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This study should serve as a complement to the others being planned on the characteristics of demand in construction, on the role played by the building and on the macro-economic constraints connected with limited available resources.

Various case studies would substantiate the whole study which in turn would constitute an input to a study on alternative strategies for development of construction and building materials industries in developing countries which is under preparation by UNIDO.

The objective is to bring to the foreground the need to promote appropriate technological policies in the field of construction and building materials industries, to review the main problems involved and to propose criteria to guide choices and rules for decision-making. The policies to be examined are at the technological level: choice of building materials, organization of production, R and D concerning the best adapted solutions.

Building materials and building techniques used for housing will remain the centre of the study.

The study will be in four parts:

1st part: A demand for housing unequally covered by technical offer

2nd part: Major options of technological strategies in the field of technical building materials
3rd part: Elements of a multi-criteria analysis for the choice of construction techniques and building materials

4th part: Summary and conclusions on the basis of the previous three parts

The documentary basis covers essentially the bibliography shown in a previous report for UNIDO\(^1\)). It has been completed by a more recent documentation, namely the reports and discussions of a symposium held in Paris, on 25-27 January 1983 on "materials, techniques and components for economical housing in developing countries ".

\(^1\) René URIEN: "Preparing a world study on building techniques and materials. Preliminary report " UNIDO/PC 57 October 1982."
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Construction in the developing countries must confront a formidable challenge characterized by the urbanization tendencies, limited resources, and the inadequacy of techniques available for the financially solvent demand.

I.1 - URBANIZATION TRENDS AND HOUSING NEEDS

I.1.1 Urbanization trends

The United Nations world housing survey of 1974\(^2\), reveals that general population growth has speeded up considerably since 1950 and that the ratio of urban population to total population is constantly increasing. Between 1970 and the year 2000 the urban population of the developing regions is expected to be multiplied by 3 and it will represent 60 per cent of the world's urban population.

In the cities of the third world over 200 million human beings live in a state of absolute poverty. Yet by the year 2000 something in the region of between a billion and a billion-and-a-half newcomers will have to be catered for\(^3\). A mammoth building effort will be needed, meaning that in 25 years as


much building will have to be done as has ever been done. What is termed "social" housing now meets the requirements only of the middle and upper classes, the housing shortage is becoming more acute and property speculation aggravates segregation.

I.1.2 Housing: situation and needs

In contrast with the trend which has emerged in the developed countries, the housing situation in most developing countries has considerably deteriorated in the last decades, and whatever the criteria applied. Three aspects of this situation are to be outlined: the occupancy rate; the utilities and facilities available; the construction of new dwellings.

Individual country statistics in the last twenty years indicate that the developed countries and the most advanced developing countries have succeeded in reducing the proportion of overcrowded dwellings. On the other hand, this proportion has somewhat increased in the least advanced developing countries.

Many countries have reported that over half their housing units do not possess running water; sanitary equipment and lavatories are often in short supply in rural and urban areas.

4) cf Table 1 "comparative housing position in the industrialized country" established by IDCHLC (intergovernmental documentation center on housing and environment for the countries of UNCEE)
The construction rate for new housing varies from between two and five dwellings per thousand inhabitants in the developing regions to about eight dwellings per thousand in Europe. It has been calculated that in order to meet the housing requirements of their populations, the developing countries would need to build dwellings at the rate of eight to ten per thousand inhabitants.

I.2 - HOUSING DEMAND ACCORDING TO INCOME

Resource limitations have a bearing not only on the production factors (building materials, skilled labour, transport and building site equipment...), but also on the means of financing. From this point of view, the capital accumulation level, generally low in the developing countries, makes it impossible to industrialize the country at a quick pace and construct mass social housing at the same time, in the manner practiced currently in the highly industrialized countries. Owing to this fact, construction often represents only 3 to 5 % of the Gross Domestic Product of the less developed countries.

To this must be added the difficulties in controlling the increase in construction costs and the price of housing: A notable increase in the relative price of housing results either in a reduction in the construction rate, or a withdrawal of resources from the other industrial sectors.

4) cf Table 1 "comparative housing position in the industrialized country" established by IDCHEC (intergovernmental documentation center on housing and environment for the countries of UPECEE

5) according to the United Nations world housing survey.
### COMPARATIVE HOUSING POSITION IN THE INDUSTRIALIZED COUNTRIES

**SITUATION COMPARÉE DE LA CONSTRUCTION DANS LES PAYS INDUSTRIALISÉS**

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<tr>
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<td>95</td>
<td>95</td>
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<td><strong>EASTERN EUROPE</strong></td>
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<td>BULGARIA</td>
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<td><strong>DEVELOPED COUNTRIES</strong></td>
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<td>NEW-ZEALAND</td>
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<td><strong>OTHER</strong></td>
<td><strong>1980</strong></td>
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**SOURCES**
- Population and G.N.P.: World Bank
- P.B. and O.C.D.E.
- Other data: N.U.E.C.

**Notes:**
- Population and G.N.P.: World Bank
- P.B. and O.C.D.E.
- Other data: N.U.E.C.
- Correspondants du C.I.O. et C.N.U.

**Other Developed Countries**
- Australia
- Israel
- Japan
- New Zealand
In absolute value, the higher the rate of new construction and the lower the income per inhabitant, the lower the permissible cost per dwelling. In general, this construction rate can only be on the order of 2 to 5 new dwellings per 1000 inhabitants in the developing regions, which is notoriously insufficient when compared to the needs.

There is a simple relationship between:

- the average acceptable building cost of a house: $C$
- the percentage of national income devoted to housing: $l$
- the number of new dwellings per 1,000 inhabitants per year: $n$
- per capita income: $r$

Namely:

$$C = 10 \cdot \frac{l}{n} \cdot r$$

For a country whose per capita income US $400 and which aims at spending 3 per cent of its national income on the construction of 4 dwellings per 1,000 inhabitants, the average acceptable cost will be:

$$10 \times \frac{3}{4} \times 400 = US \, $3000$$

which means that in this case most building will have to be carried out on the basis of sites and services arrangements or self-help housing schemes.

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(5) according to the United Nations housing world survey
Furthermore, it may be suggested\(^6\) that, as far as financing is concerned, the cost of a dwelling should not exceed the income of a family consisting of 4 persons over two years.

The following table, can be deduced\(^8\)

Table 2

<table>
<thead>
<tr>
<th>NATIONAL INCOME PER CAPITA</th>
<th>AVERAGE ACCEPTABLE COST OF A NEW DWELLING</th>
</tr>
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<tbody>
<tr>
<td>$US 200 - 400</td>
<td>$US 1,600 - 3,200</td>
</tr>
<tr>
<td>$US 400 - 800</td>
<td>$US 3,200 - 6,400</td>
</tr>
<tr>
<td>$US 800 - 1,600</td>
<td>$US 6,400 - 13,000</td>
</tr>
<tr>
<td>$US 1,600 - 3,200</td>
<td>$US 13,000 - 26,000</td>
</tr>
<tr>
<td>over $US 3,200</td>
<td>over $US 26,000</td>
</tr>
</tbody>
</table>

I.3 - CLASSIFICATION OF HOUSING SUPPLY

W.P. Strassmann\(^7\) proposes that dwelling in the developing countries should be classified in six categories:

H5 = luxury
H4 = good quality
H3 = modest quality
H2 = minimum comfort
H1 = without comfort
H0 = temporary.

<table>
<thead>
<tr>
<th></th>
<th>NO</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
<th>H5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TEMPORARY</td>
<td>WITHOUT COMFORT</td>
<td>MINIMUM COMFORT</td>
<td>MODEST QUALITY</td>
<td>GOOD QUALITY</td>
<td>LUXURY</td>
</tr>
<tr>
<td>1. Cost of construction * in 1970 dollars (excluding land)</td>
<td>US$500</td>
<td>1 000 to 1 500</td>
<td>2 000 to 3 000</td>
<td>4 000 to 6 000</td>
<td>8 000 to 12 000</td>
<td>Over 20,000</td>
</tr>
<tr>
<td>2. Number of rooms</td>
<td>1 to 2</td>
<td>2 to 3</td>
<td>2 to 3</td>
<td>3 to 4</td>
<td>5 to 8</td>
<td>6 or more</td>
</tr>
<tr>
<td>3. Materials used</td>
<td>Rudimentary waste, adobe, stakes and mud</td>
<td>Adobe and similar materials, perhaps unfinished but improvable</td>
<td>Concrete, blocks, bricks, generally unfinished with partial roofing</td>
<td>Bricks and reinforced concrete blocks and other modern materials</td>
<td>Modern materials</td>
<td>Modern materials</td>
</tr>
<tr>
<td>4. Sanitary equipment</td>
<td>No running water or waste disposal</td>
<td>Collective sanitary installations nearby and rudimentary installations inside</td>
<td>Water and sanitary installations indoors but no bathroom</td>
<td>All sanitary conveniences, including bathroom</td>
<td>All sanitary conveniences, including bathroom</td>
<td>Every convenience, several bathrooms</td>
</tr>
<tr>
<td>5. Financing available</td>
<td>None</td>
<td>Rare</td>
<td>A few public loans</td>
<td>Mixed public and private financing</td>
<td>Generally private financing,</td>
<td>Private financing</td>
</tr>
<tr>
<td>* Cost of construction in 1980 dollars</td>
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</table>

* Cost of construction in 1980 dollars
The boundaries between these categories are rather arbitrary, but on the whole the building cost doubles when we pass from one category to the one immediately above it. Categories HO and H1 employ materials having a short life and are not equipped with plumbing. H1 differs from H0 in that the surface area is not so small, in that there is running water and a drainpipe inside or nearby, and in that it is capable, as a rule, of being improved. In the large towns and cities over half the population lives in these two categories of dwelling.

About a quarter of the total population is housed in the first three categories (H5, H4 and H3). The houses in these categories are "solid", are equipped with a bathroom, and comply with modern standards.

The intermediate category H2 consists of improved H1s and various partly solid constructions with minimum equipment and no finishing; in addition, there are dwellings equipped with a technical core (this core consists of plumbing components and is designed in such a way that it can be completed and enlarged by the occupants).

The table below (table 3) summarizes the characteristics of these six categories of dwelling.

I.4 - A DEMAND UNEQUALLY COVERED BY TECHNICAL SUPPLY

The demand for housing in the third world covers the whole range of products, from luxury residences to barely healthy shelters.
I.4.1 Western-type solutions

At the technical level there is an abundance of solutions on the international market as far as highly comfortable houses equipped on Western standards are concerned when the price exceeds US $300 (1979) per square metre of floor space. At this level considerations relating to the method of financing, to the allocation of loans and to the conduct of operations are far more important than purely technical aspects.

The number and variety of technical solutions available are considerably reduced when the price per square meter has to be between US $200 and 300. There is, however, some valid know-how in the matter, and enterprises offer to apply it provided that reasonable specifications are submitted to them.

The dwellings in question are modelled on the standards prevailing in the fully industrialized Western countries and concern only households with a relatively high income, which in most cases account for less than one-quarter of the total population.

There remains the problem of housing for the majority, the price of which would range from under US $1,000 to US $10,000 - in the other words from under US $50 to US $200 per square metre of floor space. Here the margin of technical manoeuvre is extremely narrow and the know-how very incomplete.

In this sector two areas need to be distinguished: self-help building and building involving commodity production in the provision of low-cost housing.

I.4.2 Self-help building

For the great majority of low-income households without stable remunerated employment, the cost of housing cannot exceed a thousand dollars. At this level, market
economy production seems powerless to meet demand. If there are any solutions, they require both the provision, at very low cost, of essential manufactured products and materials — possibly accompanied by technical assistance — and arrangements for free mutual assistance to enable those directly concerned to build their own dwellings without spending money. A very low price for supplies excludes the profit element, and the method of building excluded the wage burden. The solutions that can be envisaged are based on self-help in the strictest sense of the term. At this level self-help building forms part of a subsistence economy on the fringe of market economy production.

I.4.3 Low-cost building linked to market economy production

In this case the problem to be solved concerns housing whose price permits and requires the bringing into play of the factors of production characteristic of market economy production activity: capital, wage-earning labour, equipment and materials. The building sector concerned is deemed to obey the laws of the market economy and in approach geared either to high productivity or to a high consumption of labour is assumed. The solutions adopted or envisaged necessarily tend to make maximum use of local and national resources, both material and human, and to contribute towards a country's industrial progress. The aim is two-fold:

- to satisfy a basic need without any excessive financial aid by the State,
- to adopt solutions which are in harmony with the country's over-all industrialization project and help, through the purchases which they generate, to invigorate development-catalyzing industries situated up the line from the building sector.
I.4.4 The Ruanda example

Figure 1, an extract of a report of the mission to Ruanda carried out by the C.S.T.B. and CRAterre for the Association "Coopération et Aménagement", gives an example of the correspondence between household incomes and the techniques under consideration.


(9) Source: H. BERRIER, P. DOAT, M. RUBAUD matériaux de construction au Ruanda; inventaires et axes de développement CSTB/CRAterre Novembre 1981.
The repartition of the different technological solutions, according to the available income is the following.

<table>
<thead>
<tr>
<th>Techniques used in Ruanda</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- stick</td>
<td>41%</td>
</tr>
<tr>
<td>- adobe</td>
<td>39%</td>
</tr>
<tr>
<td>- adobe + semi burnt bricks</td>
<td>8%</td>
</tr>
<tr>
<td>- bricks</td>
<td>10%</td>
</tr>
<tr>
<td>- sand + cement blacks</td>
<td>2%</td>
</tr>
</tbody>
</table>

I.5 - THE NEED FOR APPROPRIATE TECHNOLOGIES AND APPROPRIATE TECHNOLOGICAL STRATEGIES

As it can be understood through the preceding statements the technical supply is far from fulfilling the demand, and solvent demand is far from fulfilling housing needs. The technical and constructive solutions proposed on the international market and/or on domestic markets abound for houses built according to developed countries models, as long as the construction price can exceed $200 to 300 per square meter of floor area. But that covers only the upper fringe of the market.

The problem of mass housing, at prices ranging from $1500 to $15000 per dwelling remains to be solved. The implementation of technologies adapted to that field appears as an important priority. But, even if UNIDO is mainly concerned by industrial development, it has to take in account the fact that most housing needs cannot be provided out of the informal construction sector.

So the main question is not only that of appropriate technology for production but also appropriate building materials strategy, which should be seen as a whole problem of optimal allocation of resources linked to development policies.
2ND PART:

MAJOR OPTIONS OF TECHNOLOGICAL STRATEGIES IN THE FIELD OF CONSTRUCTION TECHNIQUES AND BUILDING MATERIALS

After defining briefly the concept of appropriate technology, its adaptation to the building industry and building materials will be reviewed. The main point is to show that, in this field very diverse and at times concomitant options can be adopted, depending on the socio-economic context and the corresponding basic implications:

- reduction of costs and improvement of productivity
- reduction of imports: use of local material, saving of incorporated energy in the production and use of material
- optimisation of durability of buildings and global actualized cost (life cycle cost)
- optimal utilization of manpower resources (local): limitation of capital/work ratio, adaptation of tasks and qualification, etc.

II.1 - THE APPROPRIATE TECHNOLOGY CONCEPT

During the Fifties and early Sixties, it was thought that the pre-eminence of the so-called primitive techniques was the primary cause of the low economic growth, and that a rapid economic growth could be attained more easily through an improvement in labour productivity. The solution was supposed to be import foreign technologies which would increase labour productivity and the growth rate.
At the end of the first United Nations decade for development, some sceptical and critical analysts questioned the feasibility of adapting technologies designed for the industrialized world, to the developing countries.

II.1.1 The principles of appropriate technologies

E.F. Schumacher took an important part in this current of ideas through the founding of the Intermediate Technology Development Group and the formulation of the following four principles (10):

a) Jobs should be created in regions where people at present live and not in the metropolitan areas to which they tend to migrate;

b) Such jobs should be sufficiently low in cost to be able to be created in large numbers without requiring an unduly high level of capital and imports.

c) The production methods used should be relatively simple in order to minimize the demand for highly skilled labour not only in the production process but also in organization, the supply of raw materials, marketing and so on;

d) Production should be mainly based on local materials and be essentially for local use.

II.1.2 The question of appropriate technologies for the building and building materials industries

United Nations agencies, especially UNIDO, have long been engaged in work on industrialization and appropriate technologies for the developing countries.

The first recommendations adopted in 1967 Athens symposium with regard to the building materials industry include the following points:

- the higher priority to be accorded in the developing countries to the establishment of building materials industries;

- the development of techniques based on the use of local raw materials, including agricultural and industrial wastes;

- a study of the feasibility of small cement plants;

- the development of research and testing centres.

In 1978 UNIDO organized an International Forum for Appropriate Industrial Technology, which was held in India; some major problems and objectives were identified.\(^{11}\)

The objectives to be established are related to building for large urban centres and to building for the poor in rural communities.

The latter have to be provided with suitable building materials at a price which they can afford to pay. These materials must be available locally and must not require very specialized labour for their utilization. The main objective should be to enable these people to accumulate wealth by building. Thus the development of the building materials industry in the developing countries has an important social dimension and redistributive implications.

Consequently, high priority must be given to the production of the necessary materials for the poorest categories, and encouragement should be given to the manufacture of durable, cheap materials produced locally by using local raw materials and skills. It is not realistic to suggest better building techniques, because that implies the need for financing, which is non-existent in the subsistence economy. Nevertheless, it is not just a question of making available the materials traditionally used by the poorest communities; there is also a need to modify building procedures and techniques so as to permit the construction of more durable and adequate dwellings.

Nevertheless, the requirements for materials for the modern sector should not be totally relegated to the background, although priority must be given to the needs of the subsistence sector of the economy. Furthermore, for many developing countries the market is not extensive enough to justify the production of all types of materials and components.
II.2 - ECONOMICAL ARGUMENTS ABOUT APPROPRIATE TECHNOLOGIES FOR BUILDING MATERIALS

II.2.1 The basic economic arguments of the concept of appropriate technology for building and building materials

The priority given to the production of building materials for the poorest housing can be understood in the economics scope as the willingness to give priority attention to the inadequacy—mentioned above—of the technical offer to fulfill the financially solvent demand. If it is associated with self-help housing, it is also the sign of a development strategy which depends on the valorisation of the accumulation of capital through human investment. This is obviously a way to enable permanent assets to be formed with the lowest budgetary cost. But it should be noted that the technologies under consideration must also offer an appropriate durability, otherwise, the capital thus constituted will deteriorate rapidly.

The second option, the systematic recourse to local resources (local materials, or recovery of agricultural or industrial wastes) favours an equilibrium of the exchange balance. Its purpose is to reduce imports and the resulting losses of foreign exchange.

The preference for highly labour intensive technologies is opposed to the productivist doctrine of industrialized building. Instead of placing the accent on savings on the costs of construction which permit increased work productivity (repetitiveness and transfer of tasks to factories) value is placed on the idea that a work intensive activity in construction creates more employment per capital unit invested, and that this type of solution is particularly well adapted.
to the developing countries where investment possibilities are limited, and where the rate of unemployment is high. It might also be added that sometimes, in this manner, construction offers transition work to unqualified manpower leaving the countrysides. The scarcity of skilled workers justifies the necessary simplicity of the technologies used in the production of materials, as well as in their use in building.

It is also the limitation of investment capabilities and the abundance of manpower which justifies the need to choose building material plants with low capital-imputs, meaning those with a minimum of equipment. In some cases, semi-traditional factories may be better adapted to the "stops and goes" of demand and be able to integrate with rural operations and sharing activities whereas very modern factories often impose a high continuous rate of production in order to be profitable (12).

Another justification for the accent placed on small scale units is the importance of transport expenses in the cost price of building materials, due in particular to the lack of infrastructures in the developing countries.

II.2.2 Appropriate technology and industrial development

In other words, as it is usually understood the notion of appropriated technology proceeds from arguments obviously very logical: in developing countries money and capital are lacking, while there is plenty of manpower and a lot of almost free of charge raw material which could be cheaply transformed into building

12) See : The examples cited regarding brick plants by J.P.M. PARRY of the ITDG at the International Symposium on appropriate technology at New Delhi, 1978 ; and the latter III.2.5 paragraph of this report.
materials, which could take the place of imported ones and/or of national materials too scarce or expensive. Therefore, it seems advisable to conceive and perfect technologies making use of available local resources, palliating capital scarcity and saving foreign currencies.

But the relation between appropriate technology and industrial development has to be clarified - some economists (13) emphasize that industrialisation lies on the development of production forces owing to the "social surplus" - ie the difference between the value of production and the expenditures - by means of capital accumulation. This social surplus depends of labour productivity: a labour intensive technology may involve a productivity too low for substantial capital accumulation, which could affect the industrial development.

However in the poorest countries, the industrial development might not be considered as a priority objective because their governments must first of all, face enormous subsistence problems, and then the strengthening of their economy is a more imperative necessity.

II.3 - APPROPRIATE TECHNOLOGY ASSESSMENT METHODS

Several different methodologies, adapted to the building material industries, have been submitted for the assessment of projects or production processes according to the concept of appropriate technology (14).

(13) See : H. PROVISOR : "Développement et technologies appropriées ; pratiques dans la production de logements à faible cout". Université des S.S de Grenoble, janvier 1983 (background paper of the PARIS symposium on "materials, techniques and components for economical housing in developing countries").

a) Following the Cement Research Institute of India's paper on "strategies for the development of cement and allied industries in developing countries" any industrial equipment project is characterized by three kinds of attributes, which are to be used as a reference system to design standards:

- its technological orientation
- its "system status", that is to say the sociological, economical and technical environment
- its "transfer interfaces". The originality of this approach lies in the prominent part of the interfaces system concerning technological transfer,

b) J.W.S. de Graft Johnson, in his paper on "mechanization of construction and choice of appropriate technology in civil engineering", emphasize that one should not speak of appropriate technology without telling precisely "to what" it seems to be appropriate. He points out that in developing countries, the technological choices are made by various kinds of decision makers, with various motivations. They have not the same objectives nor the same ideas on what is appropriate. Thus the technical selection has to be founded upon four many criterions:

- selection criterions involved in the socio-economical objectives
- available resources
- available alternative technologies
- who is the decision maker
As regards technical choices, the author recommends various arrangements of labour intensive production processes and mechanized methods adapted to various types of production sectors: large scale production (steel, aluminium, cement, glass, etc...), medium size entrepreneurs (bricks, lime, concrete product-pouzzolanas, paintings, etc...) small size entrepreneurs, namely in rural areas (lime, claytiles, bamboo and wood products, straw and agriculture wastes).

The available resources would often be different in urban and rural areas, and therefore appropriate technologies would be more capitalistic in urban areas. This could lead to promote a dual economy in which two kinds of technologies might coexist. Some authors think that uniformous intermediate technologies would be a better solution to get rid of poverty and unemployment; but others assert that there may be some complementarity between high productivity techniques and a labour intensive sector.

c) H. PROVISOR (15) points out that the selection of appropriate technologies has often a "normative" feature by referring mainly to official objectives, without taking into account actual practices of people involved in building an "integrative" assessment methodology using 2 sets of criterions:

- the first set of criterions refers to the general objectives considered:

(15) H. PROVISOR "Développement et techniques appropriées ; pratiques dans la production de logements à faible cout" U.S.S. Grenoble Janvier 1983
If the objective is industrial development, the main requirement is that the yielded added value should at least allow the reproduction of the labour forces. Several other criterions are to be considered:

- effects on employment
- effects on the consumption of non renewable factors
- effects on foreign exchanges balance
- effects on ecological environment

Two correlated parameters may interfere on techniques: the state of industrial development and the urbanisation rate. It is assumed that the concept of appropriate technology may be used not only for low cost housing; a "high level" technology may be all the more appropriate as the developing country is more advanced in its industrial and urban development.

If the objective is only to strengthen a subsistence economy, the main requirement is almost the same but the criterions to be considered are slightly different:

- effects on employment
- effects on the consumption of non renewable factors
- effects on the substitution of locally produced materials to imported ones

The second set of criterions is aimed to evaluate the chances of a successful result. The main requirement is a substantial saving in costs. But a lot of others factors may be determinant, such as:
* for the formal sector:

- the importance of the existing production equipment for conventional techniques
- the feasibility of substitution to imported materials
- the feasibility of a cost effective production
- the capacity of local organisation to develop and disseminate the new technologies

* for the informal sector:

- the required investment (should be slender)
- the personal interest of middlemen (small entrepreneurs, dealers, craftsmen...)
- the reliability of supply system (as regards quantities available and prices)
- the reliability of the material performances

II.4 - A DETERMINANT CRITERION: INTEGRAL ENERGY (16)

II.4.1 Energy, a limiting factor for building materials industry

The accent placed on the utilization of local resources to reduce imports has, until now, concerned local materials in particular.

(16) See: R. URIEN "Economical and energetical implications of the choice of appropriate technologies for developing countries" to be published in BATIMENT INTERNATIONAL / BUILDING RESEARCH AND PRACTICE 1983.
Today, the energy consumed for the manufacture, transport, and use of building materials is a limiting factor of primary importance.

To give an example, let us consider the cement industry.

According to J.P. MERIC (17), if we admit that between now and the year 2000 the world consumption of cement will rise from 800 to 1,300 million tons per year, it will be necessary to provide, essentially in the developing countries, the equivalent of 50 million tons of petroleum per year. It is feared that such a demand cannot be satisfied. Appropriate technologies must also be sparing in the use of energy, especially in imported energies. The recourse to local sources of energy such as firewood is not a long term solution, for it raises other problems such as deforestation...

In the developing countries which must import their energy, integral energy thus becomes a determining criterion in the choice of appropriate technologies for both the building materials industry and construction techniques.

II.4.2 The concept of integral energy

The concept of integral energy is not new. In France, following World War II, the agreement of new building

techniques took into account the necessary coal consumption. After the energy crisis of 1974, the question was raised again by a number of research teams under expressions such as: energy analysis, integral energy, productivity of the energy factor, energy accounting, gross energy requirement, etc...

For its part, the C.S.T.B. has contributed to these analyses (18) by developing a methodology and by applying it to the level of building elements fulfilling analogous functions.

But it should be recognized that for most industrialized countries, the challenges dealing with the rational utilization of energy in the building refer essentially to the amount of energy consumed during the time it is used. This does not exclude the manufacturers of building materials from trying to save energy in their internal profitability and their competitiveness.

II.4.3 Importance of this criterion for certain developing countries

The case of Tunisia

In some of the developing countries in warmer climates, the energy consumption during their life cycle is reduced and integral energy constitutes an important part of the total energy consumption linked to the building.

Moreover, the other conditions determined for appropriate technologies favour the consideration of a range of materials and construction techniques which may result in the saving of energy: stabilized earth, air-dried brick, stone and rubble, etc...

The Tunisian Government has undertaken a study of the integral energy in construction. The methodology was proposed by the C.S.T.B. which is intervening in this study, within the framework of bilateral cooperation.

This study consists of making a comparison of the various construction techniques based on the total energy integrated in the construction: energy consumed on the building sites, in the manufactures of the building materials and of the intermediary products, energy used in the processes necessary for handling raw materials, that used in transport, etc... (in fact, all energy used all along the chain ending at the building site and passing through the commercialization circuit, the factories for first and second transformation, and as far as the deposits of raw materials.)

In order for the comparisons to be significant, the unit of comparison selected is "the element of construction". Some comparisons will also be carried out on the micro-economic level for various building types (notably dwellings, possibly offices, schools, etc...) and on the macro-economic level starting with an apportionment of the number of buildings anticipated according to the various types of buildings and techniques.
The construction techniques to be examined are:

- the techniques currently used in Tunisia,
- the "alternative techniques", either traditional
techniques if they prove interesting to relaunch,
or innovative techniques.

The study must set forth various propositions for short and medium term action programs, as well as an evaluation of these actions with regard to criteria other than the saving of integral energy:

operating energy (heating...), manpower, needs of professional qualification and training, investments and equipment required, impacts on the structures of the production apparatus, bottlenecks to be removed, participants concerned, price impact, the quality and durability of the construction, etc...

II. 5 - DURABILITY AND MAINTENANCE COSTS REQUIREMENTS

Within the technical performances to be considered, when choosing a building material or construction technology, durability is one of the most important after mechanical resistance.

Easy to do and cheap maintenance may contribute to ensure the expected durability without diverting too scarce resources for unprofitable retrofittings.

The durability standards are generally considered as a technical matter, independent from socio-economic major options. But in fact, in developed countries
and developing countries, those standards may be rather different.

In developed countries the required durability of the structural part of a building is at least 20 or 30 years. Some people say "as long as a married couple should last", and others add "may be more, in order to be transmitted to their children and grand-children". The first requirement can be justified as an economical choice. Using the life-cycle-costing techniques, it might easily proved that the 20 or 30 years durability is an optimum, according to relative costs of constructions of little durability, and the discount rates in current use. A longer durability is not justified by economics, but sociological behaviours (some what different for instance in western Europe and north America).

In developing countries the concept of "appropriate durability standards" could be put forward. Optimal durability could be derived from the comparison of life-cycle-costs of conventional and alternative technologies. In most cases, those appropriate durability standards would be lower than the similar ones adopted in developed countries, because of two kinds of factors:

- in developing countries, there is a more important gap between the costs of high-durability solutions and the costs of low-durability solutions, because the latter are often labour-intensive, more or less linked to informal sector, while the former need costly imported and transported modern materials.
- in developing countries, the discount rate should be higher than in developed countries because of the scarcity of capital resources.

In fact longer durability standards would often be preferred, as the result of political or sociological options:

- as we have already mentioned, if they are not too expensive, the more durable building solutions are to be preferred, because they allow the accumulation of capital, and social welfare; if those solutions can be used in the self-help way it may be a very efficient valorisation of human investment

- "modern techniques", are often preferred to traditional ones because of their social or political meaning.
3RD PART - ELEMENTS OF MULTICRITERIA ANALYSIS FOR THE CHOICE OF CONSTRUCTION TECHNIQUES AND BUILDING MATERIALS

As we have seen in the previous chapter, it is not possible to speak of appropriate technologies without referring to the main socio-economical objectives which are aimed. Then, the choice of technologies should be the result of multicriteria analysis (taking into account the already mentioned criteria), possibly completed by feasibility and bottle-neck studies.

Although appropriate technology assessment should always be made for a specific country (and even for a local district) the following table 5 could be presented as an attempt to classify the main differences between developed and developing countries.

Several multicriteria analysis will be presented both at the building techniques level and at the level of material and semi-products, insisting on the technologies more suitable to economical housing or very economical, and showing to what type of objective they correspond.

This will allow to emphasize the fields in which R and D action is necessary and mention the questions raised by development and distribution of technologies.
### TABLE 5: MAIN DIFFERENCES IN CONSTRUCTION ENVIRONMENT BETWEEN THE DEVELOPED AND LESS DEVELOPED COUNTRIES

<table>
<thead>
<tr>
<th>Resources and needs</th>
<th>Industrially developed countries</th>
<th>Less developed countries</th>
<th>Those with high foreign exchange earning such as oil-producing countries</th>
<th>Those with low foreign exchange earning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) MONEY:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Capital available for construction</td>
<td>Abundant</td>
<td>Abundant</td>
<td>Scarce</td>
<td></td>
</tr>
<tr>
<td>1.2 Average family income</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>1.3 Effective interest rate</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>1.4 Public construction expenditure v.s. private sector</td>
<td>Low</td>
<td>High</td>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td>(2) MACHINERY:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Construction technology</td>
<td>Capital intensive</td>
<td>Labor intensive moving toward mechanization</td>
<td>Labor intensive</td>
<td></td>
</tr>
<tr>
<td>2.2 Modern construction equipment and machinery</td>
<td>Plentiful</td>
<td>Available, but shortage of services and operators</td>
<td>Scarce</td>
<td></td>
</tr>
<tr>
<td>2.3 Ratio of average cost of renting construction equipment to average labor wage</td>
<td>Low</td>
<td>Moderate-high</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>(3) MATERIAL:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Modern construction material</td>
<td>Plentiful</td>
<td>Impaired types available but shortage of skilled manpower constrains their use</td>
<td>Scarce</td>
<td></td>
</tr>
<tr>
<td>3.2 Quality of available construction material</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>3.3 Ratio of average cost of material per average labor wage</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>(4) MANPOWER, EMPLOYMENT, WAGES:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Indigenous skilled manpower</td>
<td>Plentiful</td>
<td>Scarce</td>
<td>Scarce</td>
<td></td>
</tr>
<tr>
<td>4.2 Foreign skilled manpower</td>
<td>Scarce</td>
<td>Available</td>
<td>Unavailable</td>
<td></td>
</tr>
<tr>
<td>4.3 Indigenous unskilled manpower</td>
<td>Scarce</td>
<td>Plentiful, but due to high demand, they are in short supply</td>
<td>Plentiful</td>
<td></td>
</tr>
<tr>
<td>4.4 Unemployment</td>
<td>Small among skilled</td>
<td>Negligible among skilled</td>
<td>Small among skilled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate among unskilled</td>
<td>Moderate among unskilled</td>
<td>High among unskilled</td>
<td></td>
</tr>
<tr>
<td>4.5 Wages</td>
<td>High</td>
<td>Very high for skilled</td>
<td>Moderate for skilled</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate for unskilled</td>
<td>Low for unskilled</td>
<td></td>
</tr>
<tr>
<td>(5) PROBLEMS AND NEEDS:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Population growth</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>5.2 Rate of urbanization</td>
<td>Slow and steady with local shifts</td>
<td>Very high</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>5.3 Urban housing shortage</td>
<td>Moderate</td>
<td>Very high</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>5.4 Rural housing shortage</td>
<td>None</td>
<td>Moderate</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>5.5 Level of competition of residential housing with key development projects in using available resources</td>
<td>Not competitive</td>
<td>Not competitive for money but highly competitive for manpower, machinery and material</td>
<td>Highly competitive for all resources except manpower</td>
<td></td>
</tr>
</tbody>
</table>

(19) From REZA RAZANICriteria for seismic design of unreinforced masonry and adobe low-cost housing" in Low Cost Housing Technology East West Center Hawai'i USA 1979
III.1 - ALTERNATIVES STRATEGIES FOR CEMENT BLOCKS IN KENYA (20)

III.1.1 Alternative technologies of cement block production

In recent book Frances Stewart devotes a chapter to technological choice in building construction in Kenya. She begins by discussing the choice of techniques in the production of cement blocks, a basic material in housing in Kenya, and divides the machinery for cement-block production into three main categories:

- hand operated machines
- electrical or diesel-powered vibrating stationary machines
- electrically-powered mobile laying machines.

The last two types of machine were also divided into large machines and small machines.

Clearly, there would be major differences between these techniques in terms of capital and foreign exchange costs, the employment of labour, scale of output, the costs of production, maintenance costs and so forth. In terms of scale output, the large vibrating machine and the large laying machine had the greatest output, but they were also the most capital intensive, employed least labour and generated the highest maintenance costs. The two most "efficient" machines, Stewart concluded, were the hand machine and the large stationary vibrating machine. The hand machine employed more labour and therefore labour was a major cost of production. The only machine which was as efficient

(20) From F. STEWART "Technology and underdevelopment" 1977 LONDON, mentioned by David BURCH in "Housing in the world countries" Mac Millan press 1979
was the large vibrating machine; the increased cost of the original investment was compensated for by the lower cost of labour, which was not always the case with the other machines. Stewart advocates the use of the small hand machine in the rural areas of Kenya, but suggested the large vibrating machine for urban areas where higher labour costs render the hand machine "inefficient".

Stewart also makes the important point that while one could, in theory, combine very labour-intensive mixing (by spade on the ground) with capital-intensive block production, in practice choice of technique at one stage did partly determine choice at another stage. This was in part a question of speed, and in part of scale.

The adoption of a capital-intensive technique for one stage of a process (for example, the large vibrating machine for cement-block manufacture) led to the necessity of utilising capital-intensive techniques for other stages (for example, mixing). Mechanised mixing became necessary to maintain a constant supply of material to the large vibrating machine, in order to keep it fully utilised and, therefore, "efficient". The more capital-intensive cement-block machines not only use mechanised mixing, but also mechanised watering and stacking.

So it may be that by choosing an efficient capital-intensive technique for one stage of a process, we may be led into a whole string of related decisions in favour of capital-intensive techniques at other points in the production process. In terms of employ-
ment and the use of scarce capital resources, there issues must be carefully considered in each individual case.

III.1.2. Alternative technologies to the use of cement blocks

Stewart goes on to point out that there is a whole range of alternatives to cement blocks in housing construction (for example, mud and wattle, clay, stone, timber, pre-cast concrete panels), each of which, again, has different consequences in terms of employment, labour skills, capital and foreign exchange requirements, and so forth.

Some of the alternatives are clearly undesirable. While pre-cast concrete panels are technologically sophisticated, they are inefficient in the Kenyan context; the technology involves considerable capital investment but makes no saving on labour to affect this. While labour-saving in production, the panels require large amounts of labour in construction, simply to put the blocks into place. The alternative to this - cranes, and so forth - simply involves the use of more capital-intensive equipment. Once again the example of one capital-intensive phase of a process leading to other capital-intensive phases presents itself.

For other reasons, timber may not be a very useful alternative. The use of timber is relatively skill intensive and may require long specialised training.
Also, the use of timber may make competing claims on a scarce resource used for other purposes, which may severely disadvantage the poorest groups in society.

Stewart made an important contribution to the debate on appropriate technologies when she argued that once the choice of product is made the choice of technique is eliminated.

Among the determinants of the choice of product, and hence the choice of technique, is the pattern of income distribution within a particular country, and the nature of effective demand that establishes standards which might be too high for labour-intensive methods of production to be used. The existence of large disparities in income leads the high-income groups (whether individuals, corporations, governments or whatever) to demand products with a high degree of finish, standard and homogenous strength (see table 6). Middle and upper-class housing will be built with quality products. They may be built to two storeys, or be multi-storeyed in the case of luxury flats, but this inevitably means that hand machines for making cement blocks (and which generate greater employment) are ruled out, since the blocks made by this technique are not sufficiently strong to support more than one storey. Equally, private corporations or governments are given to erecting sky-scraper buildings, which are inevitably bound to be more capital intensive than alternative techniques.
TABLE 8: CHOICE OF BUILDING MATERIALS IN RELATION TO QUALITY OF BUILDING
CONSUMER INCOME, SOURCE OF BASIC MATERIAL AND LABOUR INTENSITY

<table>
<thead>
<tr>
<th>Material</th>
<th>Quality of building</th>
<th>Income class of consumer</th>
<th>Source of basic material</th>
<th>Material production</th>
<th>Processing</th>
<th>Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud and wattle</td>
<td>low</td>
<td>subsistence</td>
<td>local informal</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Sun-dried clay blocks</td>
<td>low to medium</td>
<td>slightly above subsistence (rural)</td>
<td>local informal</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Murram-enforced blocks</td>
<td>medium</td>
<td>low to medium (urban)</td>
<td>local informal</td>
<td>high</td>
<td>high-medium</td>
<td>high</td>
</tr>
<tr>
<td>Black cotton bricks</td>
<td>high</td>
<td>medium</td>
<td>local informal</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Stones</td>
<td>high</td>
<td>mainly high</td>
<td>local informal</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Timber</td>
<td>medium</td>
<td>medium and high</td>
<td>local informal</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Pre-cast concrete panels</td>
<td>medium</td>
<td>medium and high</td>
<td>local informal</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Pre-cast concrete panels made with a foaming agent</td>
<td>medium</td>
<td>medium and high</td>
<td>local and imported</td>
<td>low-medium</td>
<td>low-medium</td>
<td>low-medium</td>
</tr>
<tr>
<td>Cement blocks</td>
<td>medium</td>
<td>medium and high</td>
<td>local and imported</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Cement blocks made with a chemical additive</td>
<td>high</td>
<td>medium and high</td>
<td>local and imported</td>
<td>low-medium</td>
<td>low-medium</td>
<td>low-medium</td>
</tr>
</tbody>
</table>

1 Low: rural subsistence and most small-scale market production, urban unemployed, underemployed—excluding most informal sector activities. Medium: unskilled and semi-skilled formal sector (mostly urban) workers. High: skilled and professional. The use of this classification means that the majority of the population should be classified as low-income.

2 This refers both to geographical location (local or imported) and to sector of the local economy, which is regarded as being divided into an informal and a formal sector. Broadly, the informal sector is more labour using, while formal sector production involves more equipment, often imported.

3 To classify production methods according to labour intensity implies that each material may be identified with a single technique; as the survey of cement-block making showed, that is not the case, and considerable variation may be possible.

4 Cement

5 Intensive use of skilled labour and natural resources

6 Intensive use of skilled labour and some use of machinery

7 Varies (see note 3).

Source STEWART F. : "Technology and underdevelopment" LONDON Mac Millan 1977
III.2 - BRICK MAKING IN DEVELOPING COUNTRIES:
THE CHOICE OF TECHNOLOGIES (21)

A very wide choice of technology is available to anyone contemplating brick manufacture although the higher the capital intensity, the more restrictive the process is to the type of clays which can be handled. High technology brickmaking is also restrictive in the form the energy required can be used. The very high mechanised and automated plants rely on electric power and the higher grades of fossil fuels such as natural gas and propane while traditional plants may use scrub wood or even camel dung as their only source of process energy (other than human muscle-power).

III.2.1 Operating costs (in 1978 British £)

At the highest level of mechanisation and automation which has been attained in the clay brick industry the input of labour is less than one man hour per thousand bricks, around one twentieth of a minute's work per brick produced. At the highest level of labour intensity in unmechanised brick plants, the labour content may be as high as 1.67 man-hours per thousand bricks. However, the relative cost of labour also varies over almost as great a range with some brickworks'labour in the United States earning as much as £5 an hour while in parts of Africa the hourly wage may be as low as 5 pence.

If we relate the highest labour rates to the most automated factory we arrive at a labour cost of £5.00

(21) From J.P.M. PARRY: "Brickmaking in developing countries" a review prepared for the Oversea Division Building Research Establishment, UK 1979.
a thousand bricks (1 manhour x £5). On the other hand the most labour-intensive brick plants with the lowest unit labour rates result in a labour cost of 167 man-hours x 5 pence a thousand bricks = £8.35, only slightly higher than the labour costs of the most automated plant, and £8.35 is their only significant cost and includes the work of gathering fuel. It is therefore possible for grossly labour-intensive brick factories in developing countries to put bricks on the market at between £10 and £25 a thousand. By contrast the automated factory has a whole range of other costs to contend with including fuel, power, spare parts, process additives and supplementary materials as well as the cost of providing the capital and depreciating the equipment. As a result by 1978, brick prices in the developed world were mostly in excess of £50 a thousand, more than double the price of the developing countries' bricks - that is those made in the very labour-intensive production units.

The higher price of mechanically made bricks is only justifiable where these bricks can fulfil special applications which cannot be served by traditionally-made bricks; loadbearing brickwork in high-rise buildings and acid resistant for brick for ordinary housing, schools and industrial construction and so many of the mechanised factories which have been constructed have had to struggle to find markets and frequently run at only a fraction of designed capacity and usually at a loss.

III.2.2 Implications of alternative technology

There is an interesting correlation between the level of mechanisation and automation and the scarcity rather than the cost of labour. Once a capital-intensive
factory has been decided upon it is a continual threat to the prosperity of the owners that the plant may not produce to its design capacity. The greatest single difference between the operation of capital intensive and labour intensive plant in financial terms is that in the former, most of the costs are fixed and are incurred whether or not any bricks are produced, whereas in the latter nearly all the costs are variable and once bricks stop being made the costs stop being incurred also. Managements will increase the level of mechanisation if they fear production holdups due to labour shortage.

III.2.3 Consumption of energy

The consumption of energy may not necessarily be lower for a labour-intensive plant than it is for a capital-intensive one — particularly in the area of kiln firing, as the greatest economy of scale in brickmaking is the point at which continuous firing can be achieved. This point is somewhere in the region of 3 million bricks per year produced from a single site. As a result, examples of brick industry consumption of process fuel show some extreme differences:
<table>
<thead>
<tr>
<th>Nature of fuel</th>
<th>Approx calorific value per tonne (Megajoules)</th>
<th>Weight of fuel equivalent to burn 1,000 bricks (tonnes)</th>
<th>heat needed to burn 1,000 bricks (MJ)</th>
<th>Capital cost of firing installation at 1978 costs and prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern oil-fired tunnel kiln factory</td>
<td>Oil</td>
<td>44,000</td>
<td>0.11</td>
<td>4,800</td>
</tr>
<tr>
<td>Traditional wood fired clamp brickworks (East Africa)</td>
<td>Firewood</td>
<td>16,000</td>
<td>1.00</td>
<td>16,000</td>
</tr>
<tr>
<td>Traditional coal fired Bull's Trench continuous kiln (India/Pakistan)</td>
<td>Coal</td>
<td>27,000</td>
<td>0.20</td>
<td>5,400</td>
</tr>
<tr>
<td>Coal fired clamp (India, Turkey, UK, etc...)</td>
<td>Coal</td>
<td>27,000</td>
<td>0.32</td>
<td>8,600</td>
</tr>
</tbody>
</table>
The quantity of energy consumed makes the Bull's Trench continuous kiln, a very attractive proposition. The snag with this firing system is the necessity to run the kiln with a fairly large volume of throughput which may suit market demands in the high population densities of the Indian subcontinent but may be too large for many other developing world locations. The most efficient clamp installations consume up to 50 per cent more fuel than a continuous kiln but have the advantage of being able to use a wider range of fuels, including a number of waste materials such as clinker which may be freely available in the local area.

III.2.4 Labour productivity

The other crucial determinant of a choice of technology is the amount of labour needed to operate it. Here again the difference between extreme mechanisation and extreme labour intensity is very large but so too is the range of efficiencies encountered in unmechanised brickmaking as can be seen in the following comparisons:
TABLE 8 - Manhours required to produce 1,000 bricks

<table>
<thead>
<tr>
<th>Process from clay pit up to and including formation of wet clay bricks</th>
<th>Process from commencement of drying operation to completion of fired bricks</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most highly automated brick plant USA</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Moderately mechanised brick plant UK</td>
<td>3.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Traditional slopmoulding and clamp burning, Lesotho</td>
<td>16.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Traditional slopmoulding and clamp burning, (including fuel gathering) Tanzania</td>
<td>14.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Sandmoulded brick production semi-traditional, Sudan</td>
<td>32.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Traditional slop brickmaking, coal fired clamp, Turkey</td>
<td>16.0</td>
<td>16.0</td>
</tr>
</tbody>
</table>

It can be seen from the range of results in the above table that these more efficient traditional brick plants achieved between three and five times the labour productivity of the worst known example. This is a further indication of the very wide scope that exists for improving the technologies of brickmaking in developing countries.
III.2.5 Operating flexibility

A crucial factor influencing the choice of technology to adopt for a new factory in a developing country (or for that matter in any country) is the likelihood of a steady demand for the products. It is the misfortune of most conventional brickmakers that they operate facilities which perform best technically and financially when run at a constant output, while their customers in the construction industry are more than usually prey to economic cycles and varying interest rates. Every time a surge in building activity takes place, if labour intensive, low capital production unit is in a better position to respond quickly. On the other hand, a mechanised installation may have a lead time as long as two years between the decision to proceed and having more bricks to sell.

The lack of flexibility in capital intensive brick manufacturing hurts most, however, when markets turn down. The factories have a high element of fixed costs and even some of the "variable" costs such as the skilled labour controlling kilns, are in effect fixed unless the plant actually closes down. High fixed cost plants are extremely vulnerable if the market for the products fluctuates, as construction markets tend to do:

In periods of low market demand, the brick plant has to go on producing up to 100,000 bricks a day. Each unsold day's production occupies 40 square metres of storage space which in times of severe recession has to be extended at a considerable capital cost while all the time operating costs also rise in the extra
forktruck distances involved as the stocks extend.

What usually happens next is an attempt to economise on operating costs, associated with production and maintenance labour, and maintenance material and components. Almost inevitably such economies begin to affect the plant's ability to sustain its designed output. When output falls, fixed unit costs begin to rise which in the case of the heavy capital plants usually results in overall unit costs going up in spite of the economies in variable costs.

Faced with higher total unit costs, management tries to recoup part of these from the market by raising prices. And customers tend to turn to alternative materials or revert to using the products of the traditional producers. Then the real crisis begins: stocks get out of hand and management is forced to reduce output by shutting down one kiln if two were installed or, if only one, running it at half speed which means that nearly as much fuel is still used but for a reduced quantity of bricks (a heavy capital brick plant running at half the designed output frequently incurs total unit costs 70 to 80 per cent higher than when run at normal output). Privately operated units generally close down after working for a time under these conditions.

The traditional plants during this time will have suffered an equivalent drop in demand level but their reaction will have been entirely different, which accounts for their resilience. A most notable feature
is common to the traditional brickmaking industries which exist across the world in, to name just a few examples - Malawi, Sudan, India, Indonesia, Honduras, Mexico, Turkey, Egypt and Lesotho. This feature is that the brick plant owners do not expect to keep going at the same constant output. In fact the brickmakers in most of these countries mentioned operate only seasonally anyway and stop production during the rainy season.

Having very little in the way of fixed costs to worry about, they only restart making bricks if they feel fairly sure there will be a waiting market. Such a policy does not work to the benefit of the building trade which in many countries puts up with a period of severe brick shortage while waiting for the traditional producers to make up their minds that the rains have stopped and it is safe to make bricks again.

III.2.6 Quality and pricing

Offsetting their advantages of flexibility and survival ability, the traditional brick plants have a bad reputation for quality, which is perhaps understandable for industries which in some cases have operated for 50 years or more without technical controls or R and D input. Variable quality reflects on price and in some countries, the traditional sector's burnt clay bricks are bought for as little as a half or a third the price of a machine-moulded concrete brick, simply on the grounds that the other product is more regular in shape and more predictable in performance. In industrialised countries the position is usually
reversed with the common concrete brick valued much lower than clay facing bricks.

Accordingly, the aspirations of any organisations investing in a highly mechanised brick plant might in the present circumstances be that a regularly shaped, extruded-wirecut burnt clay brick would overcome its cost disadvantages by commanding a far higher price than the traditionally made product. Unfortunately however, many plants have been bought on the assumption that with their enormously superior productivity they should make bricks more cheaply than the traditional suppliers can. This will only be the case where basic labour costs. As described earlier typical wage rates in the countries considered are very much lower than this. Where labour costs are lower than £2,00 a day, an investment decision to opt for a heavily-mechanised brick plant will only be valid if labour is scarce, or if the apparent quality of machine-made bricks puts a large premium on their price. The second justification of course evaporates if it can be shown that labour intensive plants can produce the better quality bricks demanded by the market. It is one of the central purposes of PARRY's study to investigate the factors which lead to the poor quality of most of the Third World traditional brickmakers' products. To identify means to upgrade quality without greatly altering the basic nature of traditional plants, could significantly benefit both brick-maker and customer in developing countries.

Brickmaking at the most basic level is a straightforward technology, not without pitfalls but one which can be reproduced on a very small scale. To
find the answer regarding the appropriate level of capital technology to incorporate in a new brick project, the most practical approach is first to set up a small pilot plant, employing three or four men making about 500 bricks a working day. This is because the quickest and cheapest way to determine whether a raw material is suitable for brickmaking may be simply to make a brick with it, rather than invest in elaborate and time consuming laboratory testing programmes. These would only need to come later if market needs, or the cost or scarcity of labour called for a heavily-mechanised brickmaking project - with expenditure of a million pounds or so it would be unwise to proceed without detailed prior examination of clay deposits. However for most projects, a pilot plant actually making bricks should supply all the necessary information including a realistic simulation of production economics.

III.2.7 Priorities for research and development

The need appears not so much to create technologies which would enable people to make bricks who were previously unable to do so, but more to help people make better bricks, more efficiently, less impeded by climatic changes and in more congenial conditions.

Any major advances in these four fields will have an effect on the economic viability of labour-intensive brickmaking and thereby will influence the spread of the technology to those marginal areas where previously the setting up of an industry was not quite feasible as a proposition. The research priorities are the
Followings:
- improvements to clay winning and preparation
- improvements to brickmoulding methods
- improvements to drying systems
- improvements to the methods of firing bricks
- improvements to handling systems

III.3 - EARTH AS A BUILDING MATERIAL FOR THIRD WORLD HABITAT (22)

III.3.1 Choices of technology

There are two basic approaches to intervention in the area of improving earth housing technologies. One from bottom up in improving indigenous methods and the second from the top down, popularizing or simplifying modern technologies. Almost every technical intervention, whether originating from the top or the bottom, will raise the cost of housing, often putting the product in the cost bracket of concrete block building and out of the reach of the majority. There are of course many situations where improved soil cement or stabilized "pisé" materials are appropriate and less expensive than the cement option. How much cheaper though must they be to be chosen over cement blocks which are stronger, more water resistant and durable? At best, these innovations provide intermediate solutions.

The cost of a traditional adobe block is essentially the cost of the labour that goes into making it. This may or may not be counted in monetary terms by the ow-

(22) : From Allan CAIN'S Report on earth at the PARIS symposium on "materials, techniques and components for economical housing in developing countries", January 1983. To be published by ENPC PARIS 1983.
ner builder or the volunteer building a village school, but a real cost remains. As soon as a manual press is introduced into the equation, the cost of a block almost triples in labour value and an element of capital investment is introduced.

There are many improvements that can be made to adobe production that require little or no capital costs. "Development Workshop" carried out a project in Niger several years ago, a part of which was the rationalization of production of the village mud brick yard. Rather than raising material costs, the improved management actually brought unit costs down. By mixing local soils it was possible to eliminate the traditional straw component which was needed for animal fodder and crop mulching.

Soil cement is an attempt to reduce the quantity of cement, hence the price of blocks. We are reaching the lower limits of possible cement reduction with machines able to produce 10 MN/m² of pressure, but the price still remains too high for many people. The next cycle of research has begun on how to reduce the number of soil cement blocks used in constructing the house. Cisse in Mali and the E.I.I.E.R. in Upper Volta now build with only a frame of soil cement and the infill of unstabilized pressed blocks. Plancherel proposes a skin of ceramic to protect essentially mud walls. CRATERRE talks about gradually phasing the cement out of soil cement in Mayotte, effectively moving back to adobe.

The technological problem then is redefined: as how to weatherproof a mud wall? Lime washes, cement plasters have all been tried with only mixed success.
Almost thirty years ago at the National Building Organization in India an important series of experiments on wall renders for mud buildings were carried out. Amongst the several successes one described by Mathur uses about 5% bitumen emulsion with soil spread in a thin layer on external surfaces of walls. It has been used a number of times on various buildings and it was found that it has none of the problems associated with other renders, i.e. separation from the wall because of different coefficients of thermal and moisture expansion.

Thus the technical questions are constantly being rephrased. Some of the answers to new questions have been with us for some time and need only to be rediscovered.

III.3.2. Projects, Pilots and Case Studies

Pilot demonstration units are an attempt to bring innovation to the community. They are also opportunities to teach builders how to handle new technology.

The Malian government chose to begin with a pilot of ten house units to serve as a model for a whole project of 220. Their aim was to demonstrate to the community improved wall and roof building systems. They have learned many technical lessons in the course of their project but failed to demonstrate its cost efficiency. Their pilot project using partly stabilized earth block walls and straw panelled roof, despite consuming only one third of the cement, proved to save only 6% over the cost of a conventional concrete
block unit, and costs 60% more than traditional mud brick. The crucial test of community adoption remains for time to tell.

In Rosso, ADAUA took a step by step path to the introduction of stabilized earth and vault and dome roofing. Beginning in 1977 by building a single prototype, they then moved to a 12 unit group to house project staff. In all, 35 masons were trained, who could then offer their services to the community. Aided on one hand by a law passed after the 1977 flood prohibiting new building in traditional materials such as adobe, and technical assistance from the project team on the other, the new technology is being popularly adopted. In 1980, 16 aided self help units were built and in 1981 the number rose to 250. The project team still maintains a degree of technical control through the building teams and ensures that land speculation does not occur. The aim is to move toward local control.

Two Moroccan projects aim to produce, with earth materials, systems for "mass" housing which are significantly cheaper than conventional technology. In this they appear to have succeeded.

At Daoudiate (Marrakech), 3,800 housing units using 2.5% soil cement pressed blocks with vaulted roofs stabilized with 3 to 4% cement were organized into teams of ten to do the job.

The Ourzazate project introduced a still higher level of industrialization: stabilized earth was mechanically compressed between metal formwork and the cement
content was brought down further to 2.5 to 3%. A house unit could be erected in just one day with minimal labour and maximum mechanization at a price three to four times cheaper than conventional construction. The use of metal formwork tended to transform the earth in the eyes of local people into a modern material, removing the stigma of poverty so often associated with it.

The Moroccan projects illustrate that earth housing, if seen as a product or commodity, can be significantly cheaper than conventional forms. Particularly at Ouarzazate mass production and standardization as much as the low cost of the materials used were responsible for the savings. Thus earth building methods can compete in the realm of official housing.

III.3.3 Breakthrough or impasse?

Mathur of the NBO India states that: "Absence of a technological breakthrough is among the foremost reasons for the inability to solve the colossal housing problem" becomes apparent as one reads through the various case studies presented that, but for a few notable exceptions, the technological innovations have not reached or been accepted by the communities for whom they were developed. It has not been able through innovative or conventional technology to break through the housing problem.

From the users point of view, the choice of building material is made based on hierarchy of criteria:
1) the most important being economic - what the owner can afford; 2) the second, social criteria, reflecting his personal aspirations or image to be projected; 3) only thirdly comes the technological consideration.

In the view of the concerned professional, researcher, or advocate of particular innovation, the problem is one of how to transfer new ideas or improvements to the community at large. There have been many methods attempted, from propaganda to financial incentives. The NBO of India has put up demonstration houses in some villages. As well, they have produced a film on improved mud building which has been screened all over the country. In spite of their efforts, the vast majority of people in India's 550,000 villages go on building their houses in the old manner.

In order to propagate soil cement building, the BRU of Tanzania has organized training seminars and built pilot houses in a number of locations around the country.

The spread of technology has been less rapid than hoped for. The new material still depends on cement which is expensive to buy and difficult to transport, and generally in short supply, particularly in rural areas. People are still sceptical about soil cement's durability and strength and prefer traditional sand cement blocks, even though more expensive, if they have a choice.

The images of modernity and the rejection of tradition is probably the greatest blockage to the development of earth building technology.
III.4 TECHNOLOGICAL CHOICES FOR USE AND PRODUCTION OF BINDERS (23)

Binders are basic building constituents. In developed countries they only account for 1 or 2% of building cost, but they may account for 10 to 30% of low cost housing. That is the main reason why people try to build without binders, or to use organic binders instead of cement, or to adapt well known technologies to local context in order to find a balance solution between cost and performance requirements.

III.4.1 Organic binders

The most famous is bitumen, mainly acting as hydrophobic, in a proportion of 3 to 6%. The drawback of bitumen is its cost (in France 1.5 FF/Kg while the cement costs 0.35 FF/Kg). The proportions of bitumen and cement being similar, it appears that bitumen does not retain easily the economical advantage. The energy content comparison is clearly favourable to cement, for with one ton of bitumen 10 tons of Portland cement could be made.

Organic resins confer high performances to the materials, but they are generally much more expensive than bitumens.

A lot of industrial or agricultural by-products may be used as organic binders. As any by-product, they are unsteady and it is difficult to accumulate experimental knowledge about them.

(23) From J.P. MERIC's Report on binders at the PARIS symposium on "materials, techniques and components for economical housing in developing countries" January 1983. To be published by ENPC PARIS 1983.
III.4.2 Mineral binders

Lime

Lime is of considerable importance in those countries which do not have either Portland cement or pozzolanic binding materials. Depending on conditions, it can be produced more economically than cement in small-scale unsophisticated plants and with very little investment: field kilns, small-scale vertical kilns, and semi-industrial vertical kilns.

But the energy consumption of those kilns is very important, about 200 Kg of fuel per ton of lime. Even in modern fabrics, the energy consumption of lime is more or less the same as for Portland cement.

In most developed countries artificial lime, produced by the cement industry has taken the place of natural lime. Such an evolution might be untimely in the countries when a local industry has to be promoted.

Portland cement

Most developing countries wish to equip themselves with small plants using simple but up-to-date technologies to produce high-quality Portland cement, with a capacity of around 150 tonnes per day.

Even smaller mini-cement factories, with capacities of 25 tonnes per day, have been built and have demonstrated that they are capable of producing clinker of a quality similar to that of clinker produced in a large modern

plant. Such factories, however, require very precise supervision of the calcination process and are very sensitive to fluctuations in the quality of raw materials.

The manufacture of masonry binders or of pozzolan cements by the incorporation of a high proportion of calcareous filler or pozzolana in the cement during crushing has made it possible to increase substantially the amount of cement produced from a given amount of clinker. The pozzolanas that can be used are tuffs, pumice-stone, fly ash or calcined clay.

**Lime-pozzolana binders**

A mixture of lime and pozzolana constitutes an excellent and more economical hydraulic binder and in many countries consideration has been given to the possibility of manufacturing it for those purposes for which Portland cement would be too costly.

The technology involved is simple: the material has to be dried and then crushed simultaneously with the slaked lime. The production unit can be either very large or very small.

A new technology is being studied in connection with lime-pozzolana binders. It consists of heating a mixture of fat lime and pozzolana at a temperature of 800°C.

**Plaster**

Plaster is a building material which is being used more and more in the developing countries. It is produced from gypsum in three types of kiln: the field kiln, the discontinuous kiln and the rotary kiln.
The main use of plaster, which can be produced at lower cost than hydraulic binders, is for covering the interiors of dwellings. It can also be processed into panels or slabs and in some cases into building blocks. This last use is, however, limited by the high sensitivity of plaster to humidity, but it should be noted that this sensitivity does not seem to constitute a major drawback in certain climates.

The use of wastes

Wastes are being used with increasing success in the developing countries for the manufacture of building materials. Many possibilities are beginning to be utilized on a large scale:

- the agglomeration of mineral fines and wood shavings;
- the incorporation of rice husk ashes for the manufacture of building materials.

In general ashes are being used in many new developments. Rice husk ashes, and also ashes derived from the incineration of banana skins or bagasse, can be mixed with lime, preferably in a crusher, for the manufacture of high-quality pozzolanic binders.
4TH PART - SUMMARY AND CONCLUSION

The objective of the study was to bring to the foreground the need to promote appropriate technological policies in the field of construction and building materials industries, to review the main problems involved and to propose criteria to guide choices and rules for decision-making. The policies examined are the technological level: choice of building materials, organization of production, R and D concerning the appropriate technologies.

1 - A DEMAND FOR HOUSING UNEQUALLY COVERED BY TECHNICAL OFFER

Construction in the developing countries must confront a formidable challenge characterized by the urbanization tendencies, limited resources, and the inadequacy of techniques available for the financially solvent demand.

In the cities of the third world over 200 million human beings live in a state of absolute poverty. A mammoth building effort will be needed, meaning that in 25 years as much building will have to be done as has ever been done.

Ressource limitations have a bearing not only on the production factors (building materials, skilled labour, transport and building site equipment...), but also on the means of financing.
Owing to this fact, construction often represents only 3 to 5% of the Gross Domestic Product of the less developed countries.

In absolute value, the higher the rate of new construction and the lower the permissible cost per dwelling. In general, this construction rate can only be on the order of 2 to 5 new dwellings per 1000 inhabitants in the developing regions which is notoriously insufficient when compared to the needs.

After comparing a typology of housing demand according to income with typology of housing offer, according to W.P. Strassman, the wide range of possible constructive solutions existing for the higher grade category and the small number of really adapted solutions for housing of lower grade category has been emphasized:

The technical supply is far from fulfilling the demand, and solvent demand is far from fulfilling housing needs.

The technical and constructive solutions proposed on the international market and/or on domestic markets abound for houses built according to developed countries models, as long as the construction price can exceed $200 to 300 per square meter of floor area. But that covers only the upper fringe of the market.

The problem of mass housing, at prices ranging from $1500 to $15000 per dwelling remains to be solved. The implementation of technologies adapted to that field appears as an important priority.

So the main question is not only that of appropriate technology for production but also appropriate building
materials strategy, which should be seen as a whole problem of optimal allocation of resources linked to development policies.

2 - MAJOR OPTIONS OF TECHNOLOGICAL STRATEGIES IN THE FIELD OF CONSTRUCTION TECHNIQUES AND BUILDING MATERIALS

After defining briefly the concept of appropriate technology, its adaptation to the building industry and building materials has been reviewed. The main point is to show that, in this field very diverse and at times concomitant options can be adopted, depending on the socio-economic context and the corresponding basic implications:

- reduction of costs and improvement of productivity
- reduction of imports: use of local material, saving of incorporated energy in the production and use of material
- optimisation of durability of buildings and global actualized cost (life cycle cost)
- optimal utilization of manpower resources (local): limitation of capital/work ratio, adaptation of tasks and qualification, etc.

The notion of appropriated technology proceeds from arguments obviously very logical: in developing countries money and capital are lacking, while there is plenty of manpower and a lot of almost free of charge raw material, which could be cheaply transformed into building materials which could take the place of imported ones and/or of national materials too scarce or expensive. Therefore, it seems advisable to conceive and perfect technologies making use of available local resources, palliating capital scarcity and saving foreign currencies.
But some economists emphasize that a labour intensive technology may involve a productivity too low for substantial capital accumulation, which could affect the industrial development.

Several different methodologies, adapted to the building material industries, have been submitted for the assessment of projects or production processes according to the concept of appropriate technology.

The first set of criterions refers to general objective. If it is industrial development, the main requirement is that the yielded added value should at least allow the reproduction of labour forces. Several other effects are to be considered (on employment, consumption of non renewable factors, foreign exchange balance ecological environment...)

A second set of criterions is aimed to evaluate the chance of a successful result.

In the developing countries which must import their energy, integral energy becomes a determining criterion in the choice of appropriate technologies for both the building materials industry and construction techniques.

In developing countries the concept of "appropriate durability standards" could be put forward. Optimal durability could be derived from the comparison of life-cycle-costs of conventional and alternative technologies. In most cases, those appropriate durability standards would be lower than the similar ones adopted in developed countries.
In fact longer durability standards would often be preferred, as the result of political or sociological options.

3 - THE CHOICE OF CONSTRUCTION TECHNIQUES AND BUILDING MATERIALS TECHNOLOGIES

It is not possible to speak of appropriate technologies without referring to the main socio-economical objectives which are aimed. Then, the choice of technologies should be the result of multicriteria analysis (taking into account the already mentioned criterion), possibly completed by feasibility and bottle-neck studies.

Several multicriteria analysis have been presented both at the building techniques level and at the level of material and semi-products, insisting on the technologies more suitable to economical housing or very economical, and showing to what type of objective they correspond:

- alternatives technologies of cement block production
- alternatives technologies to the use of cement blocks
- elements for the choice of technologies in brickmaking:
  - operating costs, implications of alternative technologies, consumption of energy, labour productivity,
  - operating flexibility, quality and pricing
- choices of technology of improving earth housing

This allows to emphasize the fields in which R + D action is necessary and to mention some of the questions raised by development and dissemination of new technologies.