of cost, with respect to adaptation of area of teaching spaces and the internal facilities within them, could be made. On the other hand, further aggregation of scores in all or in part of these indicators can be made by substituting the occurrence of adaptation in each particular space with its corresponding weighting scores. Given the variations in areas and the difficulty of identifying the extent of adaptation for each indicator, it becomes necessary to cross-check any possible type(s) of adaptation through detailed observation. A modified design layout indicating all alterations made during use will then be drawn and prepared. In this way, a reliable measure of cost of adaptation could be arrived at by incorporating the area of space and
### TABLE 1. Analysis of percentages of elemental costs at the tender stage of four comprehensive schools

<table>
<thead>
<tr>
<th>Building elements</th>
<th>Maiden Erleigh School</th>
<th>Sedgefield Secondary School</th>
<th>Guillemont Junior School</th>
<th>Furthorough College of Technology</th>
<th>(%)</th>
<th>(X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Columns, primary</td>
<td>10.39</td>
<td>7.32</td>
<td>10.39</td>
<td>11.13</td>
<td>9.50</td>
<td>4.2</td>
</tr>
<tr>
<td>3. Beams and slabs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Upper floors and roofing</td>
<td>3.47</td>
<td>15.18</td>
<td>14.05</td>
<td>25.39</td>
<td>12.46</td>
<td>5.6</td>
</tr>
<tr>
<td>5. Floor finishing</td>
<td>6.84</td>
<td>3.38</td>
<td>6.50</td>
<td>3.30</td>
<td>5.57</td>
<td>2.5</td>
</tr>
<tr>
<td>6. Wall finishing</td>
<td>3.62</td>
<td>4.10</td>
<td>1.75</td>
<td>3.62</td>
<td>3.6</td>
<td>1.6</td>
</tr>
<tr>
<td>7. Ceiling finishing</td>
<td>6.22</td>
<td>6.27</td>
<td>4.98</td>
<td>2.11</td>
<td>5.82</td>
<td>2.6</td>
</tr>
<tr>
<td>8. Partitions</td>
<td>8.33</td>
<td>8.49</td>
<td>6.87</td>
<td>11.98</td>
<td>7.90</td>
<td>3.5</td>
</tr>
<tr>
<td>9. Openings (external doors and</td>
<td>5.84</td>
<td>8.74</td>
<td>2.60</td>
<td>1.05</td>
<td>5.73</td>
<td>2.6</td>
</tr>
<tr>
<td>10. Sanitary services</td>
<td>4.14</td>
<td>3.72</td>
<td>2.10</td>
<td>0.46</td>
<td>3.32</td>
<td>1.5</td>
</tr>
<tr>
<td>11. Water and gas serv.</td>
<td>3.52</td>
<td>3.45</td>
<td>3.48</td>
<td>2.06</td>
<td>3.50</td>
<td>1.6</td>
</tr>
<tr>
<td>12. Fire safety and equip.</td>
<td>6.80</td>
<td>7.30</td>
<td>0.97</td>
<td>7.05</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>13. Electrical/Telecom.</td>
<td>8.88</td>
<td>5.63</td>
<td>3.15</td>
<td>8.78</td>
<td>6.35</td>
<td>2.9</td>
</tr>
<tr>
<td>14. HVAC</td>
<td>16.03</td>
<td>16.76</td>
<td>14.33</td>
<td>18.54</td>
<td>15.70</td>
<td>7.0</td>
</tr>
<tr>
<td>15. Heat source</td>
<td>-</td>
<td>0.72</td>
<td>1.61</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
</tr>
</tbody>
</table>

(*) The approximate average percentages of each elemental cost in four schools.

(X) The final average percentage of cost per building element has been calculated according to the percentages indicated in the four schools, except when there are greater variations in the design and building materials used.

Sources:

The aspect(s) of adaptation expressed by its weighting scores. A mathematical formula was developed by multiplying the weighting adaptation scores (Wx) by the areas of each space and obtaining the average scores for all spaces examined. Consequently, the Index of Adaptation Scores (IAS) proportionate with area could be identified for each department expressed by the formula:

\[
IAS = \frac{(W \times A)}{N}
\]

where,
- \(W\) = weighting adaptation scores
- \(A\) = area of teaching space
- \(N\) = number of teaching spaces
### Table 2: Association matrix between indicators of adoption and relative costs of different building elements

<table>
<thead>
<tr>
<th>Building elements</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>A9</th>
<th>A10</th>
<th>A11</th>
<th>A12</th>
<th>A13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. External walls</td>
<td>5.2</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Columns, beams, slabs</td>
<td>4.2</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Upper floors/roofing</td>
<td>3.6</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Floor finishing</td>
<td>2.5</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Wall finishing</td>
<td>1.6</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Ceiling finishing</td>
<td>2.6</td>
<td>*</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Internal partitions</td>
<td>3.5</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Openings (external)</td>
<td>2.6</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>9. Internal doors</td>
<td>1.0</td>
<td>*</td>
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<tr>
<td>10. Fixtures and equip.</td>
<td>3.2</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>11. Sanitary services</td>
<td>1.5</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12. Water and gas serv.</td>
<td>1.6</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>13. Electrical/Telecom.</td>
<td>2.6</td>
<td>*</td>
<td>*</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Heating/ventilation</td>
<td>7.0</td>
<td>*</td>
<td>*</td>
<td></td>
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<tr>
<td>15. Special install.</td>
<td>0.6</td>
<td>*</td>
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<tr>
<td>Derived weighting</td>
<td>18.9</td>
<td>7.3</td>
<td>17.4</td>
<td>3.5</td>
<td>3.2</td>
<td>2.3</td>
<td>5.1</td>
<td>6.6</td>
<td>2.6</td>
<td>2.9</td>
<td>3.1</td>
<td>6.0</td>
<td>7.1</td>
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</table>

### Table 3: Relative weighting scores of cost of adaptation

<table>
<thead>
<tr>
<th>Indicators of flexibility</th>
<th>Summation of weighting scores of adaptation indicators</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>A9</th>
<th>A10</th>
<th>A11</th>
<th>A12</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3: Addition of adjacent space</td>
<td>B6: Change in no. of openings</td>
<td>17: Adaptation in utility service (A)</td>
<td>18: Adaptation in utility service (B)</td>
<td>19: Change in movable partitions</td>
<td>(e.g. water supply, sanitary instal.)</td>
<td>20: Change in interior cabinets</td>
<td>21: Change in movable equipment</td>
<td>22: Adaptation in place-fixed equipment</td>
<td>23: Adaptation in the height of space</td>
<td>24: Addition of computer/micros.</td>
<td>25: Addition of audio-visual/video</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derived weighting</td>
<td>18.9</td>
<td>7.3</td>
<td>17.4</td>
<td>3.5</td>
<td>3.2</td>
<td>2.3</td>
<td>5.1</td>
<td>6.6</td>
<td>2.6</td>
<td>2.9</td>
<td>3.1</td>
<td>6.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Normalized weighting</td>
<td>7.4</td>
<td>5.0</td>
<td>14.5</td>
<td>1.4</td>
<td>1.2</td>
<td>1.0</td>
<td>1.2</td>
<td>2.5</td>
<td>1.0</td>
<td>1.3</td>
<td>1.2</td>
<td>2.3</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### 7. Proposed Indicators for Measuring Flexibility

#### 7.1. The Objective Indicators of Flexibility

Given the type of information demanded about flexibility and the level of specificity required, two data collection methods can be deployed. The first is by examining and observing change and
adaptation in the school buildings. The second is by asking users, who may provide supporting empirical data, about different types of change and adaptation which would occur in their particular teaching spaces. By adopting a questionnaire as a measuring instrument, two problems concerning the role of users can be identified as follows: (i) the limitations of the time interval which may highlight the issue of users' awareness of changes that have occurred in their particular spaces prior to their occupation, and (ii) the difficulties that emerged during the analysis and manipulation of the data in the pilot study, due to the multiplicity of the indicators. This might suggest further aggregation of those relevant indicators, if a questionnaire is used, resulting in a further reduction in the number of questions. Four indicators are proposed and outlined below.

7.2. OBJECTIVE INDICATORS OF FLEXIBILITY

These indicators measure flexibility of teaching departments and incorporate the change in the function and use of the teaching departments; the adaptation in the area and size of teaching spaces, which incorporates an aggregation of the sub-indicators regarding adaptation by addition of adjacent teaching space, subdivision of the space, and addition of completely new space(s); the organisational change in teaching space, which deals with change in the requirements of activities housed in the teaching space, and, finally, the internal adaptation in teaching space, which investigates different possibilities for internal adaptation regarding the physical building aspects and the contents of the space. It incorporates two main aggregations of sub-indicators of the spatial and services characteristics.

8. Proposal for Data Collection Techniques

The search for proposals for data collection methods reveals that no single method of obtaining data to test hypotheses is perfect. Each method has its own inadequacies which could lead to the possibility of rival hypotheses explaining the findings (Van Delen 1979 p.128). Three methods have been adopted in this study: the questionnaire, detailed observation, interviews. Both questionnaire and detailed observation can be considered as the main measuring instruments for acquiring data, compared to the interview which could be considered supplementary. However, both could be criticised on the basis of reliability and subjectivity compared to interviews. Despite the above disadvantages, the interview seems to be more interactive and analytical by its nature, supporting the observation and the questionnaire and enabling a discussion about the issues to be researched in parallel. Also, it may allow points of significance to emerge which might otherwise require more time.

8.1. THE QUESTIONNAIRE

A questionnaire will be adopted to enable comparison between different teaching departments in terms of their past change and adaptation in relation to the present. Several advantages of the questionnaire could be foreseen, such as its efficiency in coping with large numbers of selected schools and users which have to be questioned. Meanwhile, to overcome the dispersion of schools around different regions, the questionnaires could be mailed directly to each particular group of respondents. There are also advantages relating to the particularity of the gathered data, as well as to its usefulness in the final refinement on a more numerical basis. These advantages may facilitate data analysis and manipulation in comparable way. Further advantages of the questionnaire lie in the comprehensiveness of the data that will be collected. Comprehensiveness will thus apply to the most relevant indicators, not only to those for which records are available. This might enable users to report detailed information about a change in activities, or about the
extent of adaptation which is often reversible and not reported on the plan. A few disadvantages
can be identified, such as the probable bias of the collected data which results from the users’
interpretation, the construction and the understandability of the questions. These could be
dealt with by careful restructuring and piloting of the questionnaire on a selective group of users
before being sent to the whole school sample. Another disadvantage of the questionnaire was that
it yielded soft rather than hard data. This, however, could be compensated by other advantages
such as comprehensiveness of the collected data, larger size of sample and a higher rate of
response. It was decided that the questionnaire and the questions to be asked should be mainly of
the multiple-choice and closed-ended type. Three main types of questions have been asked to
obtain the necessary background, consisting of factual and perceptual data about flexibility.

8.2. PRETESTING THE QUESTIONNAIRE

A pilot study was undertaken and a preliminary version of two types of questionnaire for both
groups of users was distributed to a number of respondents. The aim was to test the structure of
the questionnaire and the understandability of the questions. Some very enthusiastic remarks and
suggestions emerged in the pilot study concerning the contents, the clarity of the questions and
the degree of their relevance to flexibility. These gave the necessary momentum for the next stage
of elaborating the final version and refining the questions with a few minor amendments. Both
questionnaires are self-administered; there was a concern initially, after reviewing several other
instruments, that they might prove to be too lengthy. However, in the light of the amount of
information available, it was decided to simplify the language and format. Checking the length of
the questionnaire in the test has led to a reduction in the number of the questions to be addressed.

9. The Importance and the Applicability of the Study

Flexibility refers to the ability or the capacity of buildings to cater for change and adaptation in
use. Flexibility is inherent in every building but to a different extent; the tendency to increase this
capacity is a highly desirable characteristic. The flexibility of any building can only be measured
in relation to the amount of both change and adaptation. An empirical study of a selected school
sample has been undertaken to test the framework of measurement. A few methodological points
of interest emerged from the test. First, more than one method of measurement is needed. The
emphasis on new areas of investigation most likely necessitates developing some subjective
methods compared to those already adopted in this study, highlighting the demand for the
triangulation of methods. In doing so, the validity of the data collected by the questionnaire
should under no circumstances be achieved at the expense of its reliability or representativeness.

Secondly, there is a large potential for manipulating school layouts to provide for flexibility, though on
lines that are different from what was suggested before. This may lead to more
exploratory research into other variables of the layout. This points to the importance of tackling
uncertainty through some design decision support systems, rather than adopting a historical
approach in predicting the development of organisations and designing for this development. That
is to say that the problem of obsolescence due to unpredictable change could be encompassed in
some way. This might also be very beneficial in predicting the performance of school buildings in
use, and hence determining the limits of flexibility, or the degree of planning versus techniques of
change, which could be manipulated during the initial design stage to enhance the potential of
accommodating change during use. For architects, this is likely to limit the design considerations
that architects have to encounter related to flexibility, concentrating on more demanding issues
about the human and physical environment interface. For researchers in the field, this study
demonstrates that flexibility could be manipulated more effectively during the early design stage.
This study draws their attention to the major role of design in enhancing flexibility in use. It shows that they could approach flexibility within a valid framework of measurement and deal with it empirically, rather than by relying on intuition and subjective judgement. This study supports the growing belief in the necessity of adopting research in design, arguing that architects can no longer rely entirely upon intuition, personal experience and precedent. It acknowledges that practice must be based on empirical knowledge carefully acquired through research, as well as personal experience, which can improve both the design process and the final architectural product.

References


Markus, T.A. et al. (1972) Building Appraisal, Building Performance Research Unit, University of Strathclyde.