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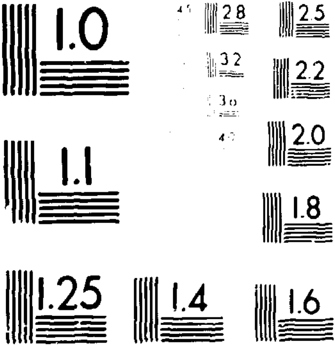

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RESEARCH PRIORITIES FOR THE BUILDING MATERIALS INDUSTRIES IN DEVELOPING COUNTRIES *

by

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1. INTRODUCTION

Consultations in sectors producing building materials have taken place on previous occasions:

Iron and steel:	I	consultation	1977
	II	"	1979
	III	"	1982
Wood:	I	"	1983

Some of the recommendations stated as a result of these earlier consultations have relevance for the building materials industries also but in general these consultations were concerned to a relatively minor extent only with applications of steel and wood as building materials and even less with research priorities for such purposes. Finally in 1983 the decision was taken to convene a First World Consultation on the Building Materials Industries. By way of preparation various studies will be undertaken into different macroeconomic, technical, financial and other aspects. One specific topic is research and development (R&D). This does (or indeed should) contribute significantly towards increasing the production of building materials, to reductions of imports and to a more economic use of resources (energy, raw materials, labour).

The objective of this study is to highlight the research aspects of the building materials industries in the developing countries. This has been carried out with due consideration for the character of the World Consultation: it concentrates on the problems of developing countries. It is, however, a specific feature of the topic that research in developed countries also allocates resources to problems of developing countries and it is desirable to maintain or even strengthen this. The timetable of preparations for the World Consultation has also acted as a constraint on the method of preparing this study. It had to be written within a strict timeschedule and in consequence it was not possible to consult experts in various countries about certain matters. Nevertheless, it obviously could be revised at a later stage if required. The Appendices quite specifically have the character of working documents; lists of institutions are given to serve rather as a first indication of institutions in the field and other Appendices are intended to complement the study itself.

The building materials industries can be divided into two groups:
- small and medium scale (low capital intensive) production
- large scale (high capital intensive) production

or, according to different criteria:

- traditional manufacturing techniques
- modern manufacturing techniques

There is a distinct difference as regards research requirements for the small scale production of indigenous materials and for the industries using modern technologies, (usually but not necessarily on a large scale). Thus, for example, some cement factories in developing countries require research on problems which occur in developed countries also. The study does not deal in detail with research problems that are present in developed countries also. It concentrates mainly on research needs specific to developing countries.

In the next Section a summary of the overall situation of research on building materials and on buildings will be given. In the following Section 3, the main objectives and trends of research will be set out. Then in Section 4 research priorities regarding the main building materials will be listed. In Section 5 methods for selecting research priorities will be introduced as well as the conditions to implement the selection.

* * *

2. PRESENT STATE OF BUILDING MATERIALS RESEARCH

Building materials research itself is a recent phenomenon. Although cement was invented back in the nineteenth century research on cement and concrete is still of extreme importance in our days. Gradually, however, research has extended to bricks and tiles, glass, timber and various other building materials (bituminous, paints, plastics, etc.). Some of the materials used as building materials are produced by other industrial sectors: steel, aluminium, plastics, etc. Research on these can be considered to some extent only as building materials research. Most building materials research activities concern cement (and other binding materials: lime, gypsum, pozzolana), concrete and mortars, burnt clay, glass, timber. Recently, however, research has gone into some new fields also: prefabrication of components, plastics, etc. Building materials research is closely related to building research. Indeed the practice in many countries is to organize research for both in one single research institute. The line of demarcation between the two fields is blurred: e.g. concrete can be considered as a building material but it can also be considered as a product of construction activity. In countries which are able to allocate resources on a major scale to building materials and building research separate research institutes can be established. In several countries there exist separate cement research institutes which frequently have in their scope lime, gypsum and eventually concrete also.

In recent years research on building materials (and on construction) made significant progress in many developing countries. In the two largest countries, (China and India), several research institutes are active in this field each with a staff of over 100, in some cases even going up to four to five hundred. In other smaller countries building materials research is carried out by small units manned by only a few staff members.

Appendix 1 contains a list of institutions active in building materials research in developing countries. Inevitably such a list cannot be exhaustive and there are other building materials research institutes also which are not mentioned. Nevertheless, the list does give a first information about existing institutional research capacities in developing countries. Several institutions in developed countries have specialized units charged with carrying out building research and building materials research for developing countries. Some of these also are listed in Appendix 1.

It can be stated that each country needs to organize on a larger or smaller scale its own building materials and building research. This does not mean that research in these sectors has to attain the levels of sophistication of, for example, biotechnology or electronics. In all countries the proportions which expenditures on building materials and building research bear to the annual turnover in these sectors are lower than the corresponding figures for high-technology sectors. Many countries, on the other hand, can avoid the necessity of establishing certain areas of domestic high-technology research; this is not possible for the building materials and building industries. Each country must develop its own building industry and it is an intolerable drain on resources to rely indefinitely on imports of building materials.

Building materials are manufactured from indigenous resources and the technical characteristics of raw materials (stone, sand, clay, etc.) are never completely identical for all countries. This in itself compels countries to reproduce experiments carried out earlie in other countries (wi ther raw materials). Such replication also makes developing countries familiar with up-to-date techniques and serves as preparatory steps in introducing new production methods and new products.

Building materials research institutes can be:

- public
- semi-public
- private

Public (i.e. state-owned) institutes exist in those countries with a central planning economic system: East European countries, China, etc. In market economy countries building materials research is usually organized by private industry or is semi-public. On the other hand, in Western market economy countries there are also public building research institutes and these deal to varying degrees with building materials research as well.

Private building materials research can be organized by large individual enterprises, (LaFarges for cement, Pilkington and Saint-Gobain for glass, etc.). It can be organized by an industrial subsectorial association, as is the case, for example, in the UK (Cement and Concrete Association) and in the FRG (Forschungsinstitut der Zementindustrie). Research carried out by research institutes in developed countries can have a relevance for developing countries or can be targeted directly at solving problems in developing countries. If the latter, then the research usually is financed by special assistance funds.

All over the World universities and higher education establishments occupy an increasingly important role in industrial research, (as regards research into natural sciences this has always been so). In several countries building materials (and building) research institutes are in some way linked to a University. Research on building materials requires suitably equipped laboratories. Sometimes these are costly and there is no need for more than one laboratory or set of apparatus in a given country or region. In such cases either an Institute or a University is appointed as the organization responsible for maintaining and developing a laboratory. Shared use of common laboratory facilities can be arranged. In developing countries Universities usually tend to be public (state) organizations. In certain developed countries (notably in the United States) some of the Universities are private institutions (e.g. Stanford University in California).

Summarizing the present situation it can be stated that developing countries have made significant steps towards establishing their own building materials research institutions. Experiences in developed countries show that newly established research institutes usually need an initial period of some ten years before they can be said to have become really efficient. The same maturing process will be repeated in newly established research institutions of developing countries also. It will be necessary to strenghthen further the research and technological potentials in developing countries.

* * *

3. OVERALL RESEARCH OBJECTIVES

3.1 General principles

This paper has a global relevance but it has to be said that it is impossible to define research priorities on a global scale; these have to be defined for a given country and within a given period. The research priorities in this document therefore are intended as a first indication. They are generally based on completed or ongoing research in one country or in some countries and constitute research topics which probably could be selected with benefit in many countries. The extremely scattered character of the construction industry and its dependence on more or less different local resources provides the explanation for this. In country A the production of lateritic blocks may be solved; this does not mean that the results could be transferred to country B without additional research, one of the reasons being the different specific nature of laterites in different countries. The selection of research priorities requires therefore the application of two distinct processes:

- the identification of potential subjects for research;
- methodology for comparing the competing potential research subjects in order to decide which to accept and which to reject.

This document seeks to elucidate both of these processes; it gives certain indications about research subjects which might be worthwhile considering and it lays down certain basic principles on selection methods to be used. These recommendations will not be adequate in every country for the actual selection process. The research subjects will have to be defined and selection methodologies will have to be adapted according to domestic conditions. In what follows certain overall research objectives are summarized.

3.2 Use of local (domestic) materials and by-products; conservation of resources and energy

In many developing countries massive quantities of building materials have to be continuously imported. This is a needless waste of the country's resources because in most countries adequate raw materials exist for the production of building materials. Research into the uses of local (domestic) materials has a top priority. In addition to conserving valuable hard currency, it also alleviates the problems of handling the imports and transporting them to distant places. Local (domestic) materials as a rule should be cheaper than the imported materials they replace.

Natural resources are different in individual countries. Some have abundant timber resources; in others there is a shortage of timber. In countries where there is not sufficient timber available, masonry arches and domes, dwellings cut into the mountainside, reinforced concrete beams have to be used. Stone, clay, gravel, sand may well seem to be present everywhere but actually this is not quite the case. In many countries, one or the other is lacking or the characteristics of those that are available are such as not to make them directly applicable for building purposes. At the same time research can open the door for uses of natural materials which formerly were avoided (e.g. certain timber species or lateritic soils). It is an important task of research to broaden the list of natural resources capable of economic use for building purposes. In addition to natural raw materials (sand, lime, stone, earth, etc.), industrial and agricultural by-products also should be used for the purpose of manufacturing building materials. This also reduces the growing heaps of slags and other unsightly wastes and can mean a first step towards rehabilitating environments disturbed e.g. by mining. Energy conservation also has top priority in research and particularly so in oil-importing countries.

3.3 Improving durability and fire resistance

Indigenous building materials (earth, palm leaves, etc.) may be very cheap but frequently their durability is low. The life-cycle of some local building materials may not exceed two years. Quite obviously lengthening the life-cycle of indigenous materials through improving their durability has a high priority in research. It is important to achieve this objective by means of methods that are cheap. Durability of building materials and of buildings has acquired a high priority in developed countries also and much research on the topic has been executed or is underway. A considerable body of knowledge has resulted but developing countries have specific durability problems. The lifetime periods are usually much shorter; also the climatic and other ecological factors affecting durability are different. Durability, therefore, qualifies as an important area for research in developing countries also.

he most important categories of building materials in this repect are earth and timber; the most important categories of building parts are the roofs and the walls. Research should concentrate on increasing the durability of these materials and parts of buildings.

Earth is a durable material provided it is adequately protected from rain, ground water and other forms of moisture. Protection from the ground water can be ensured by stopping the movement of moisture by a water insulating (bituminous, etc.) layer; waterproofing the rendering mortar affords protection from direct or splashing rain.

Plain mud plasters can be coated with thick cement slurry wash, at least on the face exposed to rain. This splash has to be renewed periodically. The waterproofing of the mortar can be achieved through adding cement or some other domestic appropriate material, e.g. calcium palmitate (an acid produced from palm oil soap). Addition of fallow to lime makes whitewash more water-resistant. Protection against rain can be obtained through having regard to appropriate architectural details: e.g. protection through roofs.

Degradation of organic fibrous materials can be caused by weather, insects, fungae. Certain timber species are susceptible to fungal and insect attack and can only be used after some form of preservative treatment. The correct timing of conversion of logs and of seasoning sawn wood at the millyard improves durability.
Several countries have devised effective ways to safeguard materials against termites. Durability can be a problem in newly developed materials also. So, for example, the embrittlement of sisal fibres in concrete can be prevented by reducing the alkalinity of pore water through replacing a part of the portland cement with silica fume or with high alumina cement or by sealing the pore system with wax or some other fibrous impregnating agent.

Besides adverse weather, fire constitutes a major hazard in destroying structures. In many developing countries this is a high risk due to the materials used. Increasing resistance to fire therefore is an important task for research.
Earthquakes, floods (tsunamis, typhoons, etc.) destroy not the materials but the whole structures. The application of existing research results as well as further research could reduce losses suffered in terms of money and of course of human life. One of the new and relatively cheap techniques is reinforced masonry which increases resistance to seismic actions. This is still being utilised to a very small extent and an expansion in its application could yield marked benefits.
Tropical wet or dry climates affect materials in various ways. This has induced some countries to undertake research on mould resistant emulsion paints.

3.4 Appropriate technologies; economics of research and technical development

It has been repeatedly stated that merely dumping the technologies evolved in developed countries onto developing countries can cause more harm than benefit. Specific conditions of developing countries require specific appropriate technologies. In many countries this may also mean reduced capacities but this is not the only feature of appropriate technologies. The principal condition is that the technology should be such that it could be mastered and maintained and gradually developed further.

One of the most important features of developing countries (from the point of view of technical developments), is the low level of incomes and the relatively high cost of materials in relation to income levels. This means that substituting labour by materials or machines may prove economical in developed countries but may frequently not be feasible for reasons of economics in developing countries. The replacement of labour-intensive methods by mechanized processes can only happen gradually, and the period of time necessary will depend on when such changes become feasible as a consequence of increasing incomes and decreasing prices of machines and materials. Research also has to consider these circumstances.

Research is not for its own sake, nor even simply for the sake of technical development; its purpose is to improve housing and living conditions and to increase productivity and well-being in a country. Many case studies can be quoted in developed as well as in developing countries to illustrate situations when research & development did not attain this goal. In some instances technical development (new factories, etc.) swallows up more of a country's resources than do the new values produced through this development. Bitter lessons have been learnt but even these afford no guarantee against similar mistakes being committed again. For this reason, when defining a list of priorities for research, high on the list must figure the economic (commercial) control of research ideas. This is necessary during all stages of research: prior to accepting a proposal for new research; while the research is progressing and upon its completion when a decision must be made as to whether or not to put the results into practice.

Implementation of the above principles requires that research institutes should be able to assess the economics of research and of its potential applications. Among the staff of research institutions there must be economists and/or technical researchers with adequate understanding of economic principles; it is their task to assess economics of research and of technical development.

3.5 Quality control

The use of indigenous building materials has always been based on practical experience. Though this could be satisfactory under traditional conditions, quality control could contribute to a better use of resources. The application of quality control techniques brings to the surface differences in quality. This allows those materials with the weakest properties to be eliminated and thereby the better properties of the remaining materials can be more advantageously utilized. This can also impart to producers a consciousness as to how they could improve the quality of the building materials. Quality control of course is not in itself research but frequently it is organized in the same institutions as research. The same laboratory equipments can be used for quality control and for research. Proper quality control will reveal deficiencies in the quality of building materials and this knowledge serves as a starting point for research aiming at eliminating these deficiencies.

Quality control laboratories are often set up at Universities because such apparatus is also necessary for teaching purposes and quality control acts as a bridge between University teaching personnel and industry.
Another solution is to establish one quality control laboratory for all industrial sectors including the building materials industries. Whatever the structural set up chosen, the establishment of a competent institution and procedures for quality control should have a high priority in developing countries (also).

3.6 Conservation of resources and energy

Regrettably mankind's awareness of the vital need to conserve resources is a relatively recent phenomenon. Initially it has been restricted to developed countries. In developing countries the need to increase production and welfare was placed above the conservation of resources. Even at the present time occasions can be found where developed countries attach a higher importance to the conservation of resources than developing countries. This discrepancy, however, is rapidly on the wane. The energy crisis beginning with 1973 speeded up this process. Oil exporting countries seek to conserve their oil stocks for as long as possible; countries importing oil are compelled to conserve energy in order to keep down rapidly increasing energy import bills.

The objective to conserve other resources (natural environment, raw materials, etc.) also receives growing attention. Much energy is used up during the operations of drying, curing and burning building materials. Solar energy is a natural form of energy which can replace part of the fuels used earlier in manufacturing. Mixing clay with organic by-products (rice husks, saw dust, etc.) also reduces fuel consumption in brick burning. Curing of concrete should be carried out as far as possible without introducing steam curing and instead making use of natural heat, eventually enhanced by solar radiation.

Building research can give guidelines to designers to enable them to design buildings which require reduced amounts of energy for heating, ventilation and air-conditioning purposes. Conservation and rehabilitation of the natural environment (e.g. restoration of abandoned quarries, etc.) also will be of growing concern in developing countries.

* * *

4. RESEARCH PRIORITIES FOR THE BASIC BUILDING MATERIALS

4.1 Earth (clay, adobe, laterite)

Earth is a peculiar building material. It is used in California (USA), France and some other countries to erect buildings for clients who are certainly in the position to afford any other structural material. On the other hand, people in many developing countries reject it as unworthy for use in building decent homes. While these two extremes occur, millions of families, unaware of the anomaly, use earth as a building material with a total indifference to research and industrialization and in doing so keep alive ancient building traditions and habits.

Research is trying to ascertain its proper place as regards earth. Its recommendations are good: to protect it from rain and splashing water, to stabilize it, to combine it with beams over openings and rooms, etc. In some countries these recommendations find their way into practice, in others the implementation process proves to be longer and less successful.
Earth, adobe, laterite, etc. can be stabilized with various materials (cement, lime, gypsum, bitumen, ash sand, grass, sisal, cow dung, etc.). The choice depends on local conditions (availability of individual binders) and research may be required to define the optimum mixing proportions and techniques taking into account characteristics of the local earth (laterite).

Despite universality of knowledge, experiences with earth vary greatly. The tools, presses, moulding tables, shutters and methods are different and these together with differences in raw materials' properties, climate and other conditions account for the greatly differing experiences. A number of presses and rams have been developed and are used for manufacturing stabilized earth and laterite blocks and bricks: CINVA-RAM (Columbia); Terstaram (Mali); BREPAK (Ghana); TEK-Block-Press (Ghana); CENEEMA (Cameroon); Ellson Blockmaster (South Africa); Supertor (Brasil); Latorex (Denmark); CONSOLID (Switzerland, Ghana).
In countries and regions where none are used a study and selection of these or their adaptation to local conditions could contribute to the development of the use of walling materials.

By means of information exchange and transfer of experiences, the global pool of knowledge is combined with local willingness or reluctance for change and yields gradual if slow progress with this ancient building material. To contribute to this development is the highest priority for research; how to achieve this is a matter of correctly assessing local conditions.

4.2 Cement, lime, gypsum, pozzolana

In the majority of developing countries there is a shortage of cement and to some extent of other binding materials too. For this reason increasing the production and securing a more economic use of these materials must have a high priority in general, not least as concerns research.
The manufacture of cement is more capital intensive than is the manufacture of lime and pozzolana. Therefore a substitution (at least partially) of cement by lime and pozzolana is important. The same objective is attained by manufacturing mixed (blended) cements in which part of the cement is substituted by natural pozzolana or by industrial by-products, (fly-ash, slags, sand), having hydraulic properties. An inadequate road and railway infrastructure and insufficient transport capacities can create local shortages of cement (or other building materials). Therefore it is in many cases important to commence or expand the manufacture of cement (and other materials) locally. The appropriate raw materials have to be investigated, the manufacture and use of cement in local (subregional) plants have to be studied. These rank as tasks of high priority for the building materials researchers.

Some developing countries have modern kilns for the burning and grinding of cement, manufacturing of lime, gypsum and pozzolana. The majority of research priorities of these plants are identical with those in developed countries. These concern:
- geological investigations of minerals and research on optimal mixes;
- improvement of quarrying and transport processes;
- improvement of burning and grinding processes;
- energy conservation;
- introduction of automatic control systems, use of computers and microprocessors (CAM);
- introduction of new and improved products, (magnesite cement, sulphate resistant cement, white cement, etc.), and their regular quality control;
- introduction of new products manufactured with cement and other binding materials;
- use of wastes and by-products (slags, fly-ash, phosphogypsum);
- protection of environment, reduction of air and water pollution, reclamation of abandoned quarries;
- research aimed at improving manufacturing equipments, their maintenance, repair, life-cycle.

In many developing countries cement (and eventually lime and gypsum also) are imported in substantial quantities. If possible the availability of volcanic pozzolana should be explored which can be used as a substitute for at least a part of cement, lime and gypsum. Rice husk ash with lime also can substitute for cement. In blended cement part of the portland cement is substituted by pozzolana or slag or fly ash. Some further research areas are:

- Elaboration of simple medium and small size manufacturing units: cement and lime burning kilns, burners for these, lime hydrators;
- use of local raw materials and by-products (magnesian and dolomitic limes, pozzolana, phosphogypsum, rice husks, fly-ash, mica scrap, mine wastes, lime sludge from acetylene, wastes from paper and sugar industries);
- use of local fuels for lime burning (e.g. pellets premixed from rice husks and clay).

4.3 Concrete, mortar, bricks, blocks, precast components

The production of concrete, bricks, blocks, etc. is a secondary manufacturing stage making use of primary raw materials and basic building materials (gravel, sand, clay, cement, lime). Some of the production processes are carried out off-site in (e.g. prefabrication) plants; others are or can be on-site processes. Building materials research and building research overlap each other in this field.

Long distance transport is usually expensive in developing countries and the necessary infrastructure for this is often not available. Consequently, plants producing bricks, blocks and precast components cannot serve too large areas and hence have to be small or medium size. Due to the usual lack of capital, they have to function with simple equipment and research has to take these constraints into account.

Research on technological processes making use of cement and other binding materials extends to curing including steam and solar curing, vibration, chemical additives to improve workability, frost resistance, processes of setting and hardening, durability, reduction of crack formation, impermeability, etc.
Steel reinforcements constitute an expensive component in producing reinforced concrete. So substituting steel by vegetal fibres (sisal, coir, wood pulp, elephant grass, wood wool, kenaf) can be the answer. Sisal fibres can be used as reinforcement in chopped form or as long fibres or twines. Cement is another expensive constituent of concrete. Research on concretes with a low cement content can save money and do much to alleviate the shortage in cement. Mixing water seems to be an inexpensive part of concrete but there is a water shortage in many places. Research can assist by clarifying the (partial) use of sea water as mixing water in concrete. In places where laterite is abundant but there is no adequate sand available, laterite can be used in concrete.
Bricks can be produced by:

- labour intensive
- semi-mechanized, and
- fully mechanized methods

The optimum sizes of manufacturing units depend on local and regional factors: including size of the market, salary levels, existence of transport network. Some clays can be used for the production only if mixed with sand, or if no sand is available, with other adequate fine material: basalt fines, fly ash, cinder, colliery wastes. Part of the fuel can be replaced (and at the same time heat insulation properties can be improved) by adding organic materials (such as husks, saw-dust) to the clay.

4.4 Timber, bamboo, other vegetal products and by-products

Wood is not used solely as a building material and it has a number of other uses. A World Consultation has already been held earlier for the wood and wood processing industries and the working papers of this Consultation contain many statements and recommendations for research regarding building timber also. A general survey on wood is provided by UNIDO/IS.398 document "First world-wide study of the wood and wood processing industries" (UNIDO, 3 August 1983, 213 pages).
The UNIDO/IS.413 document "A review of technology and technological development in the wood and wood processing industry and its implications for developing countries" (UNIDO, 18 November 1983, 157 pages) summarizes research priorities also for timber used in construction. This document restricts itself to certain specific research trends concerning timber as a building material.

Ever since ancient times, timber has been used as a building material. Nevertheless, there are research tasks which in some countries have an adequately high priority:
- Extension of the types of timber used. There are in many countries species which although hitherto not used could be made use of. Surveys and laboratory controls are necessary to achieve this;
- mixed use of timbers. In some countries the properties of individual types of timber are known but it would be more practical to use various species; the properties of such mixes have to be clarified;
- species yielding maximum efficiency. Different species grow at different rates and yield different quantities of timber per area unit. Research is required to define the optimum forestation and replacement policies;
- solar timber seasoning with the objective of energy conservation;
- fire retardant treatment of thatch, palm leaves, etc., roofs;
- various uses of agricultural wastes and by-products (rice husks, saw dust, etc.);

- replacement of asbestos fibres or steel reinforcements by vegetal fibres (sisal, etc.);
- development of new products, (roofing shingles, etc.);
- use of industrial by-products for the purpose of adhesives (e.g. lignin which is a waste in the pulp and paper industry).

In several countries it is anticipated that timber resources will be depleted if the present rate of deforestation is continued. The cultivation of good quality bamboo for building purposes can augment the supply. Poor and inefficient conversion techniques give rise to high conversion waste and costs; research can reduce these losses. Particle boards, fibre boards and wood-cement boards can be produced from wood wastes and from weeds which until now have been considered as nothing but a nuisance (e.g. eupatorium).

4.5 Other materials, components and equipments

Programmes for developing the building materials industries should not be restricted to the basic materials (cement, glass, ceramics, timber) but should take into account the growing complexity of construction. To neglect this results in continuous imports of water supply and sanitary equipments, fittings, electrical equipments, paints, plastics, lifts and others. The quantitative needs for various materials, components and equipments are extremely different and depend also on the population of the country. For certain items the domestic market may not be large enough to justify manufacturing within the country solely for the home market. In such cases manufacture would only be viable if there are expectations based on a high degree of probability that a wider market will be opened up.

The use of agricultural and industrial wastes and by-products obviously qualifies for high priority in research (rice husks, straw, paper waste, fly ash, slags, etc.). Doors, windows, shutters and their fittings (ironwork) are needed just as much in low-cost housing as in high quality urban multi-storey buildings, (banks, offices, etc.). In the first category, however, simple and inexpensive solutions are called for; in the second category products are usually at the same level as abroad in developed countries.

4.6 Interrelation between research on building materials and building research

In rural housing producing building materials is inextricably linked with the construction of houses and therefore research on building materials is interwoven with building research. Examples of this are earth walls, mortar renderings, grass roofs, etc.

To take an example, grass roofs have been made from secco since the earliest days. Research has devised improved manufacture of secco rolls or panels which ensure good waterproofing on gentle slopes under rain action. They also afford appropriate strength under self-weight and provide fixings resistant to wind pressures. As well as imparting these attributes the new manufacturing methods have improved the behaviour of secco against biological attacks by means of chemical treatment. In other countries insertion of a polyethylene sheet between two layers has been proposed for the purpose of making the roofing watertight.

In the formal (monetary) subsectors of the economy more and more components of buildings are prefabricated and such components - though replacing building materials - are studied by building research industry. Precast reinforced concrete floor beams and roofing planks can be designed only with the knowledge of their ultimate use in buildings.
Requirements in buildings and their performance are subjects for building research. Building materials research becomes intimately interrelated with building research. The transport, hoisting and assembly of building materials neccesitate machines, tools and other equipments, including scaffolds and formwork. A branch of building research is specialized in such matters.

Building research addresses itself to building materials when studying components and parts of buildings and whole buildings. An example of how this takes place is that structural engineering research devised a form of reinforced masonry with better resistance against earthquakes. Research on ventilation creates better internal environment conditions.

* * *

5. SELECTION OF RESEARCH PRIORITIES; CONDITIONS OF IMPLEMENTATION

5.1 Selection methods of research priorities

Other chapters of this study discuss research priorities from the global aspect. This, however, is not sufficient for government agencies supervising research and in the individual research institutes when making decisions on research priorities.

The selection procedure for research projects has to be based on a policy of priorities. Experience and empiric methods can give satisfactory results; in the case of a great number of competing proposals for research recourse can be had to a more formal methodology. A system of criteria can be defined and this can be used as a checklist when assessing individual proposals. A vast amount of professional literature is current on the problem of selecting research projects. There exist two basic approaches to the problem:

1. To define individual projects, and then to compare them selecting or rejecting projects based on the outcome of the comparisons.

2. To define mathematical models and to ascertain the optimum point out of the infinite number of possible alternatives.

The second (mathematical optimization) methods are less frequently employed and accordingly no further reference to these will be made. Comparison of two or indeed many (but necessarily a finite number of) projects can be based on one single criteria (e.g. production cost of product or productivity of labour) or on several criteria. If one criteria only is used then comparisons are relatively easy; they become more complex when several criteria are considered. In most cases it is necessary to take into account several factors: productivity, manufacturing costs, capital requirements, import content, etc.

If a project is superior in every aspect to all others then the selection is easy. In practice this is rarely the case; individual projects may be superior to others when matched against certain criteria; while at the same time being inferior as regards other criteria. In such (usually) complex assessment cases, methods have to be used with scoring (rating) systems in order to summarized findings for individual criteria. A significant number of such scoring techniques have been introduced and applied. The various methods have been documented e.g. in Reports published by EIRMA (European Industrial Research Management Association): "Methods for Evaluation of R&D Projects".

What follows is to some extent based on these but the publications mentioned contain many more details. Naturally it is not proposed that such "scientific" methods should be employed in every case but it is advisable to bear them in mind when arriving at decisions on research priorities. Basically answers should be sought to the following five questions before taking the decisions.

1. **What is the importance of the proposed research subject in the country concerned?**

   Comment:

   The answer to this question has to be evaluated balanced against the cost of the research. Projects with medium-level importance can be accepted if their cost is appropriately low. No projects should in general be accepted which have no relevance in the country.

2. **What are the chances for technical success?**

   Comment:

   Proposals for research projects should be rejected if sufficient probability for their technical success is lacking. This depends on the existence of adequately qualified personnel, (researchers and assistants), availability of laboratory equipment, finances, raw materials and components and the intellectual (scientific) chance of success (thus, a proposal for a "perpetuum mobile" has no technical chance of success).

3. **What is the likelihood for commercial success?**

   Comment:

   Market analysis only can provide the answer to this question. Is there a shortage of the products to be developed or on the other hand is there an abundant supply of similar products? What is the price situation: could the proposed new product be produced at less cost than its expected sale price?

4. **If the project is technically successful and would stand a good chance of commercial viability, what is the likelihood for its practical application?**

   Comment:

   In certain cases conditions for practical application are not present in the country. This situation may be due to the small demand, to lack of investment funds, to the absence of raw materials and/or components or to the inadequate professional and industrial background to design and manufacture large scale production equipments. In such cases also proposals for research should not be accepted.

5. **Is research justified in comparison to imports of products or know-how?**

   Comment:

   Even if research does promise success it has to be kept in mind that research potentials are usually restricted and other projects could perhaps yield higher benefits. It is also possible that while research on project A could be successful, its results could easily be acquired through entering into a licensing agreement, whereas research on project B is indispensable because otherwise there is no good way to solve problem B without domestic research. In such situations project B has a priority over project A, (see also the next section 5.2).

When comparing two or several research projects it is important not to limit the calculations to take account only of current conditions. Costs and prices may undergo marked changes in the future in different directions and at differing rates for individual alternatives. Therefore economic calculations should embrace a longer period, usually several years and future changes in conditions should be estimated and introduced into the calculations. In such studies it may be necessary to use the discount technique and for this purpose the trend of interest rates during the period has to be estimated. In certain cases inflation rates also have to be assessed. Despite the uncertainties inherent in such estimates, it is important to endeavour to quantify conditions changing over time. For all this there exist methodologies which can be used in the selection process of research projects.

Appendix 3 cites certain pages of the EIRMA publications. In the following some examples of checklists and scoring systems are given, based also on EIRMA Reports. It is noteworthy that while this study uses the words "likelihood" and "chance" without intentional differentiation, in the EIRMA Reports the word "credibility" is used in a somewhat narrower sense than "likelihood". The EIRMA documents include an explanatory note on this point.

> "The check lists given below have been chosen solely as representative examples to illustrate some of the different forms which they may take. Tables 1 to 4 are check lists covering all aspects of assessment of development projects from the point of view of a company or other institution including governmental ones that wants to decide on merits of proposals.
>
> One of the simplest is shown in **Table 1**. A set of twenty-one questions should be answered before launching the project. They are not divided into groups and no rating scale is defined.
>
> A more elaborate list is given in **Table 2**. It includes fifty-six items divided into six groups. Each factor is to be rated on a five-step qualitative scale. The rough assessment is to be made on the basis of the overall profile.

Table 3 shows a list of twenty-six items grouped in four categories. A four-step numerical scale is proposed for rating the factors. This example is particularly interesting because of the attempt to give an explicit definition of each step of the scales. No weights are given to the factors and, in fact, the author advocates a profile method of assessment and advises against the use of a numerical figure of merit. However, similar lists can be found which propose the use of a weighted sum merit index.

A very much simplified form of weighted check list is given in **Table 4**. **Table 5** is a checking and scaling list for technical success.

Table 1

Basic questions for initial proposal and subsequent reviews

1. What are the specific advantages accruing to the company from the development of this product idea?

2. What is the market for a product of this type?

3. What competitive products are now available?
   a. What specific advantages do they have?
   b. What specific disadvantages do they have?

4. What advantages can we incorporate in a new product?

5. Can we market this product easily, or will it require a new marketing approach such as a new sales force?

6. Will we be able to obtain a strong patent position covering this new idea?

7. What volume of sales can we expect?

8. What is the approximate market life of a product of this nature?

9. How much will it cost to develop this product?

10. How long will it take to develop this product?

11. What will be the method of approach to this development?
    a. What will be the sequence - such as exploratory, process or feasibility, etc.?
    b. What will be the time for each of these sequences?

12. What additional skills and personnel will be needed to develop and perfect this product?

13. What additional capital equipment will be needed to develop this product?

14. What are our estimates for the cost of manufacturing this product?

15. How much new manufacturing equipment will have to be acquired?

16. Can this equipment be used to manufacture other products as well?

17. Will our plant layout lend itself to the manufacturing of this product or do we have to acquire new facilities?

18. Are materials available to manufacture this product?

19. What are the consequences of stopping this product if we should learn after a year or two that the product is seemingly failing in the market place?

20. What is the total cost in processing, research development, tooling up, manufacturing, marketing, and advertising, and can we afford to take this on in relationship to other commitments already made?

21. What is our best estimate on return on investment and return on sales?

Source: J.H. Dessauer, Research Management, Vol. X, No.2, 1967.

Table 2

	Very Unfavourable	Unfavourable	Average	Favourable	Very Favourable
Financial					
Estimated annual sales of new product					
Time to reach estimated sales volume					
Ratio of annual sales: R&D costs					
Ratio of total costs: annual savings					
Return on sales					
Return on fixed capital					
Return on total investment					
R&D investment payout time					
Fixed capital investment payout time					
Profit in first year of production					
Research & Development					
Chance of technical success					
Technical novelty					
Potential know-how gain					
Relation to company's present know-how					
Time to develop product					
Manpower needed					
Lab and pilot plant equipment needed					
Competitive technical activity					
Patent status					
Production					
Process advantage					
Process versatility					
Process familiarity					
Compatibility with present operations					
Equipment availability					
Raw material availability					
By-product outlets					
Waste disposal					
Corrosion potential					
Hazard potential					
Freight position					

Table 2 (continued)

	Very Unfavourable	Unfavourable	Average	Favourable	Very Favourable
Marketing					
Product advantage					
Product competition					
Market size					
Market stability					
Market permanence					
Cyclical and seasonal demand					
Number of potential customers					
Market growth rate					
Company known in potential markets					
Compatibility with present products					
Suitable marketing organisation available					
Market development requirements					
Time required to become established in market					
Product variations and modifications required					
Difficulty of copying or substituting product					
Expert potential					
Possibility of a captive market					
Licensing potential					
Corporate position					
Relation to company objectives					
Required corporate size					
Advertising or prestige value					
Effect on purchasing other materials					
Effect on present customers					
Operating departments' desire or enthusiasm					
Other factors					

Source: KIEFER, CHEM. ENG. NEWS, 23rd March 1964, p. 95.

Table 3

CRITERIA	SCORE			
	-2	-1	+1	+2
Finacial Aspects				
Return on investment (before taxes)	< 20%	20% to 25%	25% to 30%	> 30%
Estimated annual sales	< $ 100,000	$ 100,000 - $ 1 million	$ 1 million to $ 5 million	> $ 5 million
New fixed capital payout time	> 5 years	3-5 years	2-3 years	< 2 years
Time to reach estimated sales volume	> 5 years	3-5 years	1-3 years	< 1 year
R&D Aspects				
Research investment payout time	> 3 years	2-3 years	1-2 years	< 1 year
Development investment payout time	> 3 years	2-3 years	1-2 years	< 1 year
Research know-how	No experience and no other applications	Partly new, with few other uses	Some experience or new vistas	Considerable experience or potential
Patent status	Unsettled patent situation	Open field and many licenses	Restricted to few licences	Patent or exclusive licence
Market development requirements	Extensive educational programme	Appreciable customer education	Moderate customer education	Ready customer acceptance
Promotional requirements	Extensive advertising & promotion	Appreciable requirements	Moderate requirements	Little promotion needed
Product competition	Several directly competitive products	Several competitive to some extent	One or two somewhat competitive	No competitive product
Product advantage	Higher price, equivalent quality	Competitive; or higher price and quality	Competitive price but quality advantage	Both price and quality advantage
Length of product file	Probably 1-3 years	Probably 3-5 years	Probably 5-10 years	Probably > 10 years
Cyclical and seasonal demand	Seasonal and subject to business cycle	Seasonal	Subject to business cycle	High stability
Production and Engineering Aspects				
Required corporate state	Any size	Most companies could compete	Average-size or larger companies	Only a very large company
Raw materials	Limited supply of suppliers	Limited available inside company	Readily available from outside company	Readily available from inside
Equipment	New plant needed	Mostly new equipment	Some new equipment	Recent idle plant usable
Process familiarity	New process; no other application	Partly new; few other cases	Familiar process - some other users	Routine process and prominence of other cases
Marketing and Product Aspects				
Similarity to present product lines	Entirely new type	Somewhat different	Only slightly different	Fits perfectly
Effect on present products	Will replace directly	Increase other sales	Slight effect	Increase other sales
Marketability to present customers	Entirely different customers	Some present customers	Mostly present custumers	All present customers
Number of potential customers	More than 500	Less than 5; or 1 to 500	5 to 10; or 50 to 100	10 to 50
Suitability of present sales force	Entire new group needed	Some additions necessary	Few additions necessary	No changes necessary
Market Stability	Volatile market	Unsteady	Fairly firm	Highly stable
Market trend	Increasing	Static, mature	Growing	New potential
Technical service	Extensive service required	Moderate	Slight	Negligible

Source: HARRIS, CHEM. ENG. NEWS, 17th April 1961, p. 110

Table 4

Field studied	
Chances of success:	
Remarkable	10
Low	2
Return on investments:	
From 0 to 0.1 year	20
From 0.41 to 0.8 year	11
From 3.21 to 6.4 years	2
Total profit in 10 years:	
$ 1,500,001 - 5,000,000	10
$ 120,001 - 420,000	6
$ 10,000 - 35,000	2
Other factors:	10
Good supply of raw materials	2-1
Low investment costs	2-1
Possibility of reducing licensing costs	2-1
Moderate research costs	2-1
Improvement of products	2-1
Total number of points possible	50

Table 5

Factors Affecting Credibility of Technical Success

FACTOR	SCALE OF RATING EACH FACTOR 1	2	3	4	5
Technical novelty					
. Demonstration of technical principles	Should work but not proven	Principle can be proved on paper, from basic data	Component features demonstrated and basic knowledge complete	Partly full scale/ wholly pilot scale	Principles already embodied in full scale operations, in house or elsewhere
. Technology and know-how needed for full scale production	Needs advance in basic knowledge	Major features need developing	Minor features need developing	Very close to previously commercialised projects	Completely known
. Competitive research	Many competitors have researched in related fields and failed	A few competitors have researched in related fields and failed	No known research in related fields	A few competitors have researched in related fields and succeeded	Many competitors have researched in related fields and succeeded
Specifications					
. Technical specifications to meet performance requirements during project/ process life	Very restrictive limitations	Limitations, hard to attain	Some limitations should be attainable	Some limitations easy to attain	No restrictive limitations
. Control over specifications	Monopoly buyer with own quality control	Widespread e.g. government, trade association, manufacturer	Mostly dictated by competition	Most in-house, some external	All in-house
Freedom of approach					
. Alternative approaches possible	Only one route possible	Only one probable alternative	More than one probable alternative	One sound alternative	Several alternative routes
Project plan levels 1)					
. Scope for forward planning	No plan	Probable finishing date + rough overall cost	Intermediate review + finishing dates + rough stage costs	Milestone plan submitted e.g. Gantt Chart	Full resource/time plan submitted e.g. Pert
Resources 2)					
. Project equipment	All equipment needs development	Some equipment needs development	Most equipment must be purchased or hired	Most equipment available balance can be purchased or hired	All equipment available
. Source of finance	Subscription e.g. research bodies on variable uncontrollable incomes	(External) fixed contract price	Part internal, part external (e.g. collaborative research)	Self-financed fixed limit	Self-financed no limit
. Amount of finance available 3)	Limited to minimum cost approach		Limited to optimum cost approach(es)		No effective limit
. Information services	No organised library and research divorced from production and marketing		Library facilities + normal communications between research production and marketing		Complete company database available
Personnel resources					
. In-house experience available inthe project field	None	Some individual experience	Some research activity in past	Part of current company activities	Current authorities on subject
. Quality of staff available compared with levels of skills required	Unknown	-	Competent but not experienced	-	Experienced and competent
. Motivation of research groups to success of project	Reluctant support (Not invented here factor)	-	Indifferent	-	Determined to success
. Quantity of staff available	None - all staff must be recruited	Insufficient staff; some must be recruited	Inexperienced staff available to form team	Experienced staff available to form team	Experienced team available immediately

1) Level of planning obviously interacts with size of project
2) "Needs development" infers that the equipment is novel and not available for purchase/hire; hence one has the possibility that one can fail to develop it in time
3) Cost specification is a part of the technical target

Decisions on research priorities comprize decisions as to whether to undertake research at all or whether either importing or buying know-how instead of research would not be more advantageous. Countries (and research institutes) are usually not in the position to do research on all the problems faced by the country. The selection process must not only consider which research projects could be carried out with the highest chance of success but should also come up with the answer to the question: which problems could be solved on favourable terms through buying licences giving access to the desired know-how.
Usually if the decision is to avoid independent research, some research (though on a much smaller scale) will still be required into the method of adapting the process or product to domestic conditions and for developing further the technical level acquired. It can prove to be a major error to buy know-how and to freeze production at the technical level introduced on this basis: this would merely perpetuate backwardness. Along with purchasing advanced technologies domestic research should lose no time in absorbing its technical content and in setting in motion work on continuous further future developments.

Domestic research can be regarded as being in competition with purchases of know-how from abroad only if the same funds can freely be channelled either into financing research or into buying foreign know-how. If the two types of funding are separate then only an institution or individual having power of decision over both can make an effective comparison between the two alternatives: i.e. research versus purchase of know-how.

It is not sufficient just to evaluate research projects individually; it is necessary to have an overall strategy on the allocation of research resources also. One of the components of such a strategy is a personnel policy to be integrated with the overall particular requirements of the country (region, etc.). The personnel policy should aim to reconcile a certain degree of stability (which is useful in research and development), with a limited amount of mobility (which ensures some measure of turnover in staff being equally of benefit in order to maintain efficiency). The allocation of financial resources must be justified in the light of objectives expressed by the building materials industries.

5.2 Strengthening of scientific and technological capabilities

It would be illusory to discuss research priorities if sufficient scientific and technological capabilities were not available. To strengthen such scientific and technological capabilities therefore, is in itself a top priority task.

This requirement has been investigated on many occasions, among others by UNIDO; the Fourth General Conference of UNIDO in Vienna from 2nd to 18th August 1984 will again study progress and tasks in this field. Part of the principal statements and recommendations of the issue and background paper on the subject are quoted and summarized below and they may be presumed to be fully valid for the building materials industries also.

> "The gap between developped and developing countries in technological development makes them unequal partners in international economic relations. Costs and conditions of the transfer of technology are often onerous. An inappropriate choice of technology is not only wasteful but could distort the pattern of industrial, economic and social development. Strengthening technological capabilities is a prerequisite both for the acquisition and application of imported technology and the development of endogenous technology. The way technology is applied critically affects the development process.
>
> Most developing countries show a considerable awareness of the importance of technology for development, but little attention is paid to the selection of technology at the micro and macro levels. At the micro or enterprise level, the non-availability of processed information and the lack of evaluating capacity make selection difficult. Moreover, Governments intervene relatively rarely through industrial or import policies or decisions on major projects. Selection from among all available options is further hampered by such factors as foreign investment and the availability of credit facilities from one or other country or supplier of equipment. The absence or non-association of indigenous consultancy services and multidisciplinary teams trained in technology evaluation creates a major bottleneck. The redesign of existing industrial and technological information centres and the promotion of consultancy capabilities should therefore be viewed not so much as general elements of infrastructure but rather as key factors in a better selection of technology for the country. The present status of technology selection and the difficulties inherent in the process would argue for recognition of its importance in a wide range of government policies and a conscious exercise of selection, at least in major and strategic projects.
>
> At the macro level, an assessment or at least awareness of the impact of specific technologies on society and their contribution to particular

development needs is essential and needs to be reflected in conscious decisions on the "technology mix" to be adopted. The absence of an overall approach to the selection of technology has had implications for the pattern of industrialization and employment generation in developing countries.

Most developing countries have established single-purpose and multi-purpose research institutions of various types. Institutions for scientific education and basic research have also been established. Universities in several countries have started to play a role in the development of endogenous technology. Some countries are also planning to establish science parks. The Governments of several developing countries are promoting endogenous technology through a variety of incentives such as tax concessions, liberalized licensing procedures, financial incentives and special funds to support endogenous creativity and innovation. In some countries, patent laws have been changed to eliminate restrictions on the development or use of technology. Generally speaking, most of the research and development is carried out in government-run institutes, although in a few developing countries it has been introduced at the enterprise or industry level. A few countries, too, insist on local research and development as a condition for the import of technology. Institutions for standardization, testing and quality control, which form part of the infrastructure for technology development, have also been established in a number of countries.

In regard to technological advances in general, there is a need for every developing country to take both short-term and long-term action. Short-term action should include forecasting and assessment of the socio-economic impact of technological advances, careful choice of technologies and equipment to be imported, and a strengthening of the negotiating capability for their acquisition. Such action is urgently needed so that irreversible distortion of the industrial and technological infrastructure is not created from the beginning. Long-term action should aim at strengthening technological capabilities and would require imaginative attempts to apply the technological advances to improve the standard of living and upgrade the general technological level of the population. Such action should be strategic, involving, wherever necessary, structural changes in the industrial and economic development of the country in the light of its development objectives.

Since conditions in developing countries vary and uniform prescriptions are not possible, countries may have to follow selective and differential approaches and each country may have to decide for itself the point of entry, degree of penetration, source of inputs, linkages, vehicles of implementation, etc. However, in an interdependent world economy, all countries need to have technological awareness. Whatever the level of development, there is a need for a minumum level of competence to deal with emerging technologies within realistic time horizons and for establishing effective national groups for this purpose.

The social implications of the introduction of high technology have to be carefully considered by each country in its own socio-economic context. High technology options have to be placed within the range of available technology options from the traditional to the advanced. Developing countries may have to adopt and manage a technological pluralism optimal for the objectives, problems and limitations of each country.

For the 1980s, a framework for national action is needed that will integrate the responses to technological advances with existing technology policies or efforts and at the same time make up the deficiencies of the latter. The building up of such a framework should be regarded as one of the major responsibilities of Governments in developing countries in the 1980s.

What are the possible elements for a framework of action? For drawing up such a framework a supporting mechanism may be necessary that could be, as a minimum, an interdisciplinary unit of 6-12 professionals close to a high policy-making level. Expertise has to be drawn from economists, scientists, technologists, social scientists, systems analysts, bankers, industrialists, management experts, etc.

Considerations in building up the framework include the upgrading of endogenous technologies; the integration of technology policies and actions with the industrial sectors; human resource development; the structuring and management of demand; and the rationalization and development of technological institutions having regard to their relevance, effectiveness and interaction.

A new line of action for the developing countries would be to establish appropriate mechanisms individually or collectively to forecast, monitor and assess technological trends and their implications for economic and social development and to formulate, develop and implement policies to maximize the potential benefit of the new technologies and avoid their adverse consequences. Such an assessment should be an important input to industrial, technological and general development planning and the formulation of industrial, technological, commercial and fiscal policies, and in decision-making on industrial projects. Such information should also be used to see how far the new technologies could revitalize the development process in critical sectors.

The need for greater allocation of resources for science and technology in developing countries assumes greater relevance on account of the emerging technological advances. About a decade ago it was suggested that developing countries should allocate at least 1 per cent of their GNP to research and development. It is now proposed that they aim at devoting 1.5 per cent of their GNP for research and development by 1990, and reach a minimum level of 2 per cent by 2000.

International cooperation has a vital role to play in helping developing countries to correct the deficiencies already noticed and to harness new technologies for their unique problems.

A review of the present trends in international cooperation shows that, at the enterprise level, costs and conditions of technology contracts and access to technology continue to be matters of concern to the recipients of technology. There is scope for considerable improvement in the attention to science and technology in official development assistance programmes and in intergovernmental project aid."

Over and above the maintenance and hopefully the improvement of existing methods for international cooperation, new measures and actions should be introduced.

5.3 Strengthening building materials research institutions

In Chapter 2 a general description has been given of research in the building materials industries. In Section 5.2 a general policy has been outlined for strengthening the scientific and technological capabilities for industrial development in developing countries. In this Section 5.3 the focus is put on specific problems of building materials research institutions.

Contrary to many other industrial sub-sectors in which research is carried out by private or public industry itself, in the building materials and construction industries there usually exist public research institutes even in the most liberal developed countries (e.g in the USA and Canada). The reason for this lies in the fragmented structural character of the industry. In all countries is to be found a great number of small contractors and building materials manufacturers who are confronted with very similar technical problems. These small contractors and manufacturers are not in the position separately to organized research to solve their problems; this has to be carried out by central research institutes. These centralized research institutes can be organized by the association of contractors and manufacturers; such institutes exist in the UK (CIRIA, TRADA, BSRIA, etc.), in France (CEBTP), Belgium (CSTC) and other countries. The centralized research institutes therefore can be public or semi-public institutions. In countries with central planning economies, research institutes are usually state-owned organizations.

Major cement, glass, brick companies can afford to organize research within their own organization. As a general guideline it can be stated that whatever research can be executed by the industry itself, this should be done and the state should intervene in these areas only where no effective activity by industry can be anticipated. Again, as a general guideline it can be stated that governmental and industrial research institutions should receive adequate support although their size may have to be adjusted periodically in the light of requirements.

Adequate financing of research should be ensured; industry should pay for all research which directly serves its interests and government should fund activities only where the interest of industry is too indirect or remote. Research at Universities should be supported and many countries can point to good experience gained with research institutes linked in one way or another to Universities.

In many countries a combination of building materials research and building research within the same research institute has proved to be an efficient solution and such a scheme merits continuation in the future also in suitable cases. If the scale of research activities calls for high specialization in different fields, then different research institutes can be recommended. Research on anorganic building materials (cement, concrete, bricks, etc.) and research on timber products can be organized in such cases in two different research institutes.

Research priorities can be selected only if there exists an overall strategic development policy for the building materials industries. Only after the quantitative and qualitative targets to be reached by the building materials industries have been defined, is it possible to select research priorities. Assessments will be made about the inherent development potentials of the existing building materials industries and the gaps between requirements and potentials have to be closed by imports and/or capital investments and by research. Research programming therefore is dependent on economic development plans; these in turn depend on research also.

Development policies for the building materials industries depend on many factors among which research is only one. Research by itself (even successful research) is not sufficient for the formulation of economic development policies; on the other hand, adequate mechanisms should exist so that research also can make its contribution through its opinions to such policy-making processes.
Development of research institutions requires well trained professional researchers. Developing countries have made substantial progress in education and training; obviously this is a continuous process and should receive adequate support in the future also.

5.4 Information, documentation, engineering, consultancy services

It has been repeatedly stated that the cases when building materials research in developing countries has to have the form of basic research are rare; most frequently it is applied research, development or engineering adaptation of existing knowledge to domestic/local conditions. For this reason alone the establishment and operation of documentation centres and information and engineering consultancy services have a great importance. Another important factor is the size of the country (its area and population), its financial resources and the characteristics of the domestic building materials and building industries. Many countries are too small and lack adequate resources for the creation and maintenance of large and complex research institutes. They have to rely in a great number of fields on foreign research but in so doing have to possess "gates" through which this knowledge from abroad can pass, be adapted and applied. Building research institutes and their documentation services have such a task.

Research on building materials must comprize the transfer of acquired knowledge and the application of research results. Governments and research institutions have to accord top priority to devising adequate methods for implementing this. Demonstration projects, exhibitions, training courses, contracts and cooperation with industry, financial and moral support, promotion by mass media and professional literature, posters, audio-visual aids, slide shows, films, brochures and leaflets: these are just some of the plethora of tools that can be utilized to achieve the objective of practical application.

Some countries, (like India), have good experiences in this work. In other countries (e.g. some in Africa), experiences are rather adverse: people tend to view with suspicion innovations coming from the outside World and endeavours to apply research results frequently end in failure. Such negative experiences have to be studied carefully so as to find out what needs to be changed to achieve applications in practice.

5.5 Regulations, standardization

In several developing countries, regulatory activities do not have a long past. In some countries the standards of foreign countries (BSI, AFNOR, DIN, ANSI) are accepted even eventually simultaneously as in the country where they originated.

The development of the building materials industries requires that each country should have its own standards and building codes. This regulatory work can be effectively prepared by research institutes (pre-standardization, pre-regulatory work) and for research institutions this has a high priority. Within the framework of standardization and regulations (codes, by-laws) three errors have to be avoided:

1. That the standards and codes are written without any consideration to standards and codes already existing in other countries and international organizations (ISO). This could also hamper import-export due to the discrepancies in standards and codes;

2. That standards and codes are simply copied from existing standards without paying due regard to domestic circumstances.

3. That the levels of requirements and performances are copied from standards abroad, again without adequate consideration of domestic conditions. The result of this mistake is either to make construction unnecessarily more expensive or that design and execution of buildings will not be based on these standards but will comply with domestic (local) realities.

5.6 International cooperation

International cooperation yields benefits for research institutes in developed as well as in developing countries. In the latter, however, international cooperation has certain specific features.

Large and small, rich and poor research institutions, all contribute to the enhancement of the pool of human knowledge. Despite this it is obvious that new, small and not well equipped institutes will (at least during the first ten to twenty years of their existence) give less and use more. The total contribution of small new institutes can be quite considerable and will of course gradually grow.

Some large developing countries (China, India, Brazil, etc.) will be able to finance building materials research on a major scale and the share of developing countries in global building materials research will increase correspondingly over a period of time. In regions with a number of small or medium-size countries, subregional research and/or documentation centres can increase efficiency.

Cooperation between research institutions can be organized on a bilateral and multilateral basis; in the latter case this can be subregional, regional or global. The various forms do not compete with each other but rather are complementary.
International cooperation is promoted by UN Organizations (UNIDO, UNESCO, UNCHS, UN Regional Economic Commissions) and other intergovernmental organizations.

It is important that research institutes themselves be able to cooperate on their own level. This again can be on bilateral or multilateral levels. Participation in the work of international non-governmental professional (NGO) organizations is of extreme importance for research institutes and their researchers. Such participation provides them with a feedback of experiences from abroad and this can greatly enhance the efficiency of their own research. CIB and RILEM are the two most important and most complex organizations in this field; some others (in concrete, timber, etc.) have a more limited scope but exactly for this reason, may be important for researchers in such fields.

Governments should ensure that building materials research institutes and their researchers should be able to participate on an adequate level in international cooperation.
International Organizations (ISO, CIB, RILEM, CEB, etc.) should establish funds which serve the purpose of assisting building materials research institutions and their researchers to participate in international cooperation (through travel grants, fellowships, the provision of free copies of literature, financing other expenditures, etc.)

* * *

6. SUMMARY. CONCLUSIONS

It can be foreseen with a sufficient degree of certainty that the needs for building materials will grow in developing countries during the coming decades. Efforts should be made that as high a percentage as possible of the population should continue to make use of locally available materials but the growth of the population and the inevitable process of urbanization will enlarge demand substantially. Local resources are dwindling in some areas and a better use of what is available will be necessary. More and more families will have to be supplied with building materials. The development of industry, of towns and of villages will all increase the demand for building materials.

No country can rely to an excessive extent on imports of building materials. Each country has certain types of domestic resources which can be used for the production of building materials. This production must be developed both in the informal (non-monetary) as in the formal (monetary) subsectors. Private and public capital investments must be made to achieve higher levels in the production of building materials.

A major contributing factor to this process could be research and technical development. Research for the building materials industries and the building industry must receive sufficient attention both on behalf of government and of the private sectors. Research must be suitably organized according to the characteristics (size, etc.) of the country. Research becomes efficient if its topics are adequately selected. Research priorities should be defined in order to achieve optimal efficiency.

The selection of research priorities should take into consideration certain general trends, (increasing durability, etc.), as well as domestic (local) conditions. Investigation should be directed towards determining in which areas could research promise the highest benefits and which are the areas in which imports or licensing, (purchase of know-how), could be the more effective option.

Research in the building materials industries and in the building industry should be carried out in practically all countries but this should not result in trends for autarchy in research. Efficiency of research can be greatly improved by international cooperation. This can take many forms and appropriate use should be made of the different possibilities.

* * *

APPENDICES

Appendix 1: Selective list of 115 institutions whose scope is predominantly national as opposed to international, which are active in building materials research

Appendix 2: Selective bibliography

Appendix 3: Selected pages abstracted from volumes on "Methods for the Evaluation of R&D Projects" published by the European Industrial Research Management Association

Appendix 1

Selective list of 115 institutions whose scopeis predominantly national as opposed to international, which are active in building materials research

The number of institutions carrying out research on building materials is great, in fact it runs into several hundreds. This is a selective list restricted to 120 institutions. Only institutions are listed which have research activities and whose operations essentially cover the country of domicile rather than being international in scale. For further institutions reference is made to the following publications:

1. UNIDO Guides to Information Sources (published by UN/UNIDO, New York, as a series of brochures). Those most relevant to building materials are:
   No. 2 - Cement and Concrete Industry
   No. 9 - Building Boards from Wood and other Fibrous Materials
   No. 16 - Glass Industry
   No. 17 - Ceramics Industry

   Quality control is closely related to research; this is dealt with by:
   No. 6 - Industrial Quality Control

2. Directory of Building Research, Information and Development Organizations; edited and published by the International Council for Building Research, Studies and Documentation, CIB; the 4th edition (published in 1979) contains detailed information on over six hundred institutes. The fifth edition will be published by the end of 1984.

3. The World of Learning, (Europe Publications Ltd., London); this is a Directory on Universities and scientific organizations.

AFRICA

Algeria	Institut National d'Etudes et de Recherches en Bâtiment (INERBA), Algiers (recently reorganized)
Benin	Centre National d'Essais et de Recherches des Travaux Publics, Cotonou

Cameroun	Ecole Polytechnique, Yaoundé
Congo	Laboratoire Nationale d'Essais et des Travaux Publics, Brazzaville
Egypt	General Organization for Housing, Building and Planning Research, Cairo
Ethiopia	Addis Ababa University, Addis Ababa
Ghana	. Building and Road Research Institute, Kumasi; . Forest Products Research Institute, Kumasi
Ivory Coast	Laboratoire du Bâtiment et des Travaux Publics, Abidjan
Kenya	. Building Research Centre, Nairobi; . University of Nairobi, Nairobi
Libya	University of Al-Fateh, Tripoli
Morocco	Laboratoire Public d'Essais et d'Etudes, Rabat
Nigeria	. Forestry Research Institute, Ibadan . University of Lagos, Lagos . University of Ife, Ile-Ife . Ahmadu Bello University, Zaria . College of Technology, Owerri
Somalia	National Somali University, Mogadishu
Sudan	Building and Road Research Institute, Khartoum
Tanzania	. National Housing and Building Research Unit, Dar-es-Salam . University of Dar-es-Salam, Dar-es-Salam
Togo	Centre de la Construction et du Logement, Lomé
Tunisia	Ecole Nationale d'Ingénieurs, Tunis
Uganda	Technical College, Kampala

Zaire	University of Lubumbashi, Lubumbashi
Zambia	Forest Products Research Divisi.-n, Kitwe

ASIA

(including the Pacific region)

Bangladesh	Housing and Building Research Institute, Dacca
China	. China Building Technology Development Centre, Beijing . Shanghai Research Institute of Building Sciences, Shanghai . Research Institute of Bu.lding Materials, Beijing . Beijing Institute of Glass and Fine Ceramics, Beijing
India	. Central Building Research Institute, Roorkee . National Buildings Organisaion, New Delhi . The Structural Engineering Research Centre, Madras . Cement Research Institute of India, New Delhi . Indian Institute of Technology, Kanpur
Indonesia	. Directorate of Building Research & UN Regional Centre for Research on Human Settlements, Bandung . Centre for Research & Development, Jakarta . Ceramics Research Institute, Bandung
Iran	Building and Housing Research Centre, Teheran
Iraq	National Center for Construction Laboratories, Baghdad
Israel	Technion, Israel Institute of Technology; Building Research Station, Haifa
Japan	Central Research Laboratory of Onoda Cement Co. Ltd., Tokyo
Jordan	. Building Research Center, Amman . Yarmouk University, Irbid
Korea	Technical Development Office, Seoul

Malaysia	University Pertanian Malaysia Serdang, Selangor
New Zealand	Forest Research Institute, Rotorua
Pakistan	. Building Research Station, Karachi . Building Research Station, Lahore
Philippines	Cement Institute of the Philippines, Manila
Sri Lanka	Building Research Institute, Colombo
Turkey	. Building Research Institute, Ankara . Technical University, Istanbul . Middle East Technical University, Ankara

AMERICAS
(including the Caribbean region)

Argentina	Instituto del Cemento Portland Argentino, Buenos Aires
Brazil	Instituto de Pesquisas Technologicas do Estado, Sao Paulo
Cuba	Centro Técnico de la Construcción y los Materiales, Havana
Guatemala	Centro de Investigaciones de Ingeniería, Guatemala
Jamaica	Building Research Institute, Kingston
Venezuela	Instituto Nacional de la Vivienda, Caracas
Mexico	Instituto Mexicano del Cemento y del Concreto, México D.F.
United States of America	. National Bureau of Standards, Center for Building Technology, Washington D.C. . Martin Marietta Laboratories, Baltimore, Maryland . University of Washington, Seattle, Washington . Purdue University, Lafayette, Indiana . Northwestern University, Evanston, Illinois

. University of Illinois, Champaign, Illinois
. Massachusetts Institute of Technology, Cambridge, Massachusetts
. University of California, Berkeley, California
. Glass Research Center, Pittsburgh, Pennsylvania

EUROPE

Belgium	. Post-Graduate Centre for Human Settlements, Leuven . University of Mons, Mons . Centre Technique et Scientifique de l'Industrie Belge du Verre, Brussels
Bulgaria	Research and Construction Institute for Glass and Ceramics, Sofia
Czechoslovakia	. Research Institute of Building Materials, Brno . Research Institute for Glass, Prague
France	. Centre d'Etude et de Recherche de l'Industrie des Liants Hydrauliques (CERILH), Paris . Centre Scientifique et Technique du Bâtiment (CSTB), Paris . Centre Expérimental de Recherches et d'Etudes du Bâtiment et des Travaux Publics (CEBTP). Paris Saint-Rémy-les-Chevreuses . Groupe de Recherche et d'Echanges Technologiques (GRET), Paris . REXCOOP, Paris . Laboratoires de Recherches LaFarge, Trappes . Centre Techniques des Tuiles et Briques, Paris . Centre Technique du Bois et de l'Ameublement (CTB), Paris . Centre d'Etude et de Recherches de l'Industrie du Béton Manufacturé (CERIB), Epernon
German Democratic Republic	. Zementinstitut der VVB Zement und Beton, Dessau . Institut für Baustoffe, Berlin . Institut für Bau- und Grobkeramik, Berlin
Germany, Federal Republic of	. Forschungsinstitut der Deutschen Zementindustrie, Düsseldorf . German Agency for Technical Cooperation (GTZ), Eschborn . Institute of International Studies in Housing, Planning and Building, Darmstadt

	. Technical University of Braunschweig, Braunschweig . Technical University of Stuttgart, Stuttgart . Technical University of Karlsruhe, Karlsruhe
Hungary	Central Research and Design Institute for the Silicate Industry (SZIKKTI), Budapest
Italy	Politecnico di Milano, Milano
Netherlands	. TNO Institute for Building Materials and Building Structures, Rijswijk . University of Technology, Eindhoven . University of Technology, Delft
Norway	. Norwegian Building Research Institute, Oslo-Blindern . Cement and Concrete Research Institute, Trondheim
Poland	. Building and bonding materials industry research institute, Opole . Institute of the glass and ceramic industry, Warsaw
Sweden	. Swedish Cement and Concrete Research Institute, Stockholm . Royal Institute of Technology, Stockholm . Lund University, Lund
Switzerland	Swiss Center for Appropriate Technology (SKAT), Saint-Gall
Union of Soviet Socialist Republics	. All-Union State Scientific Research Institute for the Cement Industry, Leningrad . Scientific Research Institute of Rock and Silicates, Yerevan
United Kingdom	. Building Research Establishment (BRE), Garston . Cement and Concrete Association, Wexham Springs . Timber Research and Development Association (TRADA) High Wycombe, Buckinghamshire . British Ceramic Research Association, Stoke-on-Trent

Appendix 2

Selective bibliography

Bibliographies comprizing several hundred titles exist. This particular bibliography is confined to certain recent publications in the form of anthologies and to those publications only which have been directly used for preparing this paper and the study of which can be strongly recommended to those whose task it is to define research priorities in the building materials industries.

- The UNIDO Guides to Information Sources (see Appendix 1) feature data on information sources in the building materials industries.

- Economical housing in developing countries: materials, construction techniques, components (Proceedings of an international conference in Paris, 25-27 January 1983; Presses de l'Ecole Nationale des Ponts et Chaussées, 344 pages).

- Appropriate Building Materials for Low Cost Housing in the African Region (Proceedings of a CIB-RILEM Symposium in Nairobi, November 1983; E & F.N. Spon, London 1983, 524 pages).

- Methods for the Evaluation of R&D Projects
  - Volume I - Project Evaluation and Review (EIRMA, Paris 1970, 96 pages)
  - Volume II - Estimation of Cash Flow Curves and Associated Parameters under Uncertainty (EIRMA, Paris 1973, 56 pages)
  - Volume III - Organisation of the R&D Project Evaluation Function (EIRMA, Paris 1973, 30 pages)
  - Volume IV - Choice of Selection Criteria in Relation to Company Objectives (EIRMA, Paris 1973, 50 pages)
  - Volume V - Credibility of Technical Success, its Definition, Estimation and Utilisation (EIRMA, Paris 1973, 36 pages)
  - Volume VI - Portfolio Selection in Research and Development (EIRMA, Paris 1976, 92 pages)
  - Volume VII - Credibility of Commercial Success: Its Definition, Estimation and Integration with Credibility of Technical Success (EIRMA, Paris

- The Allocation of Research Resources (European Industrial Research Management Association = EIRMA, Paris 1975. 72 pages)

- Hannah Schreckenbach (+ Jackson G.K. Abankwa): Construction Technology for a Tropical Developing Country (Published by GTZ, the German Agency for Technical Cooperation, 338 pages)

- First World-Wide Study of the Wood and Wood Processing Industries (UNIDO Sectoral Studies Series No. 2, UNIDO/IS.398, 1983, 195 pages)

- Strengthening of scientific and technological capacities for industrial development in developing countries (UNIDO issue and background paper for the Fourth General Conference of UNIDO, 2-18 August 1984, 10+45 pages)

Appendix 3

Selected pages abstracted from Volumes on "Methods for the Evaluation of R&D Projects" published by the European Industrial Research Management Association EIRMA

INTRODUCTION

When a proposal for a research and development project is evaluated three major questions are raised:

a. How much will it cost?

b. How valuable are the results of a successful development?

c. How likely is it that the project will succeed?

Many methods have been developed and tested for quantifying the answers to (a) and (b), and for combining the cost and incentive aspects of an R&D project into a form in which different projectsmay be compared, and the most promising ones selected.*) However, the answer to question (c) is often treated in a highly subjective manner, for example by asking the project proposer to "estimate the probability of success", or by the project evaluator "backing his hunches", based on previous experience of similar project proposals. In attempting to answer question (c) in an objective manner, two major areas of uncertainty must be considered:

1. Will the project achieve the level of success which is necessary to support commercialisation, and will this level of technical success be achieved within the cost and time assumed in the project proposal for completion of R&D work?
2. Will the commercialisation of the anticipated technical results of this proposal yield the benefits cited as justification for the R&D expenditure, and will these benefits be obtained within the cost and time assumed in the project proposal for reaching the necessary level of commercial activity?

So far as the project proposer is concerned, the answers to each of these questions must be "yes to the best of his knowledge", otherwise he would not have put forward his proposal in its present form. What the project evaluator must do to answer question (c) is to estimate the likelihood that the project proposer is correct in his forecasts.

*) EIRMA Working Group No.VI, Volume II: "Determination of Cash-Flow Curves and Associated Parameters under Uncertainty".

The term that has been selected to represent the result of this estimation is Credibility of Success, and it is clear from the differing questions outlined above in (1) and (2), that Credibility of Success can be subdivided into:

- Credibility of Technical Success
- Credibility of Commercial Success

SUMMARY

Credibility of Success of an R&D proposal of two major components:

- Credibility of Technical Success
- Credibility of Commercial Success

Volume V contains a definition of Credibility of Technical Success, and sets out a recommended method for its estimation, expression and utilisation. Credibility of Technical Success is defined as:

> "The degree of confidence that the project evaluator has in the fact that technical success will be achieved".

It is necessary to carefully establish the areas of work covered by the term technical success, and to define the criteria for success as quantitatively as possible. Bearing this in mind, the technical success of an R&D project is defined as:

> "The obtaining of a predetermined result, at a predetermined cost, and within a predetermined time".

Credibility of Success is a term which is not readily applied to projects of an exploratory or fundamental research nature. It is most applicable to those projects for which a clear commercial application is in sight.
Credibility of Technical Success is estimated by rating the effects of all those factors which contribute towards the technical success or failure of a project. Procedures for estimating, expressing and utilising Credibility of Technical Success are illustrated in the Appendix by use of a hypothetical example. The recommended procedure is:

- Individual factors affecting Credibility of Technical Success should be rated against a descriptive scale.
- The descriptive ratings for each factor should be developed by each company to match its own specific requirements.
- Factors should be given a numerical rating against a scale rising from an unfavourable rating of 1 to some higher value. A scale of 1 to 5 is recommended.

- The numerical ratings for each factor should be expressed in a graphical form. Predetermined values for each rating should be shown on the graph, to indicate when any factor falls to a level which is considered unacceptable.
- The graphical expression of the ratings of factors should be studied to identify factors which fall below acceptable levels. Any factors which are doubtful should be re-examined carefully to determine whether further preparation by the project proposer, or rearrangement of company resources, can improve the ratings to an acceptable level. Following this the total rating should be considered and a judgmental decision should be made on the technical viability of the proposal.
- Provided the proposal is acceptable on the basis of an examination of the graphical presentation of ratings, the overall value for Credibility of Success should be used as a measure of the likelihood that the project will succeed, when comparing projects.
- Direct use of the numerical value for Credibility of Technical Success in calculation of some overall Selection Index is not recommended unless considerable caution is exercised. It is preferred that the numerical value of Credibility of Technical Success is used only to enable comparisons between competing projects in terms of the likelihood that each will succeed technically.

Further uses for the information generated in determining Credibility of Technical Success are in project progress reviews, and in gaining an overview of research activities and resource allocation. These further applications have not yet been studied fully.

SURVEY OF EXISTING METHODS

General

An abundant literature exists concerning possible methods for the evaluation of R&D projects and, in particular, for project selection and periodic review. Attention in this report has been restricted essentially to methods of potential interest to individual industrial firms but, even so, it has been found impracticable to examine the available literature exhaustively. A short selection of references, especially to review articles, is given in the bibliography. In this chapter, an attempt has been made to give a brief general account of the salient features of various proposed methods together with a critical discussion, more particularly of the types of selection criteria utilised.

Broadly speaking, the methods described in the literature fall into two general categories:

- Scoring methods in which a subjective rating is assigned to each of the factors considered relevant to the evaluation. These ratings are very often combined in the form of a weighted sum or product to give an overall figure of merit.
- Profitability methods in which a more or less specific "utility" function, designed to give a measure of the financial attractiveness of the project, is constructed.

Scoring methods

The essential basis of all scoring methods is a more or less exhaustive check list of the various factors which are considered necessary to be taken into account for project evaluation.

An almost infinite variety of such check lists is to be found in the literature. They range from extemely short lists containing no more than half a dozen or so factors to very lengthy ones which may comprise fifty or more factors. In the case of such long lists, the related individual factors are often grouped into classes or families of factors such as technical, manufacturing, marketing, financial and so on. In many cases, however, such groupings appear to be relatively arbitrary. Some typical examples of check lists used in scoring methods are given in an Appendix. [These are to be found on pages - of this study].

Factor Ratings

Having established a suitable check list, a subjective rating is then assigned to each factor included in the list. In most methods, the ratings for each factor are grouped into a limited number of categories based upon an ordinal scale with usually not more than five steps. These may be designated purely qualitatively as, for example, in a five point scale: very good, good, average, poor, very poor. Alternatively, an arbitrary numerical value is associated with each point on the scale; the scales for the different factors need not be the same. There may be different numbers of steps in the scale and/or different numerical values associated with corresponding steps, nor need the increments between successive points on a scale be equal. In some cases a continuous scale is used rather than one with a discrete number of steps.

In most examples to be found in the literature, the scales are established in two stages. An "intrinsic" scale is set up for each factor giving the relative values of different points on the scale for a factor considered individually. The relative importance to be attached to the various factors is then assessed by means of weights attributed to the individual scales. In many such methods identical scales are used for the individual factors, usually but not invariably with equal increments between steps. When individual factors are grouped into families the allocation of weights is often carried out by stages. An individual rating and a weight are attributed to each factor within a group and these are then combined to determine the group rating. Weights are attributed to the groups and the whole combined to give an overall rating. The weights given to factors or groups of factors are usually based on a normalised cardinal scale, such that, for example, the sum of the weights is, say, 100.

Overall assessment

Various methods have been proposed for obtaining an overall judgment of the value of a project from the individual factor ratings. At one extreme, no attempt is made to combine the ratings and the decision is based on assessment of a "profile" of the individual ratings. At the other extreme all the ratings are reduced to a single figure of merit, usually a weighted sum or product taken over all the factors.

The main advantage of the profile lies in its graphic form of presentation which gives a simultaneous view of the comparative ratings of a large number of factors. As such, it is often recommended for preliminary screening of project proposals. However, it is of little help in rendering explicit the actual decision criteria utilised. Its use is sometimes justified by its apparent simplicity but this is largely illusory as in order to make any real use of a profile, the ratings of individual factors must be just as carefully determined as for incorporation in any type of composite criterion. The determination of factor ratings represents a major part of the effort associated with scoring methods.

Problems in the determination of rating scales and weights

The establishment of the individual scales and relative weights for individual factors constitutes a series of value judgments which it is quite laborious to render explicit for each project. However, if this is not done with considerable care, the ratings may very well degenerate into an incomprehensible (or even worse, misunderstood) expression of the rater's hunches. Unfortunately, the literature is not very eloquent on the subject of the possible difficulties which may be encountered in this respect. There is very little discussion of the possible effects on evaluation of using different types of scales for the ratings and weights nor even of the best choice of the final composite figure of merit. There seems to be tacit agreement that a weighted sum is somehow a natural and inevitable choice. In a relatively few cases a weighted product has been proposed, but this does not seem to find much favour, presumably because it is easier to add rather than to multiply. In any case, no reason is advanced for choosing one rather than the other.

It is important to realise that any figure of merit used for evaluating a project is in fact a "utility" function chosen to represent the attractiveness of the project to the firm. The form chosen for the figure of merit by its very structure inevitably reflects certain preferences. These should preferably be introduced explicitly and not adopted implicitly through the choice of a particular mathematical form. For example, a sum criterion favours extreme values compared with a product criterion [2+9 > 4+5 but 2x9 < 4+5]; further, a product criterion is equivalent to a sum criterion with logarithmic scales. **One should, therefore, be rather wary of the simple figures of merit advocated in many scoring methods.** In general, their apparent "obviousness" has made it seem unnecessary to analyse their meaning and it is usually by no means clear what tacit assumptions they conceal. More attention should be devoted to clarifying the choice of scales and criteria in scoring methods.

Advantages and weaknesses of scoring methods

In principle, scoring methods are inherently designed to rank projects in order of merit, and are not well adapted to furnish information on the intrinsic value of a project. This limitation is unsatisfactory for project selection since it tacitly implies that all projects submitted for evaluation are worth undertaking per se. This may well be so, but one would generally welcome reassurance on the subject. Furthermore, in the absence of any indication of intrinsic value, it is difficult to judge whether limited available resources are forcing the rejection of worthwhile projects. One can, of course, attempt to overcome the difficulty by defining threshold acceptance levels for the values of the composite figure of merit utilised. It is usually not at all clear how this should be done and again the literature is remarkably silent on the subject; at best, a figure is quoted for a particular system in a particular context but no indication is given as to how it was chosen. This again raises the question of the significance of the figure of merit being utilised and emphasises the importance of studying the matter further.

In general, in scoring methods no attempt is made to take into account uncertainty in the estimated ratings and weights. In an isolated example quoted in the literature, instead of attributing a single rating to a factor, a credibility is associated with each of its possible values and the expectation value is taken as the accepted rating for the factor. This procedure seems rather to miss the point. Quite apart from whether it is valid to use expectation values in this context, it is of no use to introduce uncertainty in the individual factors unless one thereby arrives at a range of values for the final figure of merit. The only procedure on these lines which seems at all realistic would be the use of a simulation technique of the type outlined elsewhere to obtain different possible values of the figure of merit and their associated credibilities. No example of such a procedure has come to our attention and it would presumably be very laborious.

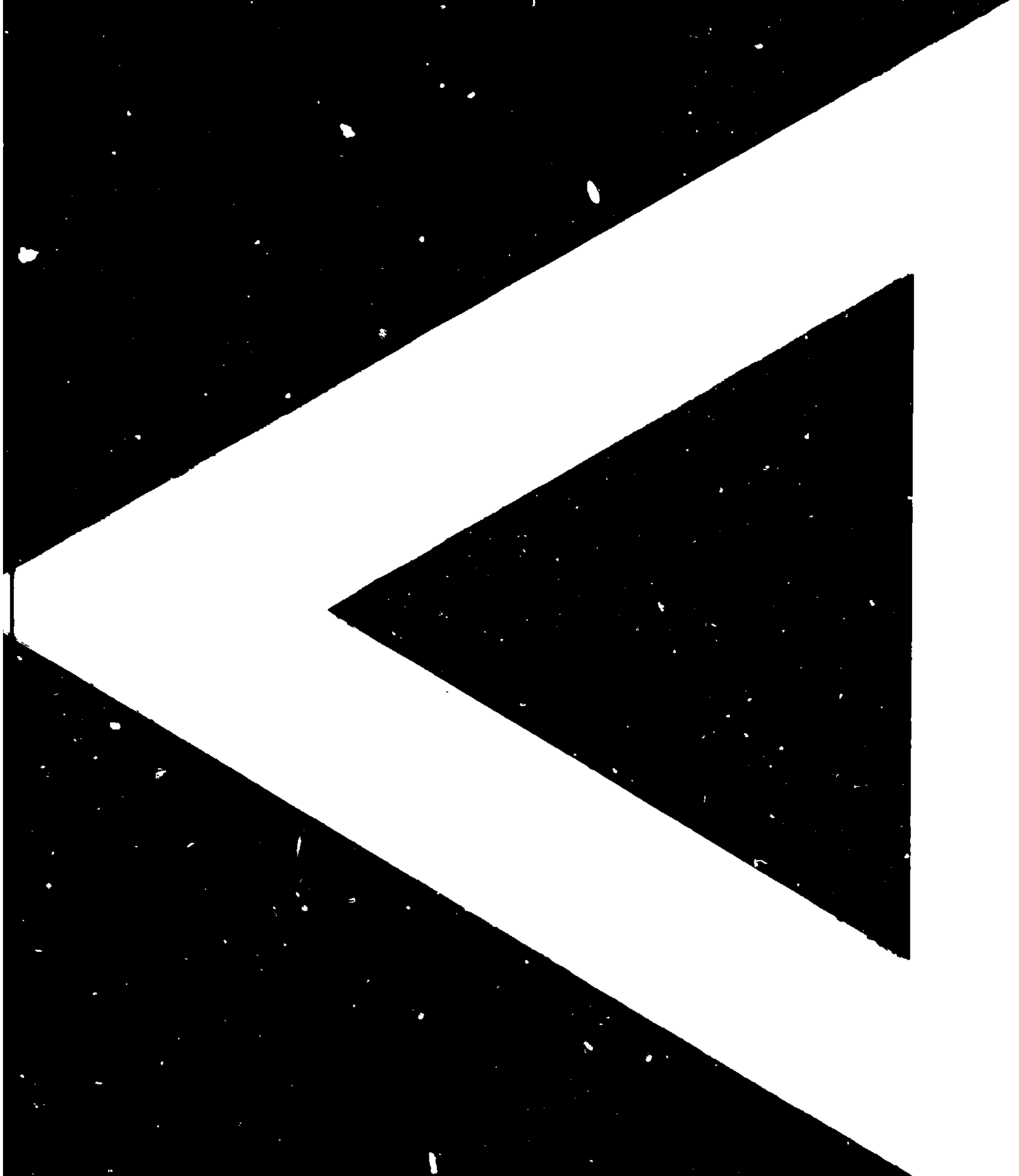
Another difficulty associated with scoring methods lies in the fact that although financial factors are included in the check lists, the actual magnitudes do not appear in the ratings and so may be lost to sight. This, of course, is again a consequence of the fact that the figure of merit has no direct financial significance.

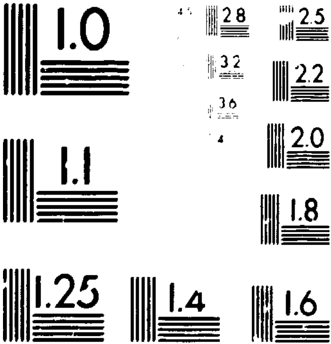
The greatest asset of scoring methods lies in the formal use of a check list which obliges explicit consideration to be given to all the identified factors. This not only prevents accidental oversights and superficial judgments, but also greatly facilitates the process of arriving at an agreed consensus of opinion on the part of the various sectors of the firm involved in project evaluation.

Profitability methods

These methods base evaluation upon a definite economic utility function which is assumed to express the degree to which the project presents financially favourable prospects for the company.

It must be stated immediately that no overall utility function has yet been defined and that most of the methods proposed take the form of a formula for a merit index which normally reflects only a particular aspect of the economic consequences of undertaking the project.





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by

Prof. Dr. Gyula Sebestyén***
UNIDO consultant

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I. INTRODUCTION

1. Consultations in sectors producing building materials have taken place on previous occasions:

Iron and steel:	I.	Consultation	1977
	II.	"	1979
	III.	"	1982
Wood:	I.	"	1983

2. Some of the recommendations made at those earlier consultations are also relevant to the building materials industry, but in general those consultations were concerned to a relatively minor extent only with applications of steel and wood as building materials and even less with research priorities for such purposes. Finally in 1983 a decision was taken to convene the First Consultation on the Building Materials Industry. By way of preparation, various studies will be undertaken on different macroeconomic, technical, financial and other aspects. One specific topic is research and development (R+D). This should contribute significantly towards increasing the production of building materials, to reductions of imports and to a more economic use of resources (energy, raw materials, labour).

3. The objective of this study is to highlight the research aspects of the building materials industry in the developing countries. This has been carried out with due consideration to the character of the First Consultation, and concentrates on the problems of developing countries. It is, however, a specific feature of the topic that research in developed countries also allocates resources to problems of developing countries and it is desirable to maintain and even strengthen this. The Appendices quite specifically have the character of working documents. Appendix 1 lists selected institutions in the field and Appendices 2 and 3 are intended to complement the study itself.

4. The building materials industry can be divided into two groups:

- small and medium scale (low capital intensive) production
- large scale (high capital intensive) production,

or, according to different criteria

- traditional manufacturing techniques
- modern manufacturing techniques.

5. There is a distinct difference as regards research requirements for the small scale production of indigenous materials and for the industries using modern technologies, (usually but not necessarily on a large scale). Thus, for example, some cement factories in developing countries require research on problems which occur in developed countries also. The study does not deal in detail with research problems that are present in developed countries also. It concentrates mainly on research needs specific to developing countries.

6. In the following chapter a summary of the overall situation of research on building materials and on buildings will be given. In Chapter III the main objectives and trends of research will be set out, and in Chapter IV research priorities regarding the main building materials will be listed. In Chapter V, methods for selecting research priorities will be introduced as well as the conditions to implement the selection.

II. PRESENT STATE OF BUILDING MATERIALS RESEARCH

7. Building materials research itself is a recent phenomenon. Although cement was invented in the nineteenth century, research on cement and conrete is still extremely important. Gradually, however, research has extended to bricks and tiles, glass, timber and various other building materials (bituminous, paints, plastics, etc.). Some of the materials used as building materials are produced by other industrial sectors, i.e. steel, aluminium, plastics, etc. Research on these can be considered to some extent only as building materials research. Most building materials research activities concern cement (and other binding materials: lime, gypsum, pozzolana), concrete and mortars, burnt clay, glass, timber. Recently, however, research has expanded into new fields: prefabrication of components, plastics, etc. Building materials research is closely related to building research. Indeed the practice in many countries is to organize research for both in one single research institute. The line of demarcation between the two fields is blurred, e.g. concrete can be considered as a building material, but it can also be considered as a product of construction activity. In countries which are able to allocate resources on a major scale to building materials and building research, separate research institutes can be established. In several countries separate cement research institutes exist, which frequently have in their scope, lime, gypsum and eventually concrete also.

8. In recent years, research on building materials (and construction) made significant progress in many developing countries. In the two largest countries (China and India), several research institutes, each with a staff of over 100, and in some cases four to five hundred, are active in this field. In other smaller countries, building materials research is carried out by small units manned by only a few staff members.

9. Appendix I contains a list of institutions active in building materials research in developing countries. Inevitably such a list cannot be exhaustive and there are some institutes which are not mentioned. Nevertheless, the list gives information regarding existing institutional research capacities in developing countries. Several institutions in developed countries have specialized units charged with carrying out research on building and building materials for developing countries. Some of these are also listed in Appendix 1.

10. There are neither national nor international statistics in existence which relate to the volume of R+D expenditure in the building materials industry. A study prepared within the International Council for Building Research, Studies and Documentation (CIB) on the measurement of expenditure on building research was actually concerned with the total value of construction. The study revealed that in 17 countries percentages lie between 0.03 and 0.57. 1/ The higher figures are found in developed countries with strong research facilities (Sweden, Denmark, etc.). As is to be expected, expenditure on research in developing countries is lower. Although the figures quoted should be accepted with caution since there were significant differences in their methods of derivation, three statements can be accepted as having a high probability of validity:

- That trends valid for R+D in the building industry are also valid for the building materials industry;
- That the volume of expenditure on R+D in the building and building materials industries is well below the levels to be found in high-technology sectors (where they can be from 5 to 20 per cent) and although they must grow, such discrepancies will persist into the foreseeable future;

1/ Measurement, Accounting and Taxation for Research and Development. Volume and Support of Construction R+D (by Prof. Dr. Gy. Sebestyén, CIB; Rotterdam 1983, 29 pages).

- that the relative volume in expenditure in developed countries exceeds that of developing countries and that together with the overall economic development of countries, the absolute and relative volumes of R+D in the building and building materials industries has to grow.

11. Attention should also be drawn to the fact that it is not only the volume of R+D expenditure as it relates to the annual turnover of the building materials sector which is of relevance, but its absolute volume also. Obviously countries with a large population may have substantial volumes of R+D activities which may well exceed the absolute volume of R+D in smaller developed countries; at the same time the relative volume in large countries may be below that of smaller countries.

12. It can be stated that each country needs to organize its own building materials and building research. This does not mean that research in these sectors has to attain the levels of sophistication of, for example, biotechnology or electronics. In all countries, expenditures on building materials and building research are lower than that for high-technology sectors. Many countries, on the other hand, can avoid the necessity of establishing certain areas of domestic high-technology research; this is not possible for the building materials and building industries. Each country must develop its own building industry as it is an intolerable drain on resources to rely indefinitely on imports of building materials.

13. Building materials are manufactured from indigenous resources and the technical characteristics of raw materials (stone, sand, clay, etc.) are never identical for all countries. This in itself compels countries to undertake experiments carried out earlier in other countries (with other raw materials). Such repetition also makes developing countries familiar with up-to-date techniques and serves as preparatory steps in introducing new production methods and products.

14. Building materials research institutes can be public, semi-public or private. Public (i.e. state-owned) institutes exist in those countries with a central planning economic system: East European countries, China, etc. In market economy countries building materials research is usually organized by private industry or is semi-public. In Western market economy countries there are also public building research institutes and these deal to varying degrees with building materials research as well.

15. Private research on building materials can be organized by large individual enterprises (LaFarges for cement, Pilkington and Saint-Gobain for glass, etc.). It can be organized by an industrial subsectorial association, as for example in the United Kingdom (Cement and Concrete Association) and in the Federal Republic of Germany (Forschungsinstitut der Zementindustrie). Research carried out by research institutes in developed countries can have a relevance for developing countries or can be aimed directly at solving problems in developing countries. If the latter, then the research is usually financed by special assistance funds.

16. All over the world, universities and higher education establishments occupy an increasingly important role in industrial research. In several countries, research institutes on building and building materials are in some way linked to a university. Research on building materials requires suitably equipped laboratories. Sometimes these are costly and there is no need for more than one laboratory or set of apparatus in a given country or region. In such cases either an Institute or a university is appointed as the organization responsible for maintaining and developing a laboratory. Shared laboratory facilities can be arranged. In developing countries universities usually tend to be public (state) organizations. In certain developed countries (notably in the United States) some of the universities are private institutions (e.g. Standford University in California).

17. In summarizing the present situation it can be stated that developing countries have made significant steps towards establishing their own building materials research institutions. Experience in developed countries shows that newly established research institutes usually need an initial period of some ten years before they can become really efficient. The same maturing process will have to be repeated in newly established research institutions of developing countries. It will be necessary to strengthen further the research and technological potentials in developing countries.

III. OVERALL RESEARCH OBJECTIVES

1. General principles

18. The two main categories of technological research are:

- R+D on products
- R+D on processes.

Much of the research into processes (technologies) is interlinked with research on products and so will be dealt with together with research on products or other research objectives. In practice, when establishing research priorities, both categories of research must be accorded adequate consideration.

19. Although this paper covers the building materials industry in general, it is not possible to define research priorities on a global scale; these have to be defined for a given country and within a given period. Research priorities in this document are generally based on completed or ongoing research in one country or in some countries and include those topics which could benefit many countries. The explanation for this is the extremely scattered character of the construction industry and its dependence on different local resources. In country A the production of lateritic blocks may be solved; this does not mean that the results could be transferred to country B without additional research, one of the reasons being the different specific nature of laterites in different countries. The selection of research priorities therefore requires the application of two distinct processes:

- The identification of potential subjects for research;
- Methodology for comparing the competing potential research subjects in order to decide which to accept and which to reject.

20. This document seeks to elucidate both of these processes; it gives certain indications about research subjects which might be worthwhile considering and it lays down certain basic principles on selection methods to be used. These recommendations will not be adequate in every country for the actual selection process. The research subjects will have to be defined and selection methodologies will have to be adapted according to domestic conditions. Certain overall research objectives are summarized below.

2. <u>Use of domestic materials and by-products; conservation of resources and energy</u>

21. In many developing countries, massive quantities of building materials have to be continously imported. This is a needless waste of the country's resources because in most countries adequate raw materials exist for the production of building materials. Research into the uses of domestic

materials has top priority. In addition to conserving valuable hard currency, it also alleviates the problems of handling the imports and transporting them to distant places. Local (domestic) materials as a rule should be cheaper than imported ones. In hot and humid climates natural organic materials (timber, bamboo, reed, thatch, straw, leaves, grass, fibres) can readily be found. In hot and dry climates inorganic materials (stone, sand, clay, laterite, pozzolana) are abundant.

22. Natural resources are different in individual countries. Some have abundant timber resources; in others there is a shortage of timber. In countries where there is not sufficient timber available, masonry arches and domes, dwellings cut into the mountainside and reinforced concrete beams have to be used. Stone, clay, gravel, and sand may well seem to be present everywhere but this is not the case. In many countries, one or the other is lacking or the characteristics of those that are available are not suitable for building purposes. At the same time research can open the door for uses of natural materials which formerly were avoided (e.g. certain timber species or lateritic soils). It is an important task of research to broaden the list of natural resources which can be used economically for building purposes. In addition to natural raw materials (sand, lime, stone, earth, etc.) industrial and agricultural by-products should also be used for manufacturing building materials. This would reduce the growing heaps of slags and other unsightly wastes and would be a first step towards rehabilitating environments disturbed e.g. by mining. Energy conservation also has top priority in research and particularly in oil-importing countries.

3. Improving durability and fire resistance

23. Indigenous building materials (earth, palm, leaves, etc.) may be very cheap but frequently their durability is low. The life-cycle of some local building materials may not exceed two years. Quite obviously lengthening the life-cycle of indigenous materials through improving their durability has a high priority in research. It is important to achieve this objective by methods that are cheap. Durability of building materials and of buildings has high priority in developed countries and much research on the topic has been executed or is underway. A considerable amount of knowledge has resulted but developing countries have specific durability problems. The lifetime periods are usually much shorter; also the climatic and other ecological factors

affecting durability are different. This, therefore, is an important area for research also in developing countries.

24. The most important categories of building materials in this respect are earth and timber; the most important categories of building parts are the roofs and the walls. Research should concentrate on increasing the durability of these materials and parts of buildings.

25. Earth is a durable material provided it is adequately protected from rain, ground water and other forms of moisture. Protection from ground water can be ensured by stopping the movement of moisture by a water insulating (bituminous, etc.) layer; waterproofing the rendering mortar affords protection from direct or splashing rain. Plain mud plasters can be coated with thick cement slurry wash, at least on the face exposed to rain. This splash has be renewed periodically. The waterproofing of the mortar can be achieved through adding cement or some other domestic appropriate material, e.g. calcium palmitate (an acid produced from palm oil soap). The addition of fallow to lime makes whitewash more water-resistant. Protection against rain can be obtained in regard to appropriate architectural details: e.g. protection through roofs.

26. Degradation of organic fibrous materials can be caused by weather, insects, fungae. Certain timber species are susceptible to fungal and insect attack and can only be used after some form of preservative treatment. The correct timing of conversion of logs and of seasoning sawn wood at the millyard improves durability. Several countries have devised effective ways to safeguard materials against termites. Durability can also be a problem in newly developed materials. For example, the embrittlement of sisal fibres in concrete can be prevented by reducing the alkalinity of pore water through replacing part of the portland cement with silica fume or with high alumina cement or by sealing the pore system with wax or some other fibrous impregnating agent.

27. Besides adverse weather, fire constitutes a major hazard in destroying structures. In many developing countries this is a high risk due to the materials used. Increasing resistance to fire therefore is an important task for research. Earthquakes, floods (tsunamis, typhoons, etc.) destroy not only the materials but the whole structures. The application of existing

research results, as well as further research could reduce losses suffered in terms of money and of course of human life. One of the new and relatively cheap techniques is reinforced masonry which increases resistance to seismic actions. This is still being utilised to a very small extent and an expansion in its application could yield marked benefits. Tropical wet or dry climates affect materials in various ways. This has induced some countries to undertake research on mould-resistant emulsion paints.

4. Appropriate technologies; economics of research and technical development

28. It has been repeatedly stated that merely dumping the technologies evolved in developed countries onto developing countries can cause more harm than benefit. Specific conditions of developing countries require specific appropriate technologies. In many countries this may also mean reduced capacities but this is not the only feature of appropriate technologies. The principal condition is that the technology should be such that it can be mastered and maintained and gradually further developed.

29. One of the most important features of developing countries (from the point of view of technical developments), is the low level of incomes and the relatively high cost of materials in relation to those incomes. This means that substituting labour by materials or machines may prove economical in developed countries but may frequently be unfeasible for reasons of economics in developing countries. The replacement of labour-intensive methods by mechanized processes can only happen gradually, and the period of time necessary will depend on when such changes become feasible as a consequence of increasing incomes and decreasing prices of machines and materials. Research also has to consider these circumstances.

30. The purpose of research is to improve housing and living conditions and to increase productivity and well-being in a country. Many case studies can be quoted in developed as well as in developing countries to illustrate situations when research and development did not attain this goal. In some instances technical development (new factories, etc.) swallows up more of a country's resources than do the new values produced through this development. Bitter lessons have been learnt but even these afford no guarantee against similar mistakes being committed again. For this reason, when defining a list

of priorities for research, the economic (commercial) control of research idea must be taken into account. This is necessary during all stages of research.

31. For implementation of the above, research institutes should be able to assess the economics of research and of its potential application. Among the staff of those institutions there must be economists and/or technical researchers with adequate understanding of economic principles; it is their task to assess economics of research and of technical development.

5. Quality control

32. The use of indigenous building materials has always been based on practical experience. Though this could be satisfactory under traditional conditions, quality control could contribute to a better use of resources. The application of quality control techniques brings to the surface differences in quality. This allows those materials with the weakest properties to be eliminated and the better properties of the remaining materials more advantageously utilized. This can also impart to producers a consciousness as to how they could improve the quality of the building materials. Quality control of course is not in itself research but is frequently organized in the same institutions as research. The same laboratory equipment can be used for both quality control and research. Proper quality control will reveal deficiencies in the quality of building materials and this knowledge serves as a starting point for research aiming at eliminating those deficiencies.

33. Quality control laboratories are often set up at universities because the apparatus is also necessary for teaching purposes and quality control acts as a bridge between university teaching personnel and industry. Another solution is to establish one quality control laboratory for all industrial sectors including the building materials industries. Whatever the structural set up chosen, the establishment of a competent institution and procedures for quality control should have the same high priority in developing countries as in developed countries.

6. Conservation of resources and energy

34. Regrettably, mankind's awareness of the vital need to conserve resources is a relatively recent phenomenon. Initially it was restricted to developed countries. In developing countries the need to increase production and welfare was placed above the conservation of resources. Even at the present time occasions can be found where developed countries attach a higher importance to the conservation of resources than developing countries. This situation, however, is rapidly changing. The energy crisis beginning with 1973 speeded up this process. Oil exporting countries seek to conserve their oil stocks for as long as possible; countries importing oil are compelled to conserve energy in order to keep down rapidly increasing energy import bills.

35. The objective to conserve other resources (natural environment, raw materials, etc.) is also receiving growing attention. Much energy is used during the operations of drying, curing and burning building materials. Solar energy is a natural form of energy which can replace part of the fuels used earlier in manufacturing. Mixing clay with organic by-products (rice husks, saw dust, etc.) also reduces fuel consumption in brick burning. Curing of concrete should be carried out as far as possible, without introducing steam curing and instead making use of natural heat, eventually enhanced by solar radiation.

36. Water is a scarce resource in many countries and therefore research into its conservation should have a high priority in such countries. It is remarkable that flushing toilets still consume much water despite the fact that efficient technical solutions with low water consumption have been devised.

37. Building research can give guidelines to designers to enable them to design buildings which require reduced amounts of energy for heating, ventilation and air-conditioning. Conservation and rehabilitation of the natural environment (e.g. restoration of abandoned quarries, etc.) is also of growing concern in developing countries.

IV. RESEARCH PRIORITIES FOR THE BASIC BUILDING MATERIALS

1. Earth (mud, clay, adobe, laterite)

38. Earth is a peculiar building material. It is used in California (USA), France and some other countries to erect buildings for clients who are certainly in the position to afford any other structural material. On the other hand, people in many developing countries reject it as unworthy for use in building decent homes. While these two extremes occur, millions of families, unaware of the anormaly, use earth as a building material with a total indifference to research and industrialization and in doing so keep alive ancient building traditions and habits. Traditional earth (mud) wall constructions are:

- the mud lump (mud ball, cobwall) walls
- sun-dried mud brick (adobe) walls
- rammed earth (pise) walls

In mud lump wall constructions local soil is dug out and mixed with water to form lumps. Lumps are laid manually in layers, if possible, on a stone strip, mud, concrete or other water resistant foundation, and then the wall is coated. Window and door apertures are left in the walls. Sun-dried mud brick or block walls are constructed from sun-dried bricks which are moulded from a mixture of clay, sand and water. Rammed earth walls are rammed between temporary, moveable timber framework. Suitable clay cannot be found in a number of countries but laterite can be used instead. Laterite is a subtropcial or tropical soil formed as a consequence of weathering of igneous rocks.

39. Researchers are trying to ascertain the proper place of earth as a building material. Earth, adobe, laterite, etc. can be stabilized with various materials (cement, lime, gypsum, bitumen, ash sand, grass, sisal, cow dung, etc.). The choice depends on local conditions (availability) of individual binders) and research may be required to define the optimum mixing proportions and techniques taking into account characteristics of the local earth (laterite). In wattle and daub walls, bamboo lath is covered on both sides with mud mixed with clay (as well as fibres or cow-dung). It may be necessary to mix the mud plaster with an anti-termite solution.

40. Despite universal knowledge, experiences with earth vary greatly. Tools, presses, moulding tables, shutters and methods are different, and these together with differences in properties of raw materials, climate and other conditions account for the greatly differing experiences. A number of presses and rams have been developed and are used for manufacturing stabilized earth and laterite blocks and bricks: CINVARAM (Colombia), Terstaram (Mali); BREPAK (Ghana), TEK-Block-Press (Ghana), CENEEMA (Cameroon), Ellson Blockmaster (South Africa), Supertor (Brasil), Latorex (Denmark), CONSOLID (Switzerland, Ghana). In countries and regions where none of these equipment is used a study and selection its adaptation to local conditions could contribute to the development of the use of walling materials.

41. By means of exchange of information and experiences, the global pool of knowledge is combined with local willingness or reluctance for change and yields gradual if slow progress with this ancient building materials. To contribute to this development is the highest priority for research; correctly assessing local conditions is therefore of utmost importance.

2. Cement, lime, gypsum, pozzolana, sulphur

42. In the majority of developing countries there is a shortage of cement and to some extent of other binding materials. For this reason increasing the production and securing a more economic use of these materials must have high priority in general, not least as concern research. Cement is the most important binding material; portland cement is the most widely used with several others (for instance "white" cement) being used in lesser quantities. The baking at 1450°C of a mixture of limestone, clay and eventually other minerals results in clinker which, when ground (and after the addition of gypsum) yields portland cement. Blast furnace slag, fly ash, pozzolana can also be added. The baking can be carried out in long or short rotary kilns or in shaft kilns. Although better and more homogenous cement can be produced in rotary kilns, small vertical kilns require less capital investment and can be established for those markets with smaller needs.

43. Lime is burnt from limestone at temperatures well below those used in cement manufacturing. Whereas cement is a product of the last two hundred years, lime is one of the most ancient building materials. Even at the present time burning is effected by simple methods calling for no other

resources than the limestone itself, and clay, fuel (wood or charcoal) and labour. There are, however, mechanized lime manufacturing processes which utilize mechanized quarrying, crushing and vertical shaft, rotary or Hoffmann kilns.

44. In general, the manufacture of cement is more capital-intensive than is the manufacture of lime and pozzolana. Therefore a substitution (at least partially) of cement by lime and pozzolana is important. The same objective is attained by manufacturing mixed (blended) cements in which part of the cement is substituted by natural pozzolana or by industrial by-products, (fly-ash, slags, sand), having hydraulic properties. An inadequate road and railway infrastructure and insufficient transport capacities can create local shortages of cement (or other building materials). Therefore it is in many cases important to commence or expand the manufacture of cement and other materials locally. The appropriate raw materials have to be investigated, the manufacture and use of cement in local (subregional) plants have to be studied. These rank as tasks of high priority for the building materials researchers.

45. In many developing countries, cement (and eventually lime and gypsum) are imported in substantial quantities. If possible the availability of volcanic pozzolana should be explored which can be used as a substitute for at least a part of cement, lime and gypsum. Rice husk ash with lime can also be substituted for cement. In blended cement, part of the portland cement is substituted by pozzolana or slag or fly ash. Some developing countries have modern kilns for the burning and grinding of cement, manufacturing of lime, gypsum and pozzolana. The majority of research priorities of these plants are identical with those in developed countries.

46. In recent years sulphur has become available in considerable quantities as a by-product of de-sulphurization and cleaning of petroleum, natural, stack and smelter gas, and of high-sulphur coal. In those countries where it is available in large quantities sulphur can replace cement and lime to serve as a binder in concrete and mortar. While it can be regarded as a major resource for binders, it still requires adequate technological research to clarify properties and technological processes.

47. A further number of application fields can be identified for sulphur: as an impregnating material in masonry, as an additive to fibrous materials, etc. In several countries during the coming years, research on sulphur and its use in the building and building materials industries will have a high priority. Research areas with a high priority in this group of building materials, both for small- and large-scale production, are:

- Geological investigation of minerals, and research on optimal mixes;
- Use of local raw materials, wastes and by-products (magnesian and dolomitic limes, pozzolana; slags, fly ash, phosphogysum, rice husk, mica scarp, mine wastes, lime sludge from acetylene, wastes from paper and sugar industries);
- Improvement of quarrying, transport, burning and grinding processes;
- elaboration of simple small- and medium-size manufacturing units; cement and lime burning kilns, burners for these, and lime hydrators;
- Introduction of automatic control systems for large scale plants, and use of computers and microprocessors;
- improvement of manufacturing equipment and its maintenance, repair, life cycle, etc.;
- Energy conservation; use of local fuels for lime burning (e.g. pellets pre-mixed from rice husks and clay);
- Introduction of new and improved products (magnesite cement, sulphate resistant cement, white cement, portland cement mixed with pozzolana or other additives; other binding materials such as sulphur);
- Protection of environment, reduction of air and water pollution; reclamation of abandoned quarries.

3. Concrete, mortar, bricks, blocks, precast components

48. The production of concrete, bricks, blocks, etc. is a secondary manufacturing stage making use of primary raw materials and basic building materials (gravel, sand, clay, cement, lime). Some of the production processes are carried out off-site (e.g. in prefabrication plants). Research on building and that on building materials overlap each other in this field.

49. Long-distance transport is usually expensive in developing countries and the necessary infrastructure for this is often not available. Consequently, plants producing bricks, blocks and precast components cannot serve too large areas and hence have to be small or medium size. Due to the usual lack of

capital, they have to function with simple equipment, and research has to take these constraints into account.

50. Research on technological processes making use of cement and other binding materials, extends to curing, including steam and solar curing, vibration, chemical additives to improve workability, frost resistance, processes of setting and hardening, durability, reduction of crack formation, impermeability, etc.

51. In countries where the supply of timber is low, horizontal floors and roofs requiring rafters are frequently avoided. Instead vaulted masonry or domes are used. Another solution would be the manufacture and use of reinforced concrete floor beams and roof rafters or roof planks.

52. Steel reinforcements constitute an expensive component in producing reinforced concrete. Thus, substituting steel by vegetable fibres (sisal, coir, wood pulp, elephantgrass, wood wool, kenaf) could be the answer. Sisal fibres can be used as reinforcement in a chopped form or as long fibres or twines. Cement is another expensive constituent of concrete. Research on concretes with a low cement content can save money and do much to alleviate the shortage in cement. Mixing water seems to be an inexpensive part of concrete but there is a water shortage in many places. Research can assist by clarifying the (partial) use of sea water as mixing water in concrete. In places where laterite is abundant but there is no adequate sand available, laterite can be used in concrete.

53. Burnt clay (and other) bricks can be produced by methods which may be:

- labour intensive
- semi-mechanized
- fully mechanized.

The traditional manufacture is based entirely on manual extraction, preparation and moulding of the clay. The formed bricks are left to dry. They are then assembled, covered by clay and burnt. Simple kilns can be used for this. In semi-mechanized manufacturing, mechanized extraction and transport of the clay, crushers, mixers and simple presses are used. In fully mechanized manufacturing, all processes become mechanized or even automated. Continuous or tunnel kilns are employed for burning the bricks. Burning (firing) and eventually artificial drying require much fuel (energy).

54. The optimum sizes of manufacturing units depend on local and regional factors, including size of the market, salary levels, and existence of transport networks. Some clays can be used for the production only if mixed with sand, or if no sand is available, with other adequate fine materials, such as basalt fines, fly ash, cinder, and colliery wastes. Part of the fuel can be replaced (and at the same time heat insulation properties can be improved) by adding organic materials such as husks and saw-dust to the clay.

4. Timber, bamboo, other vegetal products and by-products

55. Wood is not used solely as a building material - it has a number of other uses. A Consultation has already been convened on the wood and wood products industry and the working papers of this Consultation contain many statements and recommendations for research regarding building timber as a building material. 2/ This chapter summarizes in a concise form the content of these documents.

56. Since ancient times, timber has been used as a building material. However, the use of timber in construction has remained inadequate in developing countries. Especially in urban areas, one encounters prejudices with regard to timber houses; building codes sometimes go so far as to forbid the construction of timber houses. This is attributable to adverse experiences regarding behaviour in fire, durability and faulty detailing; these in turn are the result of inadequate know-how regarding construction with timber, mainly with tropical timber.

57. Technological information and design codes are based on experiences with coniferous woods which differ from tropical broadleaved timbers. The different occurrence of defects, the heterogeneity and the usually much lower moduli of elasticity are characteristic for tropical timber. The species found in tropical forests in various parts of the world are different; there

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2/ A general survey on wood is provided in document UNIDO/IS.398, "First world-wide study of the wood and wood processing industries", dated 3 August 1983. The UNIDO document ID/WG.395/2, "Promoting the use of wood in construction" (by Mr. M. Tejada, 25 May 1983) is specifically given over to research and development requirements.

are wide discrepancies too in heterogeneity. The most heterogeneous tropical forests are located in Latin America, and the least in South East Asia. This in itself necessitates technological testing of timbers in individual regions and countries. The results of technological investigations should be transformed into appropriate design codes, manuals and into suitable manufacturing and construction techniques.

58. A relatively small number of primary tropical species of timber are being utilized in construction (teak, sal, deodar, rosewood, etc.). Even these are used with much waste and the technological methods common in developed countries to make use of short pieces tend to find ready application in most developing countries.

59. It is an important task of research to popularise the use of secondary and mixed species of timber. Proper identification methods have to be developed and disseminated. A more effective use of timber is attained through air, kiln, and solar seasoning, and their protection against destruction by fungi, insects, moisture and fire. Preservative treatment of timber can prolong considerably its service life. Preservative chemicals (copper, sulphate, zinc, chloride, boric acid, borax, copper-chrome arsenic, copper-chrome acetic acid, etc.) and fire retardants (ammonium-borax-boric acid composition, chromated zinc-ammonium-copper-boric composition) have to be used. Termites can also cause much damage in timber. Their effective control requires methods which go beyond the building materials industry, e.g. by:

- sterilisation of soil and back-fill earth with termite-repellant chemicals (creosote, pentachloraphenol, etc.)
- provision of anti-termite metal shields at plinth level
- removal of all wood waste, roots, stumps, boards under earth from the vicinity of the buildings.

60. Different methods of application to those used for coniferous timber can be used for tropical timbers and bamboo. Instead of nailing (which causes splitting and notching) bamboo can be jointed in other ways. Lashes split from the bamboo itself or made from vines, reeds and the bark of certain trees can be used. Soft galvanized wire can also be applied for binding (see UNCHS Technical Notes No.4). By splitting (halving) bamboo stems, bamboo tile roofing can be made. Bamboo split into strips can be woven into matting for use as walls and partitions.

61. It is anticipated that in several countries timber resources will be depleted if the present rate of deforestation is continued. The cultivation of fast growing species of trees and good quality bamboo for building purposes can augment the supply. Poor and inefficient conversion techniques give rise to high conversion waste and costs; research can reduce these losses. Particle boards, fibre boards and wood-cement boards can be produced from wood wastes as well as from fibres and reeds which have hitherto been regarded as a nuisance (e.g. eupatorium).

62. Despite the fact that research priorities have to be defined for each region and country separately, there are some research areas which in many countries have a general high priority:

- Extension of the types of timber used. In many countries there are species which could be used. Surveys and laboratory controls are necessary to achieve this;
- Mixed use of timbers. In some countries the properties of individual types of timber are known but it would be more practical to use various species; the properties of such mixes have to be clarifed;
- Species yielding maximum efficiency. Different species grow at different rates and yield different quantities of timber per area unit. Research is required to define the optimum forestation and replacement policies;
- Solar and other timber seasoning with the objective of energy conservation;
- Fire retardant treatment of timber, thatch, palm leaves, etc.;
- Various uses of agricultural wastes and by-products (rice husks, saw dust, etc.);
- Replacement of asbestos fibres or steel reinforcements by vegetal fibres (sisal, etc.);
- Development of new products (roofing shingles and corrugated roofing sheets, etc., see e.g. UNCHS Technical Notes No.1);
- Use of wood and bamboo derivates and industrial by-products for the purpose of binders and adhesives (e.g. lignin and furfural).

5. Other materials, components and equipment

63. Programmes for developing the building materials industries should not be restricted to basic materials (cement, glass, ceramics, timber) but should

take into account the growing complexity of construction. To neglect this results in continuous imports of water supply and sanitary equipment, fittings, electrical equipment, paints, plastics, lifts, etc. The quantitative needs for various materials, components and equipment are extremely varied and depend on the population of the country. For certain items the domestic market may not be large enough to justify manufacturing within the country solely for the home market. In such cases manufacture would only be viable if there are expectations, based on a high degree of probability, of a wider market.

64. The use of agricultural and industrial wastes and by-products, obviously calls for high priority in research (rice husks, straw, paper waste, fly ash slags, etc.). Doors, windows, shutters and their fittings (ironwork), are needed equally in low-cost housing as in high quality urban multi-storey buildings (banks, offices, etc.). In the first category, however, simple and inexpensive solutions are called for; in the second category, products are usually at the same level as in developed countries.

65. The production and use of plastics in construction is and will remain rather limited in oil-importing countries; on the other hand, in oil-exporting countries their application in construction may gradually become attractive. Despite basic differences in the use of plastics, these could be applied to varying extents in all countries; at the same time (not least due to climatic conditions) their use will remain limited in all developing countries.

6. Interrelation between research on building materials and building research

66. In rural housing, producing building materials is inextricably linked with the construction of houses and therefore research on building materials is interwoven with building research. Examples of this are earth walls, mortar renderings, grass roofs, etc.

67. For example, grass roofs have been made from secco since the earliest days. Research has devised improved manufacture of secco rolls or panels which ensure good waterproofing on gentle slopes under rain action. They also afford appropriate strength under self-weight and provide fixings resistant to wind pressure. As well as imparting these attributes the new manufacturing

methods have improved the behaviour of secco against biological attacks by means of chemical treatment. In some countries insertion of a polyethylene sheet between two layers has been proposed for the purpose of making the roofing watertight.

68. In the formal (monetary) subsectors of the economy increasing components of buildings are prefabricated and such components - through replacing building materials - are studied by the building research industry. Precast reinforced concrete floor beams and roofing planks can be designed only with the knowledge of their ultimate use in buildings.

69. Requirements in buildings and their performance are subjects for building research. Building materials research becomes intimately interrelated with building research. The transport, hoisting and assembly of building materials necessitate machines, tools and other equipment, including scaffolds and formwork. A branch of building research specializes in such matters.

70. Building research addresses itself to building materials when studying components and parts of or whole buildings. An example of this is a form of reinforced masonry with better resistance against earthquakes devised after research on structural engineering.

V. SELECTION OF RESEARCH PRIORITIES; CONDITIONS OF IMPLEMENTATION

1. Selection methods of research priorities

71. Other chapters of this study discuss research priorities from the global aspect. This, however, is not sufficient for government agencies supervising research and in the individual research institutes when making decisions on research priorities.

72. The selection procedure for research projects has to be based on a policy of priorities. Experience and empiric methods can give satisfactory results; in the case of a great number of competing proposals for research, recourse can be had to a more formal methodology. A system of criteria can be defined and this can be used as a checklist when assessing individual proposals. A vast amount of professional literature is available on the problem of selecting research projects. Two basic approaches to the problem exist:

- To define individual projects and then to compare them, selecting or rejecting projects based on the outcome of the comparisons;

- To define mathematical models and to ascertain the optimum point out of the large number of possible alternatives.

73. The second (mathematical optimization) methods are less frequently employed and accordingly no further reference to these will be made. Comparison of two or indeed many (but necessarily a finite number of) projects can be based on one single criterion, e.g. production cost of product or productivity of labour, or on several criteria. If one criteria only is used the comparisons are relatively easy; they become more complex when several criteria are considered. In most cases it is necessary to take into account several factors: productivity, manufacturing costs, capital requirements, import content, etc. If a project is superior in every aspect to all others then the selection is easy. In practice this is rarely the case; individual projects may be superior to others when matched against certain criteria, and at the same time be inferior as regards other criteria. In such (usually) complex assessment cases, methods have to be used with scoring (rating) systems in order to summarize findings for individual criteria. A significant number of such scoring techniques have been introduced and applied. The various methods have been documented e.g. in Reports published by EIRMA (European Industrial Research Management Association): "Methods for evaluation of R+D projects".

74. What follows is, to some extent, based on these, but the publications mentioned contain many more details. Naturally it is not proposed that such scientific methods should be employed in every case but it is advisable to bear them in mind when arriving at decisions on research priorities. Basically, answers should be sought to the following five questions before taking the decisions.

(i) **What is the importance of the proposed research subject in the country concerned?**

<u>Comment:</u>

The answer to this question has to be evaluated and balanced against the cost of the research. Projects with medium-level importance can be accepted if their cost is appropriately low. No projects should in general be accepted which have no relevance in the country.

(ii) **What are the chances for technical success?**

Comment:

Proposals for research projects should be rejected if sufficient probability for their technical success is lacking. This depends on the existence of adequately qualified personnel (researchers and assistants), availability of laboratory equipment, finances, raw materials and components and the intellectual (scientific) chance of success. For example, a proposal for a "perpetuum mobile" would have no technical chance of success.

(iii) **What is the likelihood for commercial success?**

Comment:

Only analysis of the market can provide the answer to this question. Is there a shortage of the products to be developed, or is there an abundant supply of similar products? What is the price situation: could the proposed new product be produced at less cost than its expected sale price?

(iv) **If the project is technically successful and would stand a good chance of commercial viability, what is the likelihood for its practical application?**

Comment:

In certain cases conditions for practical application are not present in the country. This situation may be due to the small demand, to lack of investment funds, to the absence of raw materials and/or components, or to the inadequate professional and industrial background to design and manufacture large scale production equipment. In such cases proposals for research should not be accepted.

(v) **Is research justified in comparison to imports of products or know-how?**

Comment:

Even if research promises success it has to be kept in mind that research potentials are usually restricted and other projects could perhaps yield higher benefits. It is possible that while research on project A could be successful, the same results could also be acquired through entering into a licensing agreement, whereas research on project B is indispensable because there is no good way to solve problem B without domestic research. In such situations project B has priority over project A (see the next section 2 of chapter V).

75. When comparing two or several research projects it is important not to limit the calculations to only take account of current conditions. Costs and prices may undergo marked changes in the future in different directions and at differing rates for individual alternatives. Therefore economic calculations should embrace a longer period, usually several years and future changes in

conditions should be estimated and introduced into the calculations. In such studies it may be necessary to use the discount technique and for this purpose the trend of interest rates during the period has to be estimated. In certain cases inflation rates also have to be assessed. Despite the uncertainties inherent in such estimates, it is important to endeavour to quantify conditions changing over time. For all this methodologies exist which can be used in the selection process of research projects.

76. A simple technique exists which aims at establishing priorities and which is used in management. This is the comparison of alternative pairs. Certain conditions must be present in order to use this technique successfully:

- A limited number of clearly formulated alternatives whose order of preference has to be defined;
- A forceful chairman to lead the exercise, restricting it to declarations of preference and not permitting break-ups by interim discussions;
- A limited number of participants (e.g. from five to fifteen) each of whom is knowledgeable in the field and at the same time has the ability to assess the alternatives from very different points of view (scientific, commercial, industrial, personnel, etc.).

77. Pairs are constituted from all possible alternatives and each participant declares which of the two he prefers. No explanations should be asked for or allowed. Let us demonstrate the technique by a simple illustration. The Chairman wants to ascertain the priority orders for the following six projects (four can be approved and two must be rejected):

(i) Establishing an experimental lime kiln with a new type of burner;

(ii) Technological tests of some tropical timber species not used up to the present time;

(iii) Introduction of solar energy to accelerate production cycles in precast concrete yards;

(iv) Installation of natural fibre roofing sheets on a demonstration building;

(v) Collecting and testing samples of various pozzolana in the country;

(vi) Preparation of a design manual for concrete blocks masonry to be used for new housing.

78. The number of Committee Members (together with the Chairman) is five. The first step is for each member to declare his preference comparing projects 1 and 2. The results are: one for project 1 and four for project 2. Then come the comparisons of projects 1 and 3, 1 and 4, 1 and 5, 1 and 6. In each case the Chairman (or Committee Secretary) notes for each project how many times it has been preferred as against the other project. Next come comparisons 2 and 3, 2 and 4, 2 and 5, 2 and 6; 3 and 4, 3 and 5, 3 and 6; 4 and 5, 4 and 6; and finally 5 and 6. In total there are 15 scorings for each individual participant and 75 for all of them. The final scoring may be e.g. that the individual projects have received the following preferences:

Project 1	17
Project 2	13
Project 3	5
Project 4	12
Project 5	18
Project 6	10
In total	75

If then two projects have to be rejected, these will be projects 3 and 6. Despite its obvious limitations, the technique is simple, compels rational assessments and in certain cases can be used successfully.

79. Appendix 3 cites certain pages of the EIRMA publications. In the following, some examples of checklists and scoring systems are given, based on EIRMA reports. It is worth noting that while this study uses the words "likelihood" and "chance" without interntional differentiation, in the EIRMA reports the word "credibility" is used in a somewhat narrower sense than "likelihood". The EIRMA documents include an explanatory note on this point.

> "The checklists given below have been chosen solely as representative examples to illustrate some of the different forms which they may take. Tables 1 to 4 are checklists covering all aspects of assessment of development projects from the point of view of a company or other institution including governmental ones that wants to decide on merits of proposals.
>
> One of the simplest is shown in Table 1. A set of twenty-one questions should be answered before launching the project. They are not divided into groups and no rating scale is defined.
>
> A more elaborate list is given in Table 2. It includes fifty-six items divided into six groups. Each factor is to be rated on a five-step qualitative scale. The rough assessment is to be made on the basis of the overall profile.

Table 3 shows a list of twenty-six items grouped in four categories. A four-step numerical scale is proposed for rating the factors. This example is particularly interesting because of the attempt to give an explicit definition of each step of the scales. No weights are given to the factors and, in fact, the author advocates a profile method of assessment and advises against the use of a numerical figure of merit. However, similar lists can be found which propose the use of a weighted sum merit index.

A very much simplified form of weighted checklists is given in Table 4. Table 5 is a checking and scaling list for technical success."

Table 1

Basic questions for initial proposal and subsequent reviews

1. What are the specific advantages accruing to the company from the development of this product idea?

2. What is the market for a product of this type?

3. What competitive products are now available?
   a. What specific advantages do they have?
   b. What specific disadvantages do they have?

4. What advantages can we incorporate in a new product?

5. Can we market this product easily, or will it require a new marketing approach such as a new sales force?

6. Will we be able to obtain a strong patent position covering this new idea?

7. What volume of sales can we expect?

8. What is the approximate market life of a product of this nature?

9. How much will it cost to develop this product?

10. How long will it take to develop this product?

11. What will be the method of approach to this development?
    a. What will be the sequence - such as exploratory, process or feasibility, etc.?
    b. What will be the time for each of these sequences?

12. What additional skills and personnel will be needed to develop and perfect this product?

13. What additional capital equipment will be needed to develop this product?

14. What are our estimates for the cost of manufacturing this product?

15. How much new manufacturing equipment will have to be acquired?

16. Can this equipment be used to manufacture other products as well?

17. Will our plant layout lend itself to the manufacturing of this product or do we have to acquire new facilities?

18. Are materials available to manufacture this product?

19. What are the consequences of stopping this product if we should learn after a year or two that the product is seemingly failing in the market place?

20. What is the total cost in processing, research development, tooling up, manufacturing, marketing, and advertising, and can we afford to take this on in relationship to other commitments already made?

21. What is our best estimate on return on investment and return on sales?

Source: J.H. Dessauer, Research Management, Vol. X, No.2, 1967.

Table 2

	Very Unfavourable	Unfavourable	Average	Favourable	Very Favourable
Financial					
Estimated annual sales of new product					
Time to reach estimated sales volume					
Ratio of annual sales: R&D costs					
Ratio of total costs: annual savings					
Return on sales					
Return on fixed capital					
Return on total investment					
R&D investment payout time					
Fixed capital investment payout time					
Profit in first year of production					
Research & Development					
Chance of technical success					
Technical novelty					
Potential know-how gain					
Relation to company's present know-how					
Time to develop product					
Manpower needed					
Lab and pilot plant equipment needed					
Competitive technical activity					
Patent status					
Production					
Process advantage					
Process versatility					
Process familiarity					
Compatibility with present operations					
Equipment availability					
Raw material availability					
By-product outlets					
Waste disposal					
Corrosion potential					
Hazard potential					
Freight position					

Table 2 (continued)

	Very Unfavourable	Unfavourable	Average	Favourable	Very Favourable
Marketing					
Product advantage					
Product competition					
Market size					
Market stability					
Market permanence					
Cyclical and seasonal demand					
Number of potential customers					
Market growth rate					
Company known in potential markets					
Compatibility with present products					
Suitable marketing organisation available					
Market development requirements					
Time required to become established in market					
Product variations and modifications required					
Difficulty of copying or substituting product					
Expert potential					
Possibility of a captive market					
Licensing potential					
Corporate position					
Relation to company objectives					
Required corporate size					
Advertising or prestige value					
Effect on purchasing other materials					
Effect on present customers					
Operating departments' desire or enthusiasm					
Other factors					

Source: KIEFER, CHEM. ENG. NEWS, 23rd March 1964, p. 95.

Table 3

CRITERIA	SCORE			
	-2	-1	+1	+2
Finacial Aspects				
Return on investment (before taxes)	< 20%	20% to 25%	25% to 30%	> 30%
Estimated annual sales	< $ 100,000	$ 100,000 - $ 1 million	$ 1 million to $ 5 million	> $ 5 million
New fixed capital payout time	> 5 years	3-5 years	2-3 years	< 2 years
Time to reach estimated sales volume	> 5 years	3-5 years	1-3 years	< 1 year
R&D Aspects				
Research investment payout time	> 3 years	2-3 years	1-2 years	< 1 year
Development investment payout time	> 3 years	2-3 years	1-2 years	< 1 year
Research know-how	No experience and no other applications	Partly new, with few other uses	Some experience or new vistas	Considerable experience or potential
Patent status	Unsettled patent situation	Open field and many licenses	Restricted to few licences	Patent or exclusive licence
Market development requirements	Extensive educational programme	Appreciable customer education	Moderate customer education	Ready customer acceptance
Promotional requirements	Extensive advertising & promotion	Appreciable requirements	Moderate requirements	Little promotion needed
Product competition	Several directly competitive products	Several competitive to some extent	One or two somewhat competitive	No competitive product
Product advantage	Higher price, equivalent quality	Competitive; or higher price and quality	Competitive price but quality advantage	Both price and quality advantage
Length of product file	Probably 1-3 years	Probably 3-5 years	Probably 5-10 years	Probably > 10 years
Cyclical and seasonal demand	Seasonal and subject to business cycle	Seasonal	Subject to business cycle	High stability
Production and Engineering Aspects				
Required corporate state	Any size	Most companies could compete	Average-size or larger companies	Only a very large company
Raw materials	Limited supply of suppliers	Limited available inside company	Readily available from outside company	Readily available from inside
Equipment	New plant needed	Mostly new equipment	Some new equipment	Recent idle plant usable
Process familiarity	New process; no other application	Partly new; few other cases	Familiar process - some other users	Routine process and prominence of other cases
Marketing and Product Aspects				
Similarity to present product lines	Entirely new type	Somewhat different	Only slightly different	Fits perfectly
Effect on present products	Will replace directly	Increase other sales	Slight effect	Increase other sales
Marketability to present customers	Entirely different customers	Some present customers	Mostly present custumers	All present customers
Number of potential customers	More than 500	Less than 5; or 1 to 500	5 to 10; or 50 to 100	10 to 50
Suitability of present sales force	Entire new group needed	Some additions necessary	Few additions necessary	No changes necessary
Market Stability	Volatile market	Unsteady	Fairly firm	Highly stable
Market trend	Increasing	Static, mature	Growing	New potential
Technical service	Extensive service required	Moderate	Slight	Negligible

Source: HARRIS, CHEM. ENG. NEWS, 17th April 1961, p. 110

Table 4

Field studied	
Chances of success:	
Remarkable	10
Low	2
Return on investments:	
From 0 to 0.1 year	20
From 0.41 to 0.8 year	11
From 3.21 to 6.4 years	2
Total profit in 10 years:	
$ 1,500,001 - 5,000,000	10
$ 120,001 - 420,000	6
$ 10,000 - 35,000	2
Other factors:	10
Good supply of raw materials	2-1
Low investment costs	2-1
Possibility of reducing licensing costs	2-1
Moderate research costs	2-1
Improvement of products	2-1
Total number of points possible	50

Table 5

Factors Affecting Credibility of Technical Success

FACTOR	SCALE OF RATING EACH FACTOR 1	2	3	4	5
Technical novelty					
. Demonstration of technical principles	Should work but not proven	Principle can be proved on paper, from basic data	Component features demonstrated and basic knowledge complete	Partly full scale/ wholly pilot scale	Principles already embodied in full scale operations, in house or elsewhere
. Technology and know-how needed for full scale production	Needs advance in basic knowledge	Major features need developing	Minor features need developing	Very close to previously commercialised projects	Completely known
. Competitive research	Many competitors have researched in related fields and failed	A few competitors have researched in related fields and failed	No known research in related fields	A few competitors have researched in related fields and succeeded	Many competitors have researched in related fields and succeeded
Specifications					
. Technical specifications to meet performance requirements during project/ process life	Very restrictive limitations	Limitations, hard to attain	Some limitations should be attainable	Some limitations easy to attain	No restrictive limitations
. Control over specifications	Monopoly buyer with own quality control	Widespread e.g. government, trade association, manufacturer	Mostly dictated by competition	Most in-house, some external	All in-house
Freedom of approach					
. Alternative approaches possible	Only one route possible	Only one probable alternative	More than one probable alternative	One sound alternative	Several alternative routes
Project plan levels 1)					
. Scope for forward planning	No plan	Probable finishing date + rough overall cost	Intermediate review + finishing dates + rough stage costs	Milestone plan submitted e.g. Gantt Chart	Full resource/time plan submitted e.g. Pert
Resources 2)					
. Project equipment	All equipment needs development	Some equipment needs development	Most equipment must be purchased or hired	Most equipment available balance can be purchased or hired	All equipment available
. Source of finance	Subscription e.g. research bodies or variable uncontrollable incomes	(External) fixed contract price	Part internal, part external (e.g. collaborative research)	Self-financed fixed limit	Self-financed no limit
. Amount of finance available 3)	Limited to minimum cost approach		Limited to optimum cost approach(es)		No effective limit
. Information services	No organised library and research divorced from production and marketing		Library facilities + normal communications between research production and marketing		Complete company database available
Personnel resources					
. In-house experience available inthe project field	None	Some individual experience	Some research activity in past	Part of current company activities	Current authorities on subject
. Quality of staff available compared with levels of skills required	Unknown	-	Competent but not experienced	-	Experienced and competent
. Motivation of research groups to success of project	Reluctant support (Not invented here factor)	-	Indifferent	-	Determined to success
. Quantity of staff available	None - all staff must be recruited	Insufficient staff; some must be recruited	Inexperienced staff available to form team	Experienced staff available to form team	Experienced team available immediately

1) Level of planning obviously interacts with size of project
2) "Needs development" infers that the equipment is novel and not available for purchase/hire; hence one has the possibility that one can fail to develop it in time
3) Cost specification is a part of the technical target

80. Decisions on research priorities comprise decisions as to whether to undertake research at all or whether importing or buying know-how instead would not be more advantageous. Countries (and research institutes) are usually not in the position to do research on all the problems faced by the country. The selection process must not only take into account which research projects could be carried out with the highest chance of success, but should also come up with the answer to the question: which problems could be solved on favourable terms through buying licences giving access to the desired know-how.

81. Usually if the decision is to avoid independent research, some research on a much smaller scale will still be required into the method of adapting the process or product to domestic conditions and for developing further the technical level acquired. It can prove to be a major error to buy know-how and to freeze production at the technical level introduced on this basis: this would merely perpetuate backwardness. Along with purchasing advanced technologies, domestic research should lose no time in absorbing its technical content and in setting in motion work on future developments.

82. Domestic research can be regarded as being in competition with purchases of know-how from abroad only if the same funds can freely be channelled either into financing research or into buying foreign know-how. If the two types of funding are separate then only an institution or individual having power of decision over both can make an effective comparison between the two alternatives: i.e. research versus purchase of know-how.

83. It is not sufficient to evaluate research projects individually; it is necessary to have an overall strategy on the allocation of research resources. One of the components of such a strategy is a personnel policy to be integrated with the overall particular requirements of the country (region, etc.). The personnel policy should aim at reconciling a certain degree of stability (which is useful in research and development), with a limited amount of mobility (which ensures some measure of turnover in staff in order to maintain efficiency). The allocation of financial resources must be justified in the light of objectives expressed by the building materials industries.

2. Strengthening of scientific and technological capabilities

84. It would be illusory to discuss research priorities if sufficient scientific and technological capabilities were not available. It is, therefore, a top priority task to strengthen such scientific and technological capabilities.

85. This requirement has been investigated on many occasions, among others by UNIDO. The Fourth General Conference of UNIDO in Vienna (2 to 18 August 1984) studied progress and tasks in this field. Part of the principal statements and recommendations of the issue and background paper on the subject are quoted and summarized below and they may be presumed to be fully valid for the building materials industry.

> "The gap between developed and developing countries in technological development makes them unequal partners in international economic relations. Costs and conditions of the transfer of technology are often onerous. An inappropriate choice of technology is not only wasteful but could distort the pattern of industrial, economic and social development. Strengthening technological capabilities is a prerequisite both for the acquisition and application of imported technology and the development of endogenous technology. The way technology is applied critically affects the development process.
>
> Most developing countries show a considerable awareness of the importance of technology for development, but little attention is paid to the selection of technology at the micro and macro levels. At the micro or enterprise level, the non-availability of processed information and the lack of evaluating capacity make selection difficult. Moreover, Governments intervene relatively rarely through industrial or import policies or decisions on major projects. Selection from among all available options is further hampered by such factors as foreign investment and the availability of credit facilities from one or other country or supplier of equipment. The absence or non-association of indigenous consultancy services and multidisciplinary teams trained in technology evaluation creates a major bottleneck. The redesign of existing industrial and technological information centres and the promotion of consultancy capabilities should therefore be viewed not so much as general elements of infrastructure but rather as key factors in a better selection of technology for the country. The present status of technology selection and the difficulties inherent in the process would argue for recognition of its importance in a wide range of government policies and a conscious exercise of selection, at least in major and strategic projects.
>
> At the macro level, an assessment or at least awareness of the impact of specific technologies on society and their contribution to particular development needs is essential and needs to be reflected in conscious decisions on the "technology mix" to be adopted. The absence of an overall approach to the selection of technology has had implications for the pattern of industrialization and employment generation in developing countries.

Most developing countries have established single-purpose and multi-purpose research institutions of various types. Institutions for scientific education and basic research have also been established. Universities in several countries have started to play a role in the development of endogenous technology. Some countries are also planning to establish science parks. The Governments of several developing countries are promoting endogenous technology through a variety of incentives such as tax concessions, liberalized licensing procedures, financial incentives and special funds to support endogenous creativity and innovation. In some countries, patent laws have been changed to eliminate restrictions on the development or use of technology. Generally speaking, most of the research and development is carried out in government-run institutes, although in a few developing countries it has been introduced at the enterprise or industry level. A few countries, too, insist on local research and development as a condition for the import of technology. Institutions for standardization, testing and quality control, which form part of the infrastructure for technology development, have also been established in a number of countries.

In regard to technological advances in general, there is a need for every developing country to take both short-term and long-term action. Short-term action should include forecasting and assessment of the socio-economic impact of technological advances, careful choice of technologies and equipment to be imported, and a strengthening of the negotiating capability for their acquisition. Such action is urgently needed so that irreversible distortion of the industrial and technological infrastructure is not created from the beginning. Long-term action should aim at strengthening technological capabilities and would require imaginative attempts to apply the technological advances to improve the standard of living and upgrade the general technological level of the population. Such action should be strategic, involving, wherever necessary, structural changes in the industrial and economic development of the country in the light of its development objectives.

Since conditions in developing countries vary and uniform prescriptions are not possible, countries may have to follow selective and differential approaches and each country may have to decide for itself the point of entry, degree of penetration, source of inputs, linkages, vehicles of implementation, etc. However, in an interdependent world economy, all countries need to have technological awareness. Whatever the level of development, there is a need for a minimum level of competence to deal with emerging technologies within realistic time horizons and for establishing effective national groups for this purpose.

The social implications of the introduction of high technology have to be carefully considered by each country in its own socio-economic context. High technology options have to be placed within the range of available technology options from the traditional to the advanced. Developing countries may have to adopt and manage a technological pluralism optimal for the objectives, problems and limitations of each country.

For the 1980s, a framework for national action is needed that will integrate the responses to technological advances with existing technology policies or efforts and at the same time make up the deficiencies of the latter. The building up of such a framework should be regarded as one of the major responsibilities of Governments in developing countries in the 1980s.

What are the possible elements for a framework of action? For drawing up such a framework a supporting mechanism may be necessary that could be, as minimum, an interdisciplinary unit of 6-12 professionals close to a high policy-making level. Expertise has to be drawn from economists, scientists, technologists, social scientists, systems analysts, bankers, industrialists, management experts, etc.

Considerations in building up the framework include the upgrading of endogenous technologies; the integration of technology policies and actions with the industrial sectors; human resource development; the structuring and management of demand; and the rationalization and development of technological institutions having regard to their relevance, effectiveness and interaction.

A new line of action for the developing countries would be to establish appropriate mechanisms individually or collectively to forecast, monitor and assess technological trends and their implications for economic and social development and to formulate, develop and implement policies to maximize the potential benefit of the new technologies and avoid their adverse consequences. Such an assessment should be an important input to industrial, technological and general development planning and the formulation of industrial, technological, commercial and fiscal policies, and in decision-making on industrial projects. Such information should also be used to see how far the new technologies could revitalize the development process in critical sectors.

The need for greater allocation of resources for science and technology in developing countries assumes greater relevance on account of the emerging technological advances. About a decade ago it was suggested that developing countries should allocate at least 1 per cent of their GNP to research and development. It is now proposed that they aim at devoting 1.5 per cent of their GNP for research and development by 1990, and reach a minimum level of 2 per cent by 2000.

86. While the above guidelines are of a general character and should not be considered as directly specific for the building materials industry, they are nevertheless fully valid for this industrial sector.

3. Strengthening building materials research institutions

87. In Chapter II a general description has been given of research in the building materials industries. In Section 2 of Chapter V a general policy has been outlined for strengthening the scientific and technological capabilities for industrial development in developing countries. In this Section the focus is put on specific problems of building materials research institutions.

88. Contrary to many other industrial sub-sectors in which research is carried out by private or public industry itself, in the building materials and construction industries there usually exist public research institutes even in the most liberal developed countries e.g. in the USA and Canada. The reason for this lies in the fragmented structural character of the industry. In all countries there can be found a great number of small contractors and building materials manufacturers who are confronted with very similar technical problems. Individually, these small contractors and manufacturers are not in the position to organize research to solve their problems; this has to be carried out by central research institutes. These centralized institutes can be organized by an association of contractors and manufacturers; such institutes exist in the United Kingdom (CIRIA, TRADA, BSRIA, etc.), France (CEBTP), Belgium (CSTC) and other countries. The centralized research institutes therefore can be public or semi-public. In countries with central planning economies, research institutes are usually state-owned organizations.

89. Major cement, glass, and brick companies can afford to organize research within their own organization. As a general guideline it can be stated that whatever research can be executed by the industry itself, this should be done and the state should intervene in those areas only where no effective activity by industry can be anticipated. Again, as a general guideline, it can be stated that governmental and industrial research institutions should receive adequate support although their size may have to be adjusted periodically in the light of requirements.

90. Adequate financing of research should be ensured; industry should pay for all research which directly serves its interests and government should fund activities only where the interest of industry is too indirect or remote. Research at universities should be supported and many countries can point to good experience gained with research institutes linked in one way or another to universities.

91. In many countries a combination of building materials, and building research within the same institute has proved to be an efficient solution and such a scheme merits continuation in the future in suitable cases. If the

scale of research activities calls for high specialization in different fields, then different research institutes can be recommended. Research on anorganic building materials (cement, concrete, bricks, etc.) and research on timber products can be organized in such cases, in two different research institutes.

92. Research priorities can be selected only if there exists an overall strategic development policy for the building materials industry. Only after the quantitative and qualitative targets to be reached by the building materials industries have been defined, is it possible to select research priorities. Assessments will be made regarding the inherent development potentials of the existing building materials industries and the gaps between requirements and potentials have to be closed by imports and/or capital investments and by research. Research programming therefore is dependent on economic development plans; these in turn also depend on research.

93. Development policies for the building materials industry depend on many factors among which research in only one. Research by itself, if successful, is not sufficient for the formulation of economic development policies; on the other hand, adequate mechanisms should exist so that research can also make its contribution through its opinions to such policy-making processes. Development of research institutions requires well trained professional researchers. Developing countries have made substantial progress in education and training; obviously this a continuous process and should receive adequate support in the future.

4. Information, documentation, engineering, consultancy services

94. It has been repeatedly stated that the cases when building materials research in developing countries has to have the form of basic research are rare; most frequently it is applied research, development or engineering adaptation of existing knowledge to domestic/local conditions. For this reason alone the establishment and operation of documentation centres and information and engineering consultancy services are of great importance. Another important factor is the size of the country (area and population), its financial resources and the characteristics of the domestic building materials and building industries. Many countries are too small and lack adequate

resources for the creation and maintenance of large and complex research institutes. They have to rely on foreign research in a great number of fields, but in so doing have to have "gates" through which this knowledge from abroad can pass, be adapted and applied. Building research institutes and their documentation services undertake such tasks.

95. Research on building materials must comprise the transfer of acquired knowledge and the application of research results. Governments and research institutions have to accord top priority to devising adequate methods for implementing this. Demonstration projects, exhibitions, training courses, contracts and co-operation with industry, financial and moral support, promotion by mass media and professional literature, posters, audio-visual aids, slide shows, films, brochures and leaflets: these are just some of the plethora of tools that can be utilized to achieve the objective of practical application. Some countries, i.e. India, have good experiences in this work, but in others, i.e. some in Africa, experiences are rather adverse: people tend to view with suspicion, innovations coming from the outside world and endeavours to apply research results frequently end in failure. Such negative experiences have to be studied carefully so as to find out what needs to be changed to achieve applications in practice.

5. Regulations, standardization

96. In several developing countries, regulatory activites have not been long in existence. In some countries the standards of foreign countries (BSI, AFNOR, DIN, ANSI) are accepted simultaneously with the country of origin.

97. For development of the building materials industry it is necessary that each country should have its own standards and building codes. This regulatory work can be effectively prepared by research institutes (pre-standardization, pre-regulatory work) and for research institutions this has a high priority. Within the framework of standardization and regulations (codes, by-laws) three errors have to be avoided:

(i) That the standards and codes are written without consideration to standards and codes already existing in other countries and international organizations (ISO). This could also hamper import-export due to the discrepancies in standards and codes;

(ii) That standards and codes are simply copied from existing standards without paying due regard to domestic circumstances;

(iii) That the levels of requirements and performances are copied from standards abroad, again without adequate consideration of domestic conditions. The result of this mistake is either to make construction unnecessarily more expensive or that design and execution of buildings will not be based on these standards but will comply with domestic (local) realities.

6. International co-operation

98. International co-operation yields benefits for research institutes in developed as well as in developing countries. In the latter, however, international co-operation has certain specific features. Large and small, rich and poor research institutions, all contribute to the enhancement of the pool of human knowledge. Despite this it is obvious that new, small and badly equipped institutes will take some time before they produce substantial results. The total contribution of small new institutes can be quite considerable and will of course gradually grow.

99. Some large developing countries, such as China, India, Brazil, etc., will be able to finance building materials research on a major scale and the share of developing countries in global building materials research will increase correspondingly over a period of time. In regions with a number of small- or medium-size countries, subregional research and/or documentation centres can increase efficiency.

100. Co-operation between research institutions can be organized on a bilateral and multilateral basis; in the latter case this can be subregional, regional or global. The various forms do not compete with each other but rather are complementary. International co-operation is promoted by United Nations Organizations (UNIDO, UNESCO, UNCHS, UN Regional Economic Commissions) and intergovernmental organizations.

101. It is important that research institutes themselves be able to co-operate on their own level. This again can be on bilateral or multilateral levels. Participation in the work of international non-governmental professional (NGO) organizations is of extreme importance for research institutes and their researchers. Such participation provides them with a feedback of experiences

from abroad and this can greatly enhance the efficiency of their own research. CIB and RILEM are the two most important and complex organizations in this field; some others (in concrete, timber, etc.) have a more limited scope but exactly for this reason, may be important for researchers in such fields.

102. Governments should ensure that building materials research institutes and their researchers should be able to participate on an adequate level in international co-operation. International organizations (ISO, CIB, RILEM, CEB, etc.) should establish funds which serve the purpose of assisting building materials research institutions and their researchers to participate in international co-operation (through travel grants, fellowships, the provision of free copies of literature, financing other expenditures, etc.)

VI. SUMMARY - CONCLUSIONS

103. It can be foreseen with a sufficient degree of certainty that the needs for building materials will grow in developing countries during the coming decades. Efforts should be made that as high a percentage as possible of the population should continue to make use of locally available materials although the growth of the population and the inevitable process of urbanization will enlarge demand substantially. Local resources are dwindling in some areas and a better use of those available will be necessary. More and more families will have to be supplied with building materials. The development of industry, towns and villages will increase the demand for building materials.

104. No country can rely to an excessive extent on imports of building materials. Each country has certain types of domestic resources which can be used for the production of building materials. This production must be developed both in the informal (non-monetary) as in the formal (monetary) subsectors. Private and public capital investments must be made to achieve higher levels in the production of building materials.

105. A major contributing factor to this process could be research and technical development. Research for the building and building materials industries must receive sufficient attention both on behalf of government and the private sectors. Research must be suitably organized according to the characteristics (size, etc.) of the country. Research becomes efficient if

its topics are adequately selected and priorities should be defined in order to achieve optimal efficiency.

106. The selection of research priorities should take into consideration certain general trends (increasing durability, etc.) as well as domestic (local) conditions. Investigation should be directed towards determining in which areas research could yield the highest benefits and in which areas imports or licensing (purchase of know-how) could be the more effective option.

107. Research in the building and building materials industries should be carried out in practically all countries but this should not result in trends for autarchy in research. Efficiency of research can be greatly improved by international co-operation; this can take many forms, and appropriate use should be made of the different possibilities.

APPENDICES

Appendix 1: Selective list of 130 institutions whose scope is predominantly national as opposed to international and which are active in building materials research

Appendix 2: Selective bibliography

Appendix 3: Selected pages abstracted from volumes on "Methods for the Evaluation of R&D Projects" published by the European Industrial Research Management Association

Appendix I

Selective list of 130 institutions whose scope is predominantly national as opposed to international, which are active in building materials research

The number of institutions carrying out research on building materials is great, in fact it runs into several hundreds. This is a selective list restricted to about 130 institutions. Only institutions are listed which have research activities and whose operations essentially cover the country of domicile rather than being international in scale. For further institutions reference is made to the following publications:

1. UNIDO Guides to Information Sources (published by UN/UNIDO, New York, as a series of brochures). Those most relevant to building materials are:
   No. 2 - Cement and Concrete Industry
   No. 9 - Building Boards from Wood and other Fibrous Materials
   No. 16 - Glass Industry
   No. 17 - Ceramics Industry

   Quality control is closely related to research; this is dealt with by:
   No. 6 - Industrial Quality Control

2. Directory of Building Research, Information and Development Organizations; edited and published by the International Council for Building Research, Studies and Documentation, CIB; the 4th edition (published in 1979) contains detailed information on over six hundred institutes. The fifth edition will be published by the end of 1984.

3. The World of Learning, (Europe Publications Ltd., London); this is a Directory on Universities and scientific organizations.

AFRICA

Algeria	Institut National d'Etudes et de Recherches en Bâtiment (INERBA), Algiers (recently reorganized into CNERIB)
Benin	Centre National d'Essais et de Recherches des Travaux Publics, Cotonou

Cameroun	Ecole Polytechnique, Yaoundé
Congo	Laboratoire Nationale d'Essais et des Travaux Publics, Brazzaville
Egypt	General Organization for Housing, Building and Planning Research, Cairo
Ethiopia	Addis Ababa University, Addis Ababa
Ghana	. Building and Road Research Institute, Kumasi; . Forest Products Research Institute, Kumasi
Ivory Coast	Laboratoire du Bâtiment et des Travaux Publics, Abidjan
Kenya	. Building Research Centre, Nairobi; . University of Nairobi, Nairobi
Libya	University of Al-Fateh, Tripoli
Morocco	Laboratoire Public d'Essais et d'Etudes, Rabat
Nigeria	. Forestry Research Institute, Ibadan . University of Lagos, Lagos . University of Ife, Ile-Ife . Ahmadu Bello University, Zaria . College of Technology, Owerri
Somalia	National Somali University, Mogadishu
Sudan	Building and Road Research Institute, Khartoum
Tanzania	. National Housing and Building Research Unit, Dar-es-Salam . University of Dar-es-Salam, Dar-es-Salam
Togo	Centre de la Construction et du Logement, Lomé
Tunisia	Ecole Nationale d'Ingénieurs, Tunis
Uganda	Technical College, Kampala

Zaire	University of Lubumbashi, Lubumbashi
Zambia	Forest Products Research Division, Kitwe

ASIA
(including the Pacific region)

Bangladesh	Housing and Building Research Institute, Dacca
China	. China Building Technology Development Centre, Beijing . Shanghai Research Institute of Building Sciences, Shanghai . Research Institute of Building Materials, Beijing . Beijing Institute of Glass and Fine Ceramics, Beijing . Institute of Information and Standardization for Building Materials, Beijing
India	. Central Building Research Institute, Roorkee . National Buildings Organisation, New Delhi . The Structural Engineering Research Centre, Madras . Cement Research Institute of India, New Delhi . Indian Institute of Technology, Kanpur
Indonesia	. Directorate of Building Research & UN Regional Centre for Research on Human Settlements, Bandung . Centre for Research & Development, Jakarta . Ceramic Research and Development Institute, Bandung
Iran	Building and Housing Research Centre, Teheran
Iraq	National Center for Construction Laboratories, Baghdad
Israel	Technion, Israel Institute of Technology; Building Research Station, Haifa
Japan	Central Research Laboratory of Onoda Cement Co. Ltd., Tokyo
Jordan	. Building Research Center, Amman . Yarmouk University, Irbid

Korea	. Technical Development Office, Seoul . Korea Institute for Construction Technology, Seoul
Malaysia	University Pertanian Malaysia Serdang, Selangor
New Zealand	Forest Research Institute, Rotorua
Pakistan	. Building Research Station, Karachi . Building Research Station, Lahore
Philippines	. Cement Institute of the Philippines, Manila . Forest Products Research and Development Institute, Laguna
Sri Lanka	Building Research Institute, Colombo
Thailand	. Thailand Institute of Scientific and Technological Research, Bangkok . Asian Institute of Technology, Bangkok
Turkey	. Building Research Institute, Ankara . Technical University, Istanbul . Middle East Technical University, Ankara

AMERICAS
(including the Caribbean region)

Argentina	. Instituto del Cemento Portland Argentino, Buenos Aires . Instituto Nacional de Tecnología Industrial, Buenos Aires
Brazil	. Instituto de Pesquisas Technológicas do Estado, São Paulo . Fundação Centro Tecnológico de Minas Gerais, Minas Gerais
Chile	Instituto de Investigaciones y Ensayos de Materiales, Santiago
Colombia	Instituto Colombiano de Productores de Cemento, Bogotá
Cuba	Centro Técnico de la Construcción y los Materiales, Havana
Ecuador	Instituto de Investigaciones Tecnológicas, Quito

Guatemala	Centro de Investigaciones de Ingeniería, Guatemala
Jamaica	Building Research Institute, Kingston
Mexico	Instituto Mexicano del Cemento y del Concreto, México D.F.
Panama	Facultad de Arquitectura de la Universidad de Panama, Panama
Paraguay	Instituto Paraguayo del Cemento, Asunción
United States of America	. National Bureau of Standards, Center for Building Technology, Washington D.C. . Martin Marietta Laboratories, Baltimore, Maryland . University of Washington, Seattle, Washington . Purdue University, Lafayette, Indiana . Northwestern University, Evanston, Illinois . University of Illinois, Champaign, Illinois . Massachusetts Institute of Technology, Cambridge, Massachusetts . University of California, Berkeley, California . Glass Research Center, Pittsburgh, Pennsylvania
Uruguay	Instituto Técnico de Desarrollo Integrada, Montevidea
Venezuela	. Instituto Nacional de la Vivienda, Caracas . Asociación Venezolana de Productores de Cemento, Caracas

EUROPE

Belgium	. Post-Graduate Centre for Human Settlements, Leuven . University of Mons, Mons . Centre Technique et Scientifique de l'Industrie Belge du Verre, Brussels
Bulgaria	Research and Construction Institute for Glass and Ceramics, Sofia
Czechoslovakia	. Research Institute of Building Materials, Brno . Research Institute for Glass, Prague . Research Institute for Ceramics, Plzeň

France	. Centre d'Etude et de Recherche de l'Industrie des Liants Hydrauliques (CERILH), Paris . Centre Scientifique et Technique du Bâtiment (CSTB), Paris . Centre Expérimental de Recherches et d'Etudes du Bâtiment et des Travaux Publics (CEBTP), Paris Saint-Rémy-les-Chevreuses . Groupe de Recherche et d'Echanges Technologiques (GRET), Paris . REXCOOP, Paris . Laboratoires de Recherches LaFarge, Trappes . Centre Techniques des Tuiles et Briques, Paris . Centre Technique du Bois et de l'Ameublement (CTB), Paris . Centre d'Etude et de Recherches de l'Industrie du Béton Manufacturé (CERIB), Epernon
German Democratic Republic	. Zementinstitut der VVB Zement und Beton, Dessau . Institut für Baustoffe, Berlin . Institut für Bau- und Grobkeramik, Berlin
Germany, Federal Republic of	. Forschungsinstitut der Deutschen Zementindustrie, Düsseldorf . German Agency for Technical Cooperation (GTZ), Eschborn . Institute of International Studies in Housing, Planning and Building, Darmstadt . Technical University of Braunschweig, Braunschweig . Technical University of Stuttgart, Stuttgart . Technical University of Karlsruhe, Karlsruhe
Hungary	Central Research and Design Institute for the Silicate Industry (SZIKKTI), Budapest
Italy	Politecnico di Milano, Milano
Netherlands	. TNO Institute for Building Materials and Building Structures, Rijswijk . University of Technology, Eindhoven . University of Technology, Delft
Norway	. Norwegian Building Research Institute, Oslo-Blindern . Cement and Concrete Research Institute, Trondheim

Poland	. Building and bonding materials industry research institute, Opole . Institute of the glass and ceramic industry, Warsaw
Sweden	. Swedish Cement and Concrete Research Institute, Stockholm . Royal Institute of Technology, Stockholm . Lund University, Lund
Switzerland	Swiss Center for Appropriate Technology (SKAT), Saint-Gall
Union of Soviet Socialist Republics	. All-Union State Scientific Research Institute for the Cement Industry, Leningrad . Scientific Research Institute of Rock and Silicates, Yerevan
United Kingdom	. Building Research Establishment (BRE), Garston . Cement and Concrete Association, Wexham Springs . Timber Research and Development Association (TRADA) High Wycombe, Buckinghamshire . British Ceramic Research Association, Stoke-on-Trent

Appendix 2

Selective bibliography

Bibliographies comprising several hundred titles exist. This particular bibliography is confined to certain recent publications in the form of anthologies and to those publications only which have been directly used for preparing this paper and the study of which can be strongly recommended to those whose task it is to define research priorities in the building materials industries.

- The UNIDO Guides to Information Sources (see **Appendix 1) feature data on information sources in the building materials industries.**

- Economical housing in developing countries: materials, construction techniques, components (Proceedings of an international conference in Paris, 25-27 January 1983; Presses de l'Ecole Nationale des Ponts et Chaussées, 344 pages).

- Appropriate Building Materials for Low Cost Housing in the African Region (Proceedings of a CIB-RILEM Symposium in Nairobi, November 1983; E & F.N. Spon, London 1983, 524 pages).

- Methods for the Evaluation of R&D Projects
  - Volume I - Project Evaluation and Review (EIRMA, Paris 1970, 96 pages)
  - Volume II - Estimation of Cash Flow Curves and Associated Parameters under Uncertainty (EIRMA, Paris 1973, 56 pages)
  - Volume III - Organisation of the R&D Project Evaluation Function (EIRMA, Paris 1973, 30 pages)
  - Volume IV - Choice of Selection Criteria in Relation to Company Objectives (EIRMA, Paris 1973, 50 pages)
  - Volume V - Credibility of Technical Success, its Definition, Estimation and Utilisation (EIRMA, Paris 1973, 36 pages)
  - Volume VI - Portfolio Selection in Research and Development (EIRMA, Paris 1976, 92 pages)
  - Volume VII - Credibility of Commercial Success: Its Definition, Estimation and Integration with Credibility of Technical Success (EIRMA, Paris)

- The Allocation of Research Resources (European Industrial Research Management Association = EIRMA, Paris 1975, 72 pages)

- Measurement, Accounting and Taxation for Research and Development. Volume and Support of Construction R&D (by Prof. Dr. Gy. Sebestyén, CIB; Rotterdam 1983, 29 pages)

- Hannah Schreckenbach (+ Jackson G.K. Abankwa): Construction Technology for a Tropical Developing Country (Published by GTZ, the German Agency for Technical Cooperation, 338 pages)

- First World-Wide Study of the Wood and Wood Processing Industries (UNIDO Sectoral Studies Series No. 2, UNIDO/IS.398, 1983, 195 pages)

- Strengthening of scientific and technological capacities for industrial development in developing countries (UNIDO issue and background paper for the Fourth General Conference of UNIDO, 2-18 August 1984, 10+45 pages)

- Promoting the use of wood in construction (UNIDO IC/WG.395/2, by Mr. M. Tejada; 25 May 1983, 50 pages)

- G.C. Mathur: Use of Local Timber for Low-Cost Housing and Building. Problems and Potentials (CIB Working Paper, 1984, 17 pages)

- Low-Cost & Energy Saving Construction Materials (Ed.: K. Ghavamy and H.Y. Fang; ENVO Publishing Co., 1984, 640 pages)

- New Horizons in Construction Materials (Ed.: H.Y. Fang; ENVO Publishing Co.; 2 volumes 682+152 pages; 1984)

- Report of the Meeting of Directors of African Building and Building Materials Research Institutes (UN Economic Commission for Africa, 1980; Doc. E/CN.14/HUS/140)

- Anil Agarwal: Mud, mud (IIED - Earthscan Publication, 1981; 100 pages)

- R. Stulz: Appropriate Building Materials (SKAT publication, St. Gallen, Switzerland, 1981; 325 pages)

- Brickmaking in developing countries (BRE Report, 1979, 90 pages)

- J. Keddie, W. Cleghorn: Brick manufacture in developing countries (Scottish Academic Press Ltd., 1980; 134 pages)

- H.E. Gram, H. Persson, Å. Skarendahl: Natural Fibre Concrete (SAREC Report, 1984; 139 pages)

- J.J.A Janssen: Bamboo in building structures (University of Eindhoven, 1981; 235 pages)

Appendix 3

Selected pages abstracted from Volumes on "Methods for the Evaluation of R&D Projects" published by the European Industrial Research Management Association EIRMA

INTRODUCTION

When a proposal for a research and development project is evaluated three major questions are raised:

a. How much will it cost?
b. How valuable are the results of a successful development?
c. How likely is it that the project will succeed?

Many methods have been developed and tested for quantifying the answers to (a) and (b), and for combining the cost and incentive aspects of an R&D project into a form in which different projects may be compared, and the most promising ones selected.*) However, the answer to question (c) is often treated in a highly subjective manner, for example by asking the project proposer to "estimate the probability of success", or by the project evaluator "backing his hunches", based on previous experience of similar project proposals. In attempting to answer question (c) in an objective manner, two major areas of uncertainty must be considered:

1. Will the project achieve the level of success which is necessary to support commercialisation, and will this level of technical success be achieved within the cost and time assumed in the project proposal for completion of R&D work?
2. Will the commercialisation of the anticipated technical results of this proposal yield the benefits cited as justification for the R&D expenditure, and will these benefits be obtained within the cost and time assumed in the project proposal for reaching the necessary level of commercial activity?

So far as the project proposer is concerned, the answers to each of these questions must be "yes to the best of his knowledge", otherwise he would not have put forward his proposal in its present form. What the project evaluator must do to answer question (c) is to estimate the likelihood that the project proposer is correct in his forecasts.

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*) EIRMA Working Group No.VI, Volume II: "Determination of Cash-Flow Curves and Associated Parameters under Uncertainty".

The term that has been selected to represent the result of this estimation is Credibility of Success, and it is clear from the differing questions outlined above in (1) and (2), that Credibility of Success can be subdivided into:

- Credibility of Technical Success
- Credibility of Commercial Success

SUMMARY

Credibility of Success of an R&D proposal consists op two major components:

- Credibility of Technical Success
- Credibility of Commercial Success

Volume V contains a definition of Credibility of Technical Success, and sets out a recommended method for its estimation, expression and utilisation. Credibility of Technical Success is defined as:

> "The degree of confidence that the project evaluator has in the fact that technical success will be achieved".

It is necessary to carefully establish the areas of work covered by the term technical success, and to define the criteria for success as quantitatively as possible. Bearing this in mind, the technical success of an R&D project is defined as:

> "The obtaining of a predetermined result, at a predetermined cost, and within a predetermined time".

Credibility of Success is a term which is not readily applied to projects of an exploratory or fundamental research nature. It is most applicable to those projects for which a clear commercial application is in sight.

Credibility of Technical Success is estimated by rating the effects of all those factors which contribute towards the technical success or failure of a project. Procedures for estimating, expressing and utilising Credibility of Technical Success are illustrated in the Appendix by use of a hypothetical example. The recommended procedure is:

- Individual factors affecting Credibility of Technical Success should be rated against a descriptive scale.
- The descriptive ratings for each factor should be developed by each company to match its own specific requirements.
- Factors should be given a numerical rating against a scale rising from an unfavourable rating of 1 to some higher value. A scale of 1 to 5 is recommended.

- The numerical ratings for each factor should be expressed in a graphical form. Predetermined values for each rating should be shown on the graph, to indicate when any factor falls to a level which is considered unacceptable.
- The graphical expression of the ratings of factors should be studied to identify factors which fall below acceptable levels. Any factors which are doubtful should be re-examined carefully to determine whether further preparation by the project proposer, or rearrangement of company resources, can improve the ratings to an acceptable level. Following this the total rating should be considered and a judgmental decision should be made on the technical viability of the proposal.
- Provided the proposal is acceptable on the basis of an examination of the graphical presentation of ratings, the overall value for Credibility of Success should be used as a measure of the likelihood that the project will succeed, when comparing projects.
- Direct use of the numerical value for Credibility of Technical Success in calculation of some overall Selection Index is not recommended unless considerable caution is exercised. It is preferred that the numerical value of Credibility of Technical Success is used only to enable comparisons between competing projects in terms of the likelihood that each will succeed technically.

Further uses for the information generated in determining Credibility of Technical Success are in project progress reviews, and in gaining an overview of research activities and resource allocation. These further applications have not yet been studied fully.

SURVEY OF EXISTING METHODS

General

Abundant literature exists concerning possible methods for the evaluation of R&D projects and, in particular, for project selection and periodic review. Attention in this report has been restricted essentially to methods of potential interest to individual industrial firms but, even so, it has been found impracticable to examine the available literature exhaustively. A short selection of references, especially to review articles, is given in the bibliography. In this chapter, an attempt has been made to give a brief general account of the salient features of various proposed methods together with a critical discussion, more particularly of the types of selection criteria utilised.

Broadly speaking, the methods described in the literature fall into two general categories:

- Scoring methods in which a subjective rating is assigned to each of the factors considered relevant to the evaluation. These ratings are very often combined in the form of a weighted sum or product to give an overall figure of merit.
- Profitability methods in which a more or less specific "utility" function, designed to give a measure of the financial attractiveness of the project, is constructed.

Scoring methods

The essential basis of all scoring methods is a more or less exhaustive checklist of the various factors which are considered necessary to be taken into account for project evaluation.
An almost infinite variety of such checklists is to be found in the literature. They range from extemely short lists containing no more than half a dozen or so factors to very lengthy ones which may comprise fifty or more factors. In the case of such long lists, the related individual factors are often grouped into classes or families of factors such as technical, manufacturing, marketing, financial and so on. In many cases, however, such groupings appear to be relatively arbitrary.

Factor Ratings

Having established a suitable checklist a subjective rating is then assigned to each factor included in the list. In most methods, the ratings for each factor are grouped into a limited number of categories based upon an ordinal scale with usually not more than five steps. These may be designated purely qualitatively as, for example, in a five point scale: very good, good, average, poor, very poor. Alternatively, an arbitrary numerical value is associated with each point on the scale; the scales for the different factors need not be the same. There may be different numbers of steps in the scale and/or different numerical values associated with corresponding steps, nor need the increments between successive points on a scale be equal. In some cases a continuous scale is used rather than one with a discrete number of steps.

In most examples to be found in the literature, the scales are established in two stages. An "intrinsic" scale is set up for each factor giving the relative values of different points on the scale for a factor considered individually. The relative importance to be attached to the various factors is then assessed by means of weights attributed to the individual scales. In many such methods identical scales are used for the individual factors, usually but not invariably with equal increments between steps. When individual factors are grouped into families the allocation of weights is often carried out by stages. An individual rating and a weight are attributed to each factor within a group and these are then combined to determine the group rating. Weights are attributed to the groups and the whole combined to give an overall rating. The weights given to factors or groups of factors are usually based on a normalised cardinal scale, such that, for example, the sum of the weights is, say, 100.

Overall assessment

Various methods have been proposed for obtaining an overall judgment of the value of a project from the individual factor ratings. At one extreme, no attempt is made to combine the ratings and the decision is based on assessment of a "profile" of the individual ratings. At the other extreme all the ratings are reduced to a single figure of merit, usually a weighted sum or product taken over all the factors.

The main advantage of the profile lies in its graphic form of presentation which gives a simultaneous view of the comparative ratings of a large number of factors. As such, it is often recommended for preliminary screening of project proposals. However, it is of little help in rendering explicit the actual decision criteria utilised. Its use is sometimes justified by its apparent simplicity but this is largely illusory as in order to make any real use of a profile, the ratings of individual factors must be just as carefully determined as for incorporation in any type of composite criterion. The determination of factor ratings represents a major part of the effort associated with scoring methods.

Problems in the determination of rating scales and weights

The establishment of the individual scales and relative weights for individual factors constitutes a series of value judgments which it is quite laborious to render explicit for each project. However, if this is not done with considerable care, the ratings may very well degenerate into an incomprehensible (or even worse, misunderstood) expression of the rater's hunches. Unfortunately, the literature is not very eloquent on the subject of the possible difficulties which may be encountered in this respect. There is very little discussion of the possible effects on evaluation of using different types of scales for the ratings and weights nor even of the best choice of the final composite figure of merit. There seems to be tacit agreement that a weighted sum is somehow a natural and inevitable choice. In a relatively few cases a weighted product has been proposed, but this does not seem to find much favour, presumably because it is easier to add rather than to multiply. In any case, no reason is advanced for choosing one rather than the other.

It is important to realise that any figure of merit used for evaluating a project is in fact a "utility" function chosen to represent the attractiveness of the project to the firm. The form chosen for the figure of merit by its very structure inevitably reflects certain preferences. These should preferably be introduced explicitly and not adopted implicitly through the choice of a particular mathematical form. For example, a sum criterion favours extreme values compared with a product criterion [$2+9 > 4+5$ but $2 \times 9 < 4 \times 5$]; further, a product criterion is equivalent to a sum criterion with logarithmic scales. **One should, therefore, be rather wary of the simple figures of merit advocated in many scoring methods.** In general, their apparent "obviousness" has made it seem unnecessary to analyse their meaning and it is usually by no means clear what tacit assumptions they conceal. More attention should be devoted to clarifying the choice of scales and criteria in scoring methods.

Advantages and weaknesses of scoring methods

In principle, scoring methods are inherently designed to rank projects in order of merit, and are not well adapted to furnish information on the intrinsic value of a project. This limitation is unsatisfactory for project selection since it tacitly implies that all projects submitted for evaluation are worth undertaking per se. This may well be so, but one would generally welcome reassurance on the subject. Furthermore, in the absence of any indication of intrinsic value, it is difficult to judge whether limited available resources are forcing the rejection of worthwhile projects. One can, of course, attempt to overcome the difficulty by defining threshold acceptance levels for the values of the composite figure of merit utilised. It is usually not at all clear how this should be done and again the literature is remarkably silent on the subject; at best, a figure is quoted for a particular system in a particular context but no indication is given as to how it was chosen. This again raises the question of the significance of the figure of merit being utilised and emphasises the importance of studying the matter further.

In general, in scoring methods no attempt is made to take into account uncertainty in the estimated ratings and weights. In an isolated example quoted in the literature, instead of attributing a single rating to a factor, a credibility is associated with each of its possible values and the expectation value is taken as the accepted rating for the factor. This procedure seems rather to miss the point. Quite apart from whether it is valid to use expectation values in this context, it is of no use to introduce uncertainty in the individual factors unless one thereby arrives at a range of values for the final figure of merit. The only procedure on these lines which seems at all realistic would be the use of a simulation technique of the type outlined elsewhere to obtain different possible values of the figure of merit and their associated credibilities. No example of such a procedure has come to our attention and it would presumably be very laborious.

Another difficulty associated with scoring methods lies in the fact that although financial factors are included in the checklists, the actual magnitudes do not appear in the ratings and so may be lost to sight. This, of course, is again a consequence of the fact that the figure of merit has no direct financial significance.

The greatest asset of scoring methods lies in the formal use of a checklist which obliges explicit consideration to be given to all the identified factors. This not only prevents accidental oversights and superficial judgments, but also greatly facilitates the process of arriving at an agreed consensus of opinion on the part of the various sectors of the firm involved in project evaluation.

Profitability methods

These methods base evaluation upon a definite economic utility function which is assumed to express the degree to which the project presents financially favourable prospects for the company.

It must be stated immediately that no overall utility function has yet been defined and that most of the methods proposed take the form of a formula for a merit index which normally reflects only a particular aspect of the economic consequences of undertaking the project.