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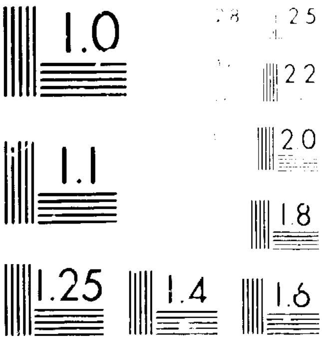

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PROMOTING THE USE OF WOOD IN CONSTRUCTION *

by

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* The views and opinions expressed in this paper are those of the author, and do not necessarily reflect the views of the Secretariat of UNIDO. This document has been translated from an unedited original.

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THE HOUSING PROBLEM IN DEVELOPING COUNTRIES

One of the most critical sectors affecting the socio-economic situation in the developing countries is that of housing. Amongst the specific characteristics which are inherent in the structure of such countries are : the levels of unemployment and under-employment, the high level of urbanization in the larger cities - primarily the result of the influx of rural populations in search of the means of subsistence, the low purchasing power of the larger part of the population as a result of the unequal distribution of wealth, the financial and operational weaknesses of the companies responsible for this sector, the lack of a vigorous and clearly defined technical and political structure which would establish effective exchanges so as to promote the development of low-priced housing, and the persistence of traditional attitudes in regard to building materials and techniques. All these, amongst other factors, make the housing problem more acute and fail to facilitate the promotion of new solutions.

At the present time, and in most of the developing countries, the housing shortages in the middle and lower economic strata of the population show no sign of decreasing; on the contrary they increase from year to year.

Studies carried out in some Latin-American countries[1] have shown that over the next fifteen years these nations will have to quadruple the present rate of construction in order to meet the needs for housing. This problem will be even more serious in certain Asian and African countries. For example in India, Pakistan, Zaire and Cameroon the rate of building will need to be at a rate of five to eight times the present rate if the existing housing deficit is to be overcome.

In the absence of substantial changes, especially in the financial system and also in regard to the building materials and techniques used, there can be no solution or short-term improvement in the housing problem of the developing countries.

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(1) Bolivia, Colombia, Ecuador, Peru and Venezuela. In this group of countries the existing rate of building economic dwellings is, in total, 150,000 units per year. In order to overcome the existing deficit and to meet the growth in the population over the next 15 years it will be necessary to build 635,000 units per year.

Summarizing, therefore, the imbalance between the housing supply and demand in the developing countries is due to a large extent to the structural problems which are typical of these countries. However the increasing rise in the cost of conventional building materials and the worsening supply position, together with the persistence of high-cost and slow building techniques, makes the general problem more acute.

PROBLEMS IN THE UTILIZATION OF TROPICAL TIMBERS AS BUILDING MATERIALS

The structure which exists at the present time in the building sector, based on traditionally accepted materials such as bricks, steel and concrete, and also on conventional building techniques, cannot provide a solution to the housing problem which is fundamentally due to shortages and rising costs of the usual building materials.

Amongst the many sectors involved in the building sector are two areas which could, at the present time, contribute towards an effective solution of the housing problem: these areas are :

a) The area of alternative building materials to those used at the present time. The utilization of materials other than steel, bricks and concrete would make it possible to increase the supply of building materials:

b) The area of building systems and technologies, the technical cover of which could be directed towards activities which can operate independently of a costly production infrastructure and which have such characteristics of versatility as would allow the industrial production and building of housing on a large or small scale.

The developing countries do not have their own resources in regard to the solution of the problem by using new building materials and techniques. The techniques and materials used at the present time are the result of importing exotic models, replacing local building materials and techniques which were the result of centuries of evolution and which are suited to the environment. Timber, and the products derived from it, which have innumerable advantages as building materials, are the major victims of this process in which they have been replaced almost totally by concrete. This situation, which reflects the indiscriminate adoption of patterns of consumption far removed from our reality, is surprising when it is realized that in some developed countries timber meets up to 70% of rural and urban housing needs, reserving steel and concrete for large buildings and infrastructure works.

The use of timber, which was intensive in many developing countries up to the beginning of the present century, was reduced to minimal levels with the advent of the concrete era. From that moment onwards the utilization of wood in building was progressively reduced at the same time that, as a consequence, technological progress in regard to its properties and conditions of use was largely halted, whilst the financial and economic structure of the wooden house building industries became weakened with the reduced interest shown by users.

An overall survey of housing in those countries which produce tropical timbers may be summarized as follows :

On the one hand the existence of an actually or potentially extensive resource with, on the other hand, the presence of a housing deficit which can clearly not be covered either with conventional building materials nor with the building systems which exist at the present time.

The housing problem in these countries can be ameliorated by means of new formulæ. The intensive use of wood and wood products in building and the introduction of prefabrication would contribute decisively towards solving the problem of the housing shortage.

Some of the considerations which emphasize the possibility of introducing timber into the building trade are as follows :

1) Wood is a renewable resource, unlike the other materials used in building. It has other and additional advantages over other materials, especially in regard to its high strength to weight ratio and its resilience (modulus of elasticity), the ease with which it can be worked and handled, its versatility and its aesthetic appeal. Some of its relative disadvantages which result from its organic composition, such as its susceptibility to attack from fungi, insects and weather, and its reduced resistance to fire may be largely overcome by the adoption of preservation techniques and by the use of safety standards and designs, to such an extent that in some of the developed countries the financial and insurance systems give similar treatment to timber houses as is given to those constructed with the use of conventional materials;

2) Timber houses are tending to follow a process of gradual adaptation on the part of users. Discontinuation of the use of wood in the building of houses resulted in the loss of local "timber culture" and halted the technical evolution which is, by contrast, being pursued in other countries. In this way the prejudices which would have been eliminated by technological progress have inhibited its incorporation into the building sector.

Nevertheless the timber house could be an immediate and valid solution in certain areas, especially the rural areas, because the raw material is cheap and because the tradition of using it has not been completely lost in such areas:

3) Timber has undeniable advantages as a structural material when compared with other materials. Its use, especially for roofs, can be easily encouraged by the construction of houses using mixed building materials in the urban and rural areas.

Incorporation of wood as a structural material, on an adequate technical basis, would have a favourable incidence on both costs and the time needed for building:

4) Wood, because of its versatility and workability, is suited to the development of industrialized prefabrication systems and can facilitate the structuring of supervised self-building schemes which could, potentially, be one of the most viable solutions which can be proposed for providing houses for the low-income classes:

5) Timber, for use as a primary material for building houses, can be obtained relatively easily on the basis of the existing industrial infrastructure. It is well-known that, in the tropical countries, the greater part of the production consists of sawn timber and that within the wood processing industry it is sawmills and joinery shops which are predominant.

THE FACTORS WHICH AT THE PRESENT TIME LIMIT THE USE OF WOOD IN BUILDING

There are many factors which have restricted the use of wood in building. The most important relate to the rejection by the population, especially in urban areas, of timber houses because of their prejudices in regard to the behaviour of such houses to fire and biological agents, the failure to disseminate the technical information necessary for overcoming these prejudices, the lukewarm response from the financial sector in the face of solutions which involve timber houses, the technical shortcomings of the production infra-structure, etc. However the principal causes for those aspects which limit the use of timber in building are to be found in the technical area. Amongst those technical difficulties which impede the use of tropical timbers as building materials the following must be mentioned :

1) The lack of specialized technological investigational work on tropical timbers. Due to the shortage of laboratories and personnel in the field of timber engineering, coupled with the low level of importance which is given to investigational work, the technological knowledge of tropical timbers is, in many cases, limited and inappropriate. The available information, which is needed for timber engineering studies, does not offer the required statistical reliability. Those results which are available on technological trials have, in general, been obtained from a small number of samples, and wood technology in the vast majority of tropical countries has been limited to the study of small test-pieces free from defects and which do not therefore take the effect of these into consideration when elements of normal size are involved: hence they do not, of themselves, allow the establishment of design parameters. In addition to this the information which is generally available does not cover all the significant properties which are needed for design work.

   The greater part of the available technological information, and the criteria used for design work with tropical woods, are based on tests carried out with coniferous woods, and these present considerable differences in respect to their anatomical properties and their behaviour.

   The constructional components fabricated with these species react in a distinct manner to the applied loads. The design textbooks and manuals which are available come from those countries which use mainly coniferous woods for building purposes. Irrespective of any differences in the anatomical constitution of coniferous and broadleaved timbers the behaviour which they show is different, together with the way in which this behaviour is very substantially affected by the presence of defects.

2) The heterogeneity of the tropical forest.

In the tropical forests of the world it is estimated that there are about 5,000 species of tree, and at least 1,500 of these should be suitable for building work. By contrast the number of coniferous species currently used in those countries with a long tradition in the use of timber in building is no more than about twenty. To overcome these characteristics of tropical forests, which vary according to the tropical regions involved[(2)], presents great difficulties if it is desired to know in detail the physical and mechanical properties of every one of these species so that they may be individually used for building purposes. In actual fact the degree of variation between the properties of the tropical species is so great that, in the case of density, it is possible to find in the same forest species which have densities of 120 kg/m^3 and others with densities of 1300 kg/m^3. The concept of grouping these species together according to their strength is, therefore, a technological necessity which has not been faced in sufficient depth to meet the needs of the developing countries.

3) Lack of design techniques suited to tropical timbers.

As a consequence of these differences in properties the concepts of structural and architectural design will differ considerably according to whether broadleaved tropical or coniferous woods are involved. The same lack of technical information on timbers has limited builders to the use of the traditionally-known species, and has meant that the design criteria are based on data derived from experiments carried out with coniferous timbers. For example it is now recognized that one of the most obvious differences between broadleaved tropical timbers and conifers from a temperate climate is the different relationship between their strength and their modulus of elasticity. Broadleaved tropical species, under the same conditions of density, show strength characteristics which are the same or better than conifers, but their moduli of elasticity are much lower. Therefore the structural design criteria for broadleaved tropical woods are governed by deformations and not by strength. These aspect needs to be taken into consideration in the case of designing with broadleaved tropical woods.

(2) The degree of heterogeneity of tropical forests, and hence of differences in densities and physical and mechanical properties, varies with the region. The natural mixed forests of Latin America are more heterogeneous than those in Africa, which are themselves more heterogeneous than those in S.E. Asia.

4) Lack of an appropriate industrial infrastructure.

As a consequence of this low level of timber investigations in the developing countries, together with the limited qualitative and quantitative demands made by the incipient local building market, the sawn timber market is, generally speaking, both modest and inefficient. It is characterized by its selectivity in regard to the number of timber species processed and by the continuing use of obsolete equipment and inadequate processing techniques. The yields for round logs are very low (in general the yield is in the region of 35%). The shortage of preservation and drying lines, together with the lack of methods for solving problems of sawing and workability in the industrial timber sector aggravate the problem even further, and are major factors in impeding the inclusion of new species in the market; this would undoubtedly improve the conditions of economic profitability and technical efficiency of the industrial extraction and processing sectors.

5) The non-acceptability of timber housing, due to social and economic factors.

Within the populations of the developing countries there are prejudices in regard to the acceptability of timber houses. These prejudices relate fundamentally to problems of fires and durability. Although in many tropical countries the acceptability problems are smaller the lack of a technical and financial effort to meet adequately the anxieties of the users has had a negative effect on the increasing use and acceptability of timber houses on the part of the building market. Many programmes for timber houses - in some cases as government developments - have had negative results on their future expansion and development as a result of technical faults resulting from a lack of knowledge of suitable ways of handling timber as a building material or of design of the houses themselves.

6) The lack of codes and regulations promoting the use of timber in building.

In the great majority of tropical countries there is no appropriate legislation, supported by building codes and standards which would guarantee the efficiency of timber constructions. In many cases, as confirmed by findings in some Latin-American countries, the laws covering the building of houses do not include timber as a building material, and exclude it from potential housing programmes[3]. The absence of building codes and of appropriate legislation is due fundamentally to the lack of technological knowledge of tropical timbers and this, in turn, prevents placing before the politicians the advisability of introducing wood as a building material in such a way as to eliminate the many negative arguments and prejudices against wood and which exist, at all levels, in the developing countries.

GENERAL CRITERIA FOR PROMOTING TROPICAL WOOD AS A BUILDING MATERIAL

There are many arguments which support firmly the view that the utilization of tropical wood could provide valuable assistance in solving the problem of housing in those countries which produce it :

a) There are, in the world, large forest areas which have not so far been worked, and which constitute sources of raw materials which could be incorporated immediately into production. Even in those regions of the world where the tropical forests have been intensively worked there are still remaining considerable quantities of those species which have been less sought after commercially, and these could be used for building. Even more so: in all the tropical regions of the world there exists sufficient land to establish plantations of species of rapid growth from which an important return could be obtained in the contruction of houses.

b) Within governmental circles there is now an understanding of and a pre-occupation with the way in which the housing problem is becoming more acute, and the necessity to confront this as a matter of urgency. It is also recognized that the narrowness and the persistence of inadequate building techniques complicate the finding of a solution to the problem. At the same time it is universally accepted that one way of reducing the cost and of extending the production of houses is to introduce and to apply the concepts of industrialization, pre-fabrication, self-production and self-construction.

Within these policies, which are now being stressed in many developing countries, timber presents innumerable advantages when compared with

(3) In one tropical city in Ecuador, located in a timber-rich zone, existing municipal legislation prohibits the building of wooden houses. According to the investigations carried out this is due to negative experiences with buildings of this type which have suffered from fires or biological attack.

other materials.

c) In the prospects for improving the timber industry in the tropical countries it is universally recognized that it is necessary to encourage and develop local markets. From this point of view the market for house building shows an enormous potential for development. The advantages of consuming a large part of the timber production of tropical countries in the building of houses are manifold and obvious. Firstly it would contribute towards solving the housing shortage. Secondly there is the possibility of introducing secondary species, not wanted for the export trade, which would reinforce the sawmilling and industrialization activities. A third major advantage is that it would initiate a degree of integration in industrial processing which would be of enormous benefit to the timber producing countries. Finally this industrial development could give rise, on the basis of the existing industrial infrastructure or capital investments, to new plants characterized by the fact that they are not capital intensive but are labour intensive and are almost exclusively dependent on locally produced inputs.

d) As may be seen, the industrial structure which is necessary to initiate the development of the production of timber houses or of structural elements already practically exists in the developing countries. This infrastructure consists of sawmills and secondary processing lines which operate at low technical levels in these countries. With programmes of technical assistance for improvements in the processes and capacities, and the introduction of standards for quality and dimensions, actions which it is possible to implement within reasonable limits of time and cost, so that it may be said that the industrial infrastructure which is basically necessary for the production of timber houses and elements has already been formed in the tropical countries, and all that needs to be hoped for is the demand from a market with high quality exigencies so that its operating level can be improved.

e) The production of timber houses and elements must, primarily, correspond to the existence of an industrial base which has a rationalized and standardized structure. Equally the construction industry will require the existence of simple, versatile and standardized building techniques.

Timber-based building systems could meet these requirements in a relatively simple manner if technical concepts are applied which are related to the quality standards, codes of practice and standards concerning dimensions and methods of construction. These normative elements, in the light of the analysis of experiences in some Latin-American countries, are easily achieved and applied through investigational and development programmes which are manageable in an autonomous manner by those countries producing tropical woods.

BASIC PRINCIPLES FOR FORMULATING A PROGRAMME FOR THE PROMOTION OF TIMBER HOUSES IN THE BUILDING SECTOR

The effective introduction of wood as a constructional material must, necessarily, correspond to the creation or progressive strengthening of an overall structure which has to integrate all the essential factors involved in the building sector: technical aspects related to an understanding of the raw material and constructional techniques, industrial and commercial aspects, legislation and standardization and institutional aspects, together with those dealing with finance and promotion.

The integral inclusion of all these factors would be a formula capable of producing effective and permanent results.

1) Technical aspects

As in the case of all building materials wood must be technically guaranteed and must seek adoption and endorsement in engineering and architectural circles, since it is only with this endorsement that the financial and user sectors will have confidence in new materials and new solutions.

It is necessary to consider that the technical construction sectors have been accustomed to work with materials such as steel and concrete which have an established normative basis and endorsement as a result of investigation, offering them sufficient security in handling these materials. Before adopting a "new" material the engineering and architecture sectors demand endorsements in regard to its properties and behaviour.

A first step along this path to gain acceptance of wood as a constructional material in technical circles is to establish reliable endorsements at a level which is sufficient to overcome the principal doubts.

From this it may be deduced that the tropical countries must undertake technological investigations designed to provide technical inputs to the engineering sector. This concept is sufficient to direct the lines along which the investigational work must be carried out, in terms of pragmatism and applicability.

Unfortunately the investigational work on tropical timbers has, in general, not been structured in such a way as to be of practical applicability, and its greater part has been converted into speculative scientific exercises. A change in this respect is an urgent necessity, and it is perfectly viable to put this into concrete effect.

Technical development relating to the constructional sector itself is one more of the important factors to which attention must be paid.

A knowledge of the material and of its properties and qualities is not, of itself, sufficient for utilizing it in buildings. It is necessary to establish also the conditions and requirements for the utilization of timber elements and components. It is necessary to face up to the need to develop simple and versatile constructional systems, adapted to the local conditions and designed to facilitate acceptance by both builders and users.

The central objective of the constructional systems to be put forward is to reconcile both the possibilities of pre-fabrication and total industrialization with modes of use whose implementation may be more attractive, such as self-fabrication, self-construction and techniques for the progressive growth of housing.

In this regard it will be necessary to develop training programmes at engineer level and also at middle-level training staff and building workers.

2) Industrial aspects

The availability of technological knowledge regarding tropical wood as a constructional material, and also in regard to constructional techniques, is not enough to guarantee its entry into the constructional industry.

The wood must be processed industrially so as to obtain those conditions which will convert it into an adequate raw material for building houses. The primary and secondary industrial processing sector is therefore an important factor within this scheme.

If we consider that, in general, the timber industry in tropical countries, and especially in respect of primary processing, has developed at very low technical levels, and when we take into account the fact that the aspects of quality and dimensional precision are critical if wood is to prove a promotable material in the technical construction sectors, it may easily be deduced that a great part of the effort must be directed towards an integral improvement in the industrial area.

In this case the dissemination of technologies designed to improve the quality of sawing, the finding of solutions for the industrial use of species which are particularly difficult to saw and the introduction of preservation and drying techniques (which are the factors which generally limit the introduction of new species onto the market), together with the introduction of grading techniques which will guarantee a material of proven quality for the builder, will be important elements in obtaining an adequate response from the industrial sector towards a new potential market. In addition the implementation of programmes which tend towards achieving industrial rationalization in respect of qualities and quantities, the demonstration of production techniques which integrate the primary processing industries with those carrying out the secondary processing, and preparation of feasibility studies for the installation of model plants designed to produce pre-fabricated components or elements and houses made from wood are all factors which will need to be considered.

The organization of training activities at all levels in the industrial field, and the creation or strengthening of those structures which can supply technical assistance to the primary and secondary processing industries are important actions which will need to be provided for.

3) Standardization

The introduction of tropical timbers into the building sector has one important advantage and prospect, namely the possibility of creating a standardized industrial production structure.

Effectively, therefore, those technical inputs which it must be possible to offer the engineering sector in the form of codes or manuals must include standards in regard to qualities, dimensions and conditions of use for timber elements, structures or complete modules. With this information the builders will require from the industry standardized materials which will meet the design exigencies. In this way a "technical demand" will be progressively created which will force the processing industry to provide materials of the form and quality demanded by the user.

Under the present conditions there is a shortage of norms and standards for the use of tropical timbers in the building trade in most of the producer countries. Where such standards exist they have, in most cases, been almost indiscriminatively adopted from similar productions for the use of coniferous or temperate deciduous woods in very different social and economic environments. Generally speaking standardization in respect of tropical timbers has not been developed on the basis of actual experiments on these species.

To some extent the present situation of a shortage of norms is an advantage since it means that the new proposals will be more easily accepted by the production sector. Naturally this implies great responsibility on the part of the standardization sector and the necessity for the proposed standards to comply with the standards of scientific rigorousness and accuracy.

4) Aspects of the market

An accurate knowledge of the housing market is another essential element in the promotion of wood as a building material.

At the present time timber is basically used in the construction of temporary housing, hutments or housing in those areas where it is abundant. At the other extreme timber is used as a structural and decorative element in high-cost houses.

However with very few exceptions, mostly verified on the basis of past experience, timber houses have not been adopted in the mass programmes designed to meet the demand from low and medium income social groups. It is however precisely in this area that the best possibilities are offered for the development of timber constructions.

From this point of view the promotion of timber houses should initially be preferentially directed towards the middle strata of the population; under the effect of emulation the lower-income groups would then more easily accept this type of construction.

Analysis of past experience has shown that this effect of emulation acts generally from the lower sectors to the higher, but only with difficulty in the inverse direction. In a similar way it is possible that this effect would be more appreciable from the rural areas to the towns.

Another important consideration in respect of the market is the fact that the initial timber housing programmes should begin in those areas where the raw material is available, where the users will accept this type of building and where there exist both the industrial infrastructure and housing programmes which contemplate the provision of services, in particular sanitary services and drinking water. Gradually, as the industrial supply increases and where pre-fabrication is developed, timber constructions can eventually supply markets at a distance from the resources and progressively gain acceptance in urban zones.

5) Institutional and promotional factors

Up to the present time those official sectors responsible for economic housing policies and development have not, in the majority of cases, incorporated timber constructions in their programmes. Although there are various factors which have limited their acceptance the most prob is that the lack of consistent projects, solidly supported with cor technical arguments, has been the cause of this rejection. Negative experiences in some countries in respect of wooden houses, and which have damaged their image and potential, have been the result of a lack of any integral knowledge in respect of the use, control and handling of the material or in respect of constructional techniques using it.

The existing prejudices in regard to the problems of combustibility and of susceptibility to attack from biological agents have been extended not only from user level but also to decision-making levels in regard to housing policies, even up to the point where in some cases building with timber is prohibited.

This aspect serves to emphasize the need to have available answers which will remove doubts and prejudices in regard to timber as a constructional material.

As a consequence of this limitation the financial and insurance systems and the incentives which exist for other industries have not given their approval to timber constructions.

Amongst those options open for initiating the development of timber houses the most realistic seems to be that of capturing the interest of the housing authorities so that they can establish specific programmes. This situation would generate a market on a considerable scale which, in its turn, would require the qualitative and quantitative growth of the forestry sector and the industrial sector. This would also strengthen the constructional activity at the engineering and architectural levels and this, in turn, would strengthen the technological and educational sectors.

One of the options continually suggested and analyzed is that of "Do it yourself" and this, whether supervised and directed or not, cannot become accessible to the individual person without peripheral development factors due to the conditions in developing countries which may be characterized by low levels of literacy and a lack of an industrial and commercial infrastructure for wood products.

An important line of action would therefore seem to be the intensive and objective pro otion of timber constructions in the technical governmental circles concerned with the housing sector. The construction of prototypes, the supplying to these bodies of constructional manuals and codes and the training of their staff would become important elements.

COMPARATIVE COSTS OF TIMBER AND CONVENTIONAL HOUSES (4)

INTRODUCTION

The comparative analysis of costs between traditional building systems and systems based on the use of wood must be carried out by taking into account three basic aspects : Direct Costs, Indirect Costs and Supplementary Profits: the latter are generally less obvious, but are no less important.

It should be pointed out that direct costs established for timber houses have been based on the real unit costs obtained from the construction of prototypes, which is equivalent to saying that scale economy benefits are not incorporated in them, as is the case with constructions using traditional materials.

In the same way the percentages of indirect costs set out in the table on the following page are those which are applied in the case of conventional buildings (an average of 28% of the direct costs), due principally to the fact that there is no better available concerning timber-based buildings.

Table 1 gives a comparison of three types of houses of social interest in Colombia, Ecuador and Peru, using traditional systems and timber-based systems.

These results, although they do not lead to any spectacular results in comparative terms, indicate that timber buildings are more economical than similar buildings using traditional materials; the percentage advantage varies between 10% and 20% of the total cost. This is equivalent to saying that, under the worst conditions of competition, it is possible to build more housing units (or square metres) with the same capital investment.

No account has been taken in this comparison of the larger floor area used by walls in the traditional system, which means a smaller usable area for the occupant for the same overall building area. As an example it may be pointed out that the comparative effect of losses in net floor area due to walls in two houses of 54 m^2 (similar to those in Table 2) means for the occupant, in the case of the traditional system, a payment of about $930 for an area which is useless since it is not habitable.

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(4) This study was carried out on the basis of prototypes built in three countries of the Andean Group.

TABLE 1

COMPARATIVE COSTS BETWEEN TRADITIONAL AND TIMBER-BASED HOUSING

All costs in Dollars

	TRADITIONAL SYSTEM	TIMBER-BASED SYSTEM	SAVING
COLOMBIA* ($68m^2$)	Blocks and panels		
Direct costs	130.09 (100%)	106.48 (81.85%)	18.15%
Indirect costs	35.12	27.75	-----
Total cost	165.21	135.23	18.15%
ECUADOR* ($54m^2$)	JNV*** (PL)		
Direct costs	128.18 (100%)	115.17 (89.85%)	10.15%
Indirect costs	38.45	30.60	-----
Total cost	166.63	149.72	10.15%
PERU** ($66m^2$)	Cement-steel-brick		
Direct costs	113.54 (100%)	100.00 (88.07%)	11.93%
Indirect costs	30.66	27.00	-----
Total cost	144.20	127.00	11.93%

* August 1981 rate of exchange

** June 1981 rate of exchange

*** JNV: Junta Nacional de la Vivienda (National Housing Bureau)

Independently of these undoubtedly important results it is necessary to analyse the reasons why these cost comparison criteria could be substantially modified once timber construction represents a stable and systematic solution where it becomes widely used.

To do this it is necessary to analyse, separately, some modification factors in the areas of both direct and indirect costs.

Direct costs

In the case of the direct costs it is estimated that there are two factors which will result in a future reduction in the cost of timber houses.

The first of these relates to the effect of massive pre-fabrication which will make it possible to benefit from the advantages of greater scale economies. It has been estimated that the factor of repetitiveness in timber constructions will make it possible to reduce the direct costs by about 12%, on the basis of assuming a shorter time for the manufacture and erection of the components of the house, a lower cost of building materials, especially when industrialized and standardized (reduced wastage), better quality control and lower timber treatment costs.

In the same way it is possible to forecast a reduction, estimated to be in the region of 8%, for adjustments in the architectural, structural and constructional design of the houses. This is due to greater familiarization with the material on the part of the investigators, technicians and users, this being reflected in a lower level of caution in terms of technological confidence, safety in respect of accidents and damage, and also in regard to all the problems of inadequately trained manpower.

This makes it possible to conclude that it is possible that the transition from the experimental stage to industrial production should represent, at a conservative estimate, a reduction of not less than 20% in the direct building costs.

Indirect costs

The average indirect costs in the five countries of the Andean sub-region represent about 28% of the direct costs. In the comparisons set out in Table 1 the same indirect costs as for another type of building have been taken into account.

As an example we can give a list of the items, as percentages, which contribute to the indirect costs of traditional buildings in the countries of the Andean Pact :

- Technical management	5%
- General administration	10%
- Monetary depreciation	2%
- Rate of inflation	5%
- Financial interest	6%
- Bank commission	2%
- Depreciation of equipment, furnishings and tools	1%
- Social charges	5%
- Contingencies	5%

As may be seen the greater part of these criteria are closely linked with the time factor (time required for building) and in the case of timber houses this can be reduced by no less than 40% as compared with traditional systems.

This reduction in the time needed is due to the fact that the work in timber-based systems is not sequential, as is the case with the traditional system, but can be carried out in parallel or superimposed, principally in the case of operations carried out "under cover" and finished in the factory, free from the incidence of climatic factors, and this is also reflected in lower labour costs.

This makes it possible to state that these percentages will, by the fact of the shorter building times which are characteristic of the manufacture and construction of timber houses, be further modified. The indirect costs which will be subject to modification include technical management, general administration, monetary devaluation, rates of inflation, financial interest and the depreciation of plant and machinery.

In this way it may be estimated that the factors previously mentioned would reduce the indirect costs by some 30%; this is equivalent to saying that the average figure would be reduced to 20% instead of the 28% as previously estimated.

It should be pointed out that, in this analysis, no attempt has been made to consider the effect which a significant modification of the legal and normative framework of the countries in regard to tax or fiscal incentives for building houses, recognizing their social content, their geographical location (generally in the region of the timber resources, and decentralized) and the non-traditional character of the solutions employed, would have on costs.

Once the possible modifications in the principal components of the costs of building with wood have been analysed it is possible to draw up the following table which indicates a reduction in the direct costs of 20% and of indirect costs of 30% in a comparison of both systems used for building houses of 54 m^2 in Ecuador :

TABLE 2

COMPARISON OF ESTIMATED COSTS IN ECUADOR
(1981)

	ACTUAL COMPARISON		ESTIMATED COMPARISON	
	Traditional system	Timber system	Traditional system	Timber system
DIRECT COSTS	$7,034.7 (100%)	$6320.6 (89.9%)	$7,034.7 (100%)	$5,056.5 (71.9%)
INDIRECT COSTS	$2,110.4 (100%)	$1,896.2 (89.9%)	$2,110.4 (100%)	$1,011.3 (47.9%)
TOTAL COST	$9,145.1 (100%)	$8,216.8 (89.9%)	$9,145.1 (100%)	$6,067.8 (66.4%)

It may be seen that, in this way, the reduction in the costs will reduce the cost of timber houses by some 33.6% as compared with buildings produced on the basis of traditional materials, once massive programmes have been drawn up for the construction of timber houses; this implies the manufacture of 1000 or more housing units per year.

Finally it is important to point out that, in this last comparison, none of the benefits of self-construction or self-manufacture have been included; these would considerably reduce the influence of skilled labour costs and the corresponding indirect costs.

From this point of view if building programmes using wood are considered, on both criteria and in a marginal manner, preliminary studies indicate an additional reduction of the order of 25% to 30% of the total cost. The utilization of these same advantages in the traditional cement, steel and brick systems is considerably more difficult in the case of self-construction and little less than impossible to achieve in the case of the self-manufacture of floor, wall and roofing components.

Supplementary benefits

The previous analysis was based on pointing out only the comparatively direct or "visible" advantages reflected in the difference in costs between one building system and another. There are however indirect or "invisible" benefits which are as important, or even more important, than those quoted above; these are generally not taken into account when housing policies of greater benefit for the countries are being proposed.

In order to be better able to understand this it is necessary to imagine that that which is most significant for a country is the fact the same amount of money is invested in building houses by the one or the other system, whilst also considering the marginal benefits in terms of the need to import capital goods, the consumption of energy and the employment of labour, from the first stage of extracting the raw material through its transformation into a building material and up to its subsequent utilization.

As a result it is possible to analyse the large capital investments which are essential for the establishment of factories producing cement or iron and steel works, together with the corresponding energy consumption needed to produce the materials required for the construction of the same floor area of housing as can be obtained from wood, with the consequent savings for the country under both of these headings. It is enough to point out that wood can be converted into a constructional material such as a round beam simply by cutting down a tree and without any further transformation.

These differences operate much more clearly in favour of wood when they are considered in terms of the employment of skilled labour and even more in the case of unskilled labour when replacing the resource (irrelevant in the case of non-renewable resources), in the stages of extraction and logging, transport, primary and secondary converting, marketing and subsequent utilization not only for construction work but also as by-products and in secondary activities.

The final conclusion indicates that if private industry or the state bodies invest the same amount of money, using both constructional systems, not only will they be able to supply cheaper housing or to build more units but at the same time they will confer a variety of supplementary benefits on the country, and so increase the multiplier effect.

SUMMARY

Summarizing the points analysed above, and on the basis of experience in some of the Andean Pact countries, it is possible to draw up the following table :

	TRADITIONAL SYSTEM(*)	TIMBER-BASED SYSTEM
Costs and estimates on the basis of constructing unit houses	$9,145.1 (100%)	$8,216.8 (89.9%)
Estimated costs on the basis of industrialized production	$9,145.1 (100%)	$6,067.8 (66.4%)
Estimated costs on the basis of applying self-manufacture and self-construction systems	$9,145.1 (100%)	$4,550.9 (49.7%)

(*) This type of system, and he corresponding costs, represent the greater part of the housing programmes implemented by the governments of the Andean Pact countries. Estimated costs correspond to the year 1981.

WAYS AND MEANS FOR PROMOTING THE USE OF WOOD IN THE BUILDING INDUSTRY[5]

As has been indicated the introduction of tropical timbers onto the building market requires programmes directed towards organizing an integral productive structure covering the technological, technical, social, financial and industrial aspects of the sector.

A development programme would involve covering the following areas :

1) Understanding the material

2) Construction techniques

3) The industrial base

4) The market and promotion.

1) Understanding the material

In regard to understanding the material, that is to say wood as the raw material for building houses, it is necessary to carry out a series of investigations which will make it possible to arrive at a sufficient understanding in regard to the properties and characteristics of wood. Some important criteria need to be taken into account when organizing the technological investigation programmes.

The laboratory activities to be developed must serve to achieve these principal objectives :

i) The acquisition of reliable technical data which would make it possible to draw up tables of structural values for the use of engineers:

ii) Achieving on an experimental basis those improvements in the field of wood processing which could then be applied at an industrial level.

Within this first group of investigations (i) it is necessary to carry out technological investigations in the following areas :

a) The physical and mechanical properties of the wood;
b) Structural joints;
c) The anatomy of the wood;
d) The influence of defects on the physical and mechanical behaviour of the wood;

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(5) This methodology is based on the information collected by the Integral Study on Wood for Building, carried out by the Cartagena Agreement Board, Technical Secretariat of the Andean Countries.

e) Tests on full-scale elements and components, principally beams, pillars, wall modules and roofing structures.

This group of investigations should make it possible to draw up design manuals which would provide engineers with sufficient information for them to work with tropical timbers.

The investigations in the technological field should be carried out on the basis of criteria of applicability. From this point of view it will be necessary for them to be of the multidisciplinary type, in particular with engineers and architects as well as forestry specialists.

In regard to those technological investigations which will subsequently serve to improve the industrial sector (see under ii) above), these must be programmed to develop the following work :

- A study of the suitability of timbers for sawing and workability with a view to preparing guidelines which can subsequently be used in industry [(6)].
- Investigations into the preservation and drying of wood. The objective of this work will also be to develop and promote the most suitable techniques for drying and preservation in the processing industry.

The validity, reliability and applicability of this investigational work can only be successful if it takes into account the following concepts :

- The species which are selected for the studies must have the necessary characteristics of abundance and accessibility for their utilization. Another important group of species are those which would be used in programmes for forest plantations.
- The technological studies described above should be carried out simultaneously and integrated.
- The samples tested should be representative of the total population of trees [(7)].
- The botanical and dendrological identification of the species must be carried out in order to ensure their promotion on the market.

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(6) Experiments carried out in the National Forest Products Laboratory, Mérida, Venezuela, have solved the problems of sawing high density species. On the basis of these experiments the timber industry has introduced species onto the market which could not previously be marketed because of sawing problems.

(7) In the experiments carried out in the Andean Group it has in general been reported that technological tests should be carried out on samples taken from 10 trees per species to obtain the necessary statistical reliability.

- The technical standards used for carrying out the tests must be carefully verified. In some cases it has been found to be necessary to alter some of the parameters and criteria in current international standards so as to match the results of the investigations to the objective of applicability to a given environment.

When designing the initial projects for investigations in the technical field it is preferable to concentrate the efforts on in-depth investigations of a smaller number of species rather than carry out superficial studies in order to cover a wider range of species.

- It is necessary to include methods for full-scale testing. The trials which have been carried out in the Andean countries' project have confirmed the reliability and representativeness of full-scale tests for engineering purposes(8).

- The combination of all the tests should make it possible to develop rules for the classification of defects, the grouping of species according to their strength and for deriving the design values which can be used in engineering(9).

2) Construction techniques

A second area which has to be covered within the promotional programmes is the development of appropriate construction systems. Once tropical timbers have been recognized as a constructional material and their basic technical characteristics are known it will be necessary to organize and rationalize the use of this raw material by way of the development of construction systems.

Some of the basic criteria which have to be taken into account in the development of such systems are the following :

- The elements and components must be selected as a function of the existing industrial infrastructure and of future possibilities of industrialization.

(8) Full-scale tests require some special equipment, the training of personnel and a higher cost when designing investigational materials. As a result the co-participation of various countries is important in this type of work. Andean experience has shown objectively that scale economies in investigational matters are as important as in other production sector activities.

(9) On the basis of technological studies carried out on 105 forest species for the five countries of the Andean Group there have been developed : an Andean Classification System for Structural Timbers (SACLAME), the Design Manual for Tropical Timbers and a System for Grouping Species into three structural groups, to each of which may be assigned specific design values.

- It must be ensured that the proposed systems can be readily industrialized, that the constructional techniques can be rapidly assimilated by builders, and that the building processes require only the use of simple carpenters' tools.

- The jointing systems must in the same way be designed on the basis of jointing elements already existing in the trade, preferably by using nails.

- From the beginning the constructional systems must consider the aspects of standardization in regard to dimensions. In order to achieve economies and functionality in the systems it is important that the timber parts used involve the least number of sections, with the object of facilitating industrial processing and self-manufacture. Similarly the systems must fit in with the techniques of modular coordination for the production of pre-fabricated elements. The modules must be rationalized in such a way as to simplify their assembly and the process of erection, together with the interchangeability of components.

- In order to select the dimensions of the timber parts and also the flooring, walling and roofing modules, it is necessary to carry out investigations based on the following principal aspects :

  - Preferred sizes based on industrial production techniques, typological and anthropometric studies and an analysis of the complementary materials used in the construction of houses.

  - From the point of view of architectural design it is important to produce systems which are versatile, open-ended and flexible so as to make the progressive enlargement of houses possible.

    This aspect is particularly important since in many countries there is a definite tendency to provide the tenant with a site with services and the minimal habitable nucleus with the prospect of progressively supplying - as the purchasing power of the tenant rises - those pre-fabricated materials which make it possible for him to expand his house to meet his needs.

    Consideration of this criterion becomes of importance when developing programmes for guided self-manufacture or self-construction.

- In the development of contructional systems it is necessary to seek the participation of organized groups of engineers and architects belonging to professional associations, universities and housing authorities. This participation will be particularly important for ensuring that the constructional systems are adapted to the structure of the housing sector in each country.

- In many cases it is necessary to confirm experimentally the suitability of the proposed elements or modules before they are are applied in practice. Full-scale experimentation on flooring, walling and roofing structures and other constructional components, together with facing materials, provides indications as to the behaviour and functionality of these components when used in buildings.

- In regard to facing materials it is necessary to carry out investigations on those materials which are available and on their use, as a function of time and cost. Considering the fact that the appearance of the facings may be critical for the development of timber houses those solutions which restrict the use of wood in construction to producing solely the structure of the building must not be underestimated[(10)].

- The design must be especially careful with the aspects of protection of the wood both against fire and also against attack by biological agents. When it is considered that one of the most vulnerable places in timber houses is the wall facings when these consist of wood-based planks or panels those solutions described above can offer advantages in regard to these problems. Consideration of the use of non-combustible materials in the kitchen in particular, and planning to use fire-check walls between adjacent houses, are other aspects which must be fully taken into account.

- As in the case of the raw material the training of personnel at all levels as timber design and construction technicians seems to be an important activity.

- Drawing up constructional codes for timber houses must be the primary objective of these activities. It is not possible to hope for the acceptance of wood constructions on the part of the housing authorities if they are not offered, in advance, those technical tools which make it possible for them to control and manage this type of building in an appropriate manner.

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(10) In the case of the Programmes of the Andean Group some of the solutions proposed for the walls consist of panels of wood covered externally and internally with successive layers of polyethylene, wire-mesh and a sand-cement mortar.

3) The industrial base

a) Development of the industrial infrastructure

The industrial base is fundamental if the development of timber houses is to be successful. Within the programmes to achieve its promotion in the building trade the following aspects must be taken into account :

i) It is necessary to carry out studies to obtain an overall view of the present state of the wood processing industry in the tropical countries. These studies should include analyses of the logging and marketing activities. A detailed evaluation of the timber sector will, in general, provide information on the commercial species, the sizes in which the sawnwood is produced, the marketing systems, the defects which are commonly present in the timber, the prices and the defining of the technological areas which are lacking. In the same way a precise knowledge of the location and potential of production will assist in the drawing up of plans for future expansions and for the supplying of the building trade by the wood processing industry.

ii) One step towards the technical and economic improvement of the wood processing industry in the tropical countries is the introduction of new species. This would provide a remedy for the level of under-utilization of the production potential which is principally due to a shortage of supplies of raw materials occasioned by the preference of the processing industry for a few species. The industry now processes those timbers which do not present difficulties in sawing or working, which can be easily dried, which have properties of high natural durability and good appearance.

The incorporation of new species into the construction industry requires a knowledge of their mechanical behaviour and solutions to the problems of sawing, planing and nailing and of the techniques for drying and preservation.

The problems of dimensional stability, sawing, workability and attack by moulds and insects can be overcome by the use of processes which are already largely available from the laboratories and which could be transferred to industry. The primary and secondary processing industries prefer those species which are easy to process because of their limited capability to find their own solutions to the technical problems which arise from their generally low technological level.

From this point of view the essential link between the investigational sector and the industrial sector, by means of functional programmes of technical assistance, can be seen to be an important requirement.

iii) The programmes for the development of the industrial infrastructure must consider, as a matter of priority, the formation of permanent technical assistance units for the industry. This implies the prior need to train the personnel belonging to the bodies responsible for these functions.

iv) The actions for the technical improvement of the wood processing industry must initially concentrate on a selected group of industries which have both the capability and the interest needed to assimilate the improved technologies. This policy will make it possible to rationalize the technical assistance efforts and to produce results, so that the rest of the industry can then become progressively interested, obtaining the same benefits from the technical assistance of "copying" the solutions adopted by the "improved" companies.

v) It is necessary to set up demonstration workshops and promotional seminars for industrialists and workers. The object of these workshops will be to promote the processing and use of wood in the building industry by way of familiarizing those who attend them with the techniques of industrial management and in improving the processing technologies.

b) The industrial production of timber houses

As has already been pointed out there is, basically, in the tropical countries an already existing industrial infrastructure which is sufficient to start, with some changes and orientation, supplying the construction industry. The principal obstacle which has hindered the full development of the production of wooden elements, components and houses has been the lack of a demand from the market with clear specifications concerning dimensions and qualities. If this demand were to be defined the more technically advanced part of the existing wood processing industry is already capable of producing satisfactory products for the building industry.

i) It is necessary to carry out such studies as will make it possible to define the integration of the primary and the secondary processing industries. Such an integration need not necessarily be a physical one but would involve the complementarity and specialization of their individual productions. For example the building sector could ask for structural components, such as beams and supports, directly from the sawmills; many sawmills are able to provide these to the quality standards which are required. On the other hand the production of pre-fabricated elements and components could come from the existing secondary processing industry.

   Initially, these solutions will operate to supply the first requests of the building industry. When this demand increases the processing industry must develop to a higher level of specialization in order to meet a demand which will be greater in quantity and more demanding in terms of quality.

ii) There will be a need to draw up industrial rationalization studies for plants of various sizes for the production of timber houses and elements. The purpose of this activity would be to promote the creation of an appropriate industrial infrastructure for supplying the timber construction market. In some cases the proposals would be simply for the rationalization of the existing production units, whilst in others it will involve new plants. In these studies it will be necessary to apply all the technical developments which are available or which will be generated in the technological investigation phase.

   The studies must include the following types of production units :

   a) Production units based on the existing small industries.

      For this type of plant an analysis will be made of the equipment and processes available in the small-scale or artisan-type industrial units, and the types of elements which can be produced under the existing processing conditions, or with slight modifications of these, will need to be verified.

      In these studies, and given the economic structure of these plants, the emphasis must be placed on putting forward simple drying and preservation methods.

b) Studies to adapt medium-sized factories to the production of timber houses and components.

As a result of these studies changes in the equipment and processes used in the plants in operation at the present time will be suggested. The integration of sawmills with the secondary processing lines will be given special attention.

c) Studies on establishing new and specialized plants, of various sizes, for the production of timber houses and components.

These studies will put forward designs for complete and integrated plants covering all activities from primary converting to the production of complete timber houses, including classification, preservation and drying lines.

4) The market and promotion

a) The development of local markets.

The principal criterion for success in the development of the timber housing market is that of ensuring the carrying out of housing programmes with the official bodies responsible for that sector.

This route seems to offer the best possibilities of increasing production, of stimulating private building activity and of initiating projects with reliable engineering and architectural bases.

In addition to this the carrying out of building programmes based on timber houses which have adequate technical bases requires industrial production of high quality as a result of the demands made on the builder and which are, in turn, made on the industrial sector.

- This industrial improvement, and the production of preserved, dried and classified material, requires a certain level of investment on the part of the wood processing industry, and this can only be justified when there is a demand for considerable quantities of the raw material.
- It is necessary that the technical sectors in the tropical countries which are connected with the wood processing sector should develop, in conjunction with the housing authorities, housing programmes which are appropriate to government policies.

These programmes must be carefully planned, and must involve the following aspects :

- Siting of the programmes (climatic considerations, proximity to forests and the existence of an industrial infrastructure must be taken into account).
- Typological investigations designed to ensure the acceptability of timber houses to the occupants.
- Cost aspects; these must be consistent with the financing policies in force in each country.
- Requirements in regard to appearance, economy and comfort; the programmes must provide houses which cover these requirements, so that they will be accepted on the market.
- Technical characteristics. The programmes to be developed must exploit the advantages that wood offers as compared with other materials. From this point of view experiments on guided self-manufacture and self-construction will be important, as will also be the demonstration of the possibilities of timber-based systems in regard to the progressive increase in building and their advantages in respect of building times and costs.
- Market preferences: in many cases certain groups prefer wooden houses faced with this material both internally and externally. Other groups, however, associate timber houses with temporary or provisional housing. In such a case the initial housing programmes must contemplate building houses which are timber-based but which are so faced as to appear to be built of concrete. This solution, which has already been discussed, can be realized by using cement-based exterior and interior coatings. Apart from overcoming the problem of appearance this is an advantageous result from the point of view of protecting the building against fire and biological agents.
- Promotion: the various aspects here must cover the following principal fields :
  - Preparing and disseminating simple publications designed to overcome the resistance of tenants in regard to timber houses.
  - Educational publications to familiarize university engineering and architectural sectors where, in many cases, inadequate academic instruction is received on the use of wood in building.
  - Production of technical material for the use of engineers and architects.
  - Printing of building booklets for distribution to the population generally.

POSSIBILITIES FOR INTERNATIONAL COOPERATION IN THIS FIELD

International cooperative actions will be decisive in achieving the introduction of tropical timbers as constructional materials.

Considering the enormous potential which exists in tropical forests in terms of raw materials for building houses, and the considerable housing shortage in the developing countries, international cooperation should concentrate its efforts on the integral improvement of those technical areas involved in the sector that provides constructional timber.

The following are some of the criteria which need to be stated :

- International technical assistance must promote the development of those efforts which will integrate the technological sectors and the industrial sectors. The improvements which can be made in the wood processing industry must originate in its own intensive investigations, developed to meet the local conditions.
- International cooperation must facilitate the horizontal tranfer of knowledge from those countries which have achieved advances in this field to the others. In many cases this will ensure that the less technologically developed countries will be able to economize on investigational time and costs. This transfer of knowledge should take place in the following areas :
  - Technological understanding of the raw material in all the necessary phases.
  - The drawing up of manuals and codes which include techniques for the classification of defects, systems for grouping the species and methodologies for defining design efforts.
  - Techniques in the development of construction systems.
  - Technologies for improving the industrial processes.
- Another important area which should be a reason for international cooperation is that of the development of work which would make it possible to integrate the activities of the primary processing industry with that engaged in secondary processing.

- International technical assistance should give priority to the development of industrial rationalization and technico-economic feasibility studies in order to provide for the installation of model plants for the production of timber houses and elements.
- Technical assistance should cooperate in the organization of permanent technical assistance structures for the wood processing industry, reinforcing the forestry bodies which are responsible for these tasks.
- Technical cooperation should facilitate the organization of multi-disciplinary projects which will integrate the wood sector with other industrial sectors, the housing sectors and the technical standardization bodies, amongst others.
- Technical cooperation should also be able to provide facilities for intensifying the establishment of demonstration workshops and training programmes for technical personnel involved in technological investigation in the industrial and construction sectors.

SPECIFIC PROJECTS

In the following pages are listed the basic profiles involved in carrying out projects in the following areas :

1) Technological investigations :

a) Physical properties

b) Mechanical properties :
- Static flexure
- Compression along the grain
- Compression across the grain
- Shearing
- Hardness
- Tensile strength
- Nail withdrawal resistance

c) The influence of defects on the rigidity and strength of full-scale beams

d) Stress graded beams subjected to flexure

e) Workability :

- Planing
- Drilling
- Profiling
- Turning
- Sounding

f) Nailed and bolted joints

g) Preservation

h) Air- and kiln-drying

Details of test specifications and of equipment are given in annex I.

ANNEX I

TESTS FOR DETERMINING THE PHYSICAL PROPERTIES

Objectives :

- The determination of densities : air-dried, overdried, basic.
- Evaluating tangential, radial and volumetric shrinkage between the green and air-dried states and between the green and oven-dried states.
- Determination of the equilibrium moisture content.

Standards to be considered : COPANT* 460, 461 and 462.

Number of test-pieces per species : 40 (10 trees, 4 random samples per tree). The same test-pieces may be used for the various tests, carried out successively.

Dimensions of the test-pieces : 3cm x 3cm x 10cm.

Initial state : green (MC about 35%)

Other characteristics : the test-pieces are to be of a well-defined cut (radial-tangential) and are to be free from defects. The slope of grain is to be less than 1 in 20.

Equipment required :

- Balance, with a minimum capacity of 2kg and an accuracy of 0.1g
- Electric oven, with thermostat, operating at 103 ± 2°C
- Desiccator, with hygroscopic substances

* COPANT: Comisión Panamericana de Normas Téchicas.

- Micrometer of 0.1mm accuracy
- Apparatus for measuring volumes by immersion in water.

DETERMINATION OF MECHANICAL PROPERTIES ON SMALL DEFECT-FREE TEST-PIECES

Objectives :

The evaluation of the most significant mechanical properties using small defect-free test-pieces. These include :

a) Static flexure : Modulus of elasticity and Modulus of torsion.

b) Compression along the grain : Modulus of elasticity and torsional stress.

c) Compression across the grain : stress at yield point.

d) Shearing along the grain, radial and tangential : mean torsional stress.

e) Hardness, sides and ends : force required for standard penetration (Janke).

f) Tensile strength, radial and tangential : energy needed to break a standardized test-piece.

g) Nail withdrawal, sides and ends : maximum load.

Standards to be considered : COPANT 458, 459, 555, 464, 466, 463, 465, 556, 744.
ASTM D 143-53 (1972) (Part II).

Number of test-pieces per species : 40 of each type (10 trees, 4 test-pieces per tree). For the shearing and tensile strength tests a total of 80 test-pieces are to be prepared, 40 being tested in the radial direction and 40 in the tangential direction.

Dimensions of the test-pieces :

a) Flexure : 5cm x 5cm x 75cm. In the case of trees with trunks of less than 30cm diameter test-pieces of 2.5cm x 2.5cm x 41cm (ASTM) will be used.

b) Compression along the grain : 5cm x 5cm x 20cm. In the case of trees of small diameter or high-density species test-pieces of 2.5cm x 2.5cm x 10cm may be used, and these may also be used when the capacity of the equipment does not allow the use of larger size specimens.

c) Compression across the grain : 5cm x 5cm x 15cm

d) Shearing along the grain : 5cm x 5cm x 6.5cm, notched on one face, according to the standards.

e) Hardness : 5cm x 5cm x 15cm

f) Tensile strength : 2cm x 2cm x 30cm

g) Extraction of nails : 5cm x 5cm x 15cm.

Condition of the test-pieces : 20 test-pieces of each type are tested in the green state (MC about 35%); the remaining 20 will be tested in the air-dried state, that is to say at the equilibrium moisture content.

Other characteristics : All the test-pieces are to be of a well-defined cut (radial or tangential). They are to be free from defects and plane-finished. The slope of grain is to be less than 1 in 20.

Equipment required :

- Universal test machine, controlled by displacement or (preferably) by deformation. Capacity : minimum of 10 tonnes, preferably 25 tonnes. The direct recording of load-deformation curves is desirable but not essential.
- Ancillary apparatus for application of the load and measuring the load and deformations according to the relevant COPANT or ASTM standards.
- Humidity conditioning chamber (to maintain moisture above fibre saturation point).
- Special machine for tensile strength tests.
- Apparatus for determining physical properties (see above).

TESTS FOR DETERMINING THE INFLUENCE OF DEFECTS ON THE RIGIDITY AND STRENGTH OF FULL-SIZE BEAMS

Objective :

To study the influence of defects on the rigidity and strength of full-scale beams, so as to supplement the existing information concerning timbers of similar characteristics, and to draw up a Visual Stress Grading Rule for timbers for structural use.

Standards to be considered : ASTM D 198-67 (1974), D 143-52 (1972).

Test programme :

Number of species :	5, distributed within the range of basic densities of between 0.3 and 0.8. Species will be selected which, taken as a group, present the widest range of possible defects.
Number of beams :	120 per species (as a minimum), taken from 10 different trees. All the timber is to be collected directly in the forest. Four beams are to be taken from each of three sections corresponding to the base, centre and upper part of the trunk.
Dimensions of the beams :	4cm x 14cm x 330cm.
Orientation of the cut :	arbitrary
Finish :	planed
Quality :	The beams are to include defects, singly or in combination, of various levels of magnitude or extent. The quality of the material being studied must be representative of that which would normally be encountered in a sawmill, it be understood that some of the beams would be rejected for structural use.

Condition : 50% of the beams of each species will be tested in the green condition (MC about 35%); the remainder will be tested in the air-dried state (equilibrium moisture content).

Equipment required :

- Tools for classification (slope of grain detector, knives, lenses, etc.) and photographic darkroom.
- Humidity conditioning chamber (to hold a maximum of 60 beams).
- Test frame, of 10-tonne capacity, with ancillary equipment for load application and support, in accordance with the ASTM D 198-67 standard. A universal test machine may be used with modifications making it possible to test beams with a clearance of 3 metres between the supporting points.

The equipment should preferably be controlled by displacement, but equipment controlled by the applied force is acceptable. The applied force should be measured directly, for example by means of a load-cell. Direct recording of the load-deflection curves is desirable but not essential.

- Apparatus for testing small defect-free test-pieces subject to flexion (accessories for test-pieces 2.5cm x 2.5cm x 41cm, according to ASTM D 143-52, part II).
- Apparatus for the determination of physical properties.

TESTS ON STRESS GRADED BEAMS SUBJECTED TO BENDING

Objective :

To verify the applicability of the Visual Stress Grading Rules for Structural Timber of various species considered in the programme for determining the influence of defects on the rigidity and strength of full-scale beams.

Standards to be considered : ASTM D 198-67 (1974), D 143-52 (1972).

Programme of tests :

Number of beams :	30 per species (10 trees, 3 sections per tree, 1 beam per section).
Dimensions of the beams :	4cm x 14cm x 330cm
Orientation of the cut :	arbitrary
Finish :	planed
Quality :	all the beams are to be of structural quality, according to the Visual Stress Grading Rules.
State of the test beams :	green (MC about 35%)

Equipment required :

The same as for the influence of defects on the rigidity and strength of full-scale beams.

TESTS ON WORKABILITY

Objectives :

- To evaluate the suitability of the various species for machining under conditions typical of manufacturing processes.
- To determine the most suitable conditions for working each species.

This group includes tests of :

a) Planing

b) Drilling

c) Profiling

d) Turning

e) Sanding

Reference standard : ASTM D 1666-64

Number and dimensions of the test-pieces :

a) Planing : 30 test-pieces are prepared for each species, 10 to be radially cut, 10 tangentially cut and 10 obliquely cut, the dimensions being 4cm x 10cm x 100cm.

b) Drilling : 60 test-pieces, 3cm x 12cm x 30cm, 20 of each orientation.

c) Profiling : 30 test-pieces, 2cm x 7.5cm x 100cm, 10 of each orientation.

d) Turning : 20 test-pieces, each 2cm x 2cm x 12.5cm.

e) Sanding: the test-pieces used for the planing tests will be used.

Condition of the wood at the time of testing : air-dried.

Number of tests :

a) Planing : a minimum of 12 repetitions per test-piece, planed with and against the grain and with various rates of feed.

b) Drilling : the test-pieces are divided into two groups of similar characteristics for testing at various speeds. At least two repetitions will be carried out in each test-piece.

c) Profiling : 2 tests per test-piece (with and against the grain) as a minimum.

d) Turning : 3 tests will be carried out on each test-piece, with various angles of cut.

e) Sanding : tests will be carried out on each test-piece using sandpaper of grades 60 and 100.

Equipment required :

- Planing machine : Speed of knife-holder 5000 rpm. Diameter of knife-holder 10 to 12 cms. Angle of knife-holder 30^{o} to 35^{o}. 3 or 4 HSS* knives. Feed perpendicular to the axis of rotation at rates of 3, 6, 9 and 12 metres/sec.
- Single-axis drilling machine with two speeds of approximately 500 and 1000 rpm. HSS ¼" bit.
- Spindle moulder with speed of rotation between 5000 and 7000 rpm. Knife-holder of 10cm diameter for 2 or more knives.
- Lathe with speed of rotation of approximately 2500 rpm.
- Band sander, port ble or fixed.

* HSS = high speed steel.

TESTS ON STRUCTURAL JOINTS

A. TESTS ON NAILED JOINTS

Objective :

To determine the strength of nailed joints subjected to simple shear, using 2½" and 4" nails (63 and 102mm respectively).

Standard to be considered : ASTM D 1761-74, with some modifications in the case of joints subject to double shear.

Species : Nailed joints will only be tested in the case of species with a basic specific gravity of less than 0.60.

Number of test-pieces : 20 of each type will be tested (10 trees, 2 test-pieces per tree, 4 types) of nailed joints, as described hereunder.

Dimensions of the test-pieces (in cm)

a) Joints subject to simple shear (a single nail) -

	2½" nail	4" nail
Element adjacent to the head	2 x 5 x 30	3 x 5 x 40
Element containing the point	5 x 5 x 30	8 x 5 x 40

b) Joints subject to double shear (4 nails) -

	2½" nail	4" nail
Central element	3.2 x 10 x 30	5 x 10 x 40
Lateral elements	1.6 x 10 x 30	2.5 x 10 x 40

Condition of the test-pieces at the time of testing : green (MC about 35%).

Other characteristics of the test-pieces : The elements are to be defect-free, with a grain deviation of less than 1 in 20. The finish is to be planed.

Equipment needed :

- Universal test machine, with accessories for tensile testing in accordance with ASTM D 1761 (joints subject to simple shear) and accessories for compression testing (double shear). The equipment should preferably be controlled by deformation or displacement.
- Humidity conditioning chamber.
- Equipment for the determination of physical properties.

B. TESTS ON BOLTED JOINTS

Objective :

To determine the strength of bolted joints, subjected to double shear, using 3/8" (9mm) bolts and insertion ratios of 2, 4, 6 and 8, and with different orientations of the components of the joint in respect of the load.

Standard to be considered : ASTM D 1761-74, with modifications.

Species : bolted joints will only be tested on species with a basic specific gravity of more than 0.4.

Number of test-pieces : 20 test-pieces will be tested for each of the 8 types being considered (10 trees, 2 test-pieces per tree, 4 insertion ratios and 2 orientations of the elements).

Dimensions of the test-pieces : All the elements will be 2½" (6.3cm) wide and 6" (15.3cm) long, with the exception of those loaded in a direction perpendicular to the grain where the length will be 12" (30.5cm). The thickness of the central element will be 2, 4, 6 or 8 times the diameter of the bolt, according to the case. The thickness of the lateral elements will be equal to half the thickness of the central element.

Condition of the test-pieces at the time of testing : green (MC about 35%).

Other characteristics : all the test-pieces are to be defect-free, with a maximum slope of grain of 1 in 20. The pieces are to be planed.

Equipment necessary : the same as for the nailed joints.

PRESERVATION TESTS

Objectives :

To determine the absorption and penetration of preservatives when the following treatments are used :

a) Diffusion during immersion, using borax and boric acid;
b) Immersion in 5% pentachlorphenol in No.2 Diesel fuel;
c) Immersion in a 4% aqueous solution of salts of the CCB type;
d) Hot and cold 5% pentachlorphenol baths;
e) Vacuum-pressure treatment with 5% pentachlorphenol in No.2 Diesel fuel
f) Vacuum-pressure treatment with 4% aqueous solution of salts of the CCB type.

Reference standard : AWPA A3-71

Number of test-pieces : 40 test-pieces will be used in each case, covering 10 trees x 2 types of wood (sapwood and heartwood) x 2 repetitions.

Dimensions of the test-pieces : 5cm x 5cm x 50cm.

Condition : all the test-pieces are to be initially at the equilibrium moisture content. The ends will be sealed with epoxy resins.

Other characteristics of the test-pieces : these are to be selected with a minimum of defects, avoiding the presence of cracks, splits, pith or rotten wood. All the test-pieces are to be planed and squared off.

Equipment necessary :

- Open tanks for immersion.
- Hot and cold baths.
- Preservation equipment providing vacuum and pressure.
- Refrigerator.
- Balance of 5kg capacity and 0.2g accuracy.
- Heavy plastic for wrapping (diffusion tests).

DRYING TESTS

A. AIR-DRYING OF STRUCTURAL TIMBER

Objectives :

To determine the drying times from the green state to equilibrium moisture content, the magnitude of the transversal shrinkage and the frequency of drying defects.

Standards to be considered : COPANT 460, 461, 462 and 746.

Number of species : Five, with basic densities between 0.3 and 0.8.

Number of test-pieces : 60 per species (10 trees x 3 directions of cut x 2 repetitions). These elements are to be those used in the programme on the influence of defects on the rigidity and strength of full-scale beams.

Dimensions of the test-pieces : 4cm x 14cm x 330cm.

Condition : all the elements are to be in the initial green state (MC about 35%).

Equipment needed :

- Balance of 25kg capacity and 10g accuracy
- Deformation meter with accessory to measure contractions
- Equipment for the determination of physical properties.

B. AIR-DRYING OF PLANKS

Objectives :

To determine the drying time, magnitude of transverse contractions and the frequency of defects in the air-drying of planks.

Standards to be considered : COPANT 460, 461, 462 and 746.

Number of test-pieces : 20 per species (10 trees x 2 repetitions).

Dimensions of the test-pieces : 2.5cm x 15cm x 150cm.

Initial condition : green (MC about 35%).

Equipment needed :

The same as for the air-drying of structural timber programme.

C. KILN DRYING OF PLANKS

Objectives :

To evaluate the frequency of defects with three different drying programmes.

Standards to be considered : COPANT 460, 461, 462 and 746.

Number of test-pieces : 60 per species (10 trees x 3 drying programmes x 2 repetitions).

Dimensions of the test-pieces : 2.5cm x 15cm x 150 cm.

Initial condition : green (MC about 35%).

Drying programmes

Severe programme

Woods which dry well with an initial temperature of 60°C and a final temperature of 80°C, resulting in a moisture content of 15 ± 2%.

MC (%)	Dry bulb $^{\circ}$C	Wet bulb $^{\circ}$C	RH %
Green	60	56	80
60	65	58	70
50	70	60	70
40	75	61	50
30	80	62	40
20	80	60	35

Moderate programme

Woods which dry well with an initial temperature of 50°C and a final temperature of 70°C, resulting in a moisture content of 15 ± 2%.

MC (%)	Dry bulb $^{\circ}$C	Wet bulb $^{\circ}$C	RH %
Green	50	47	80
60	55	49	70
40	60	51	60
30	65	52	50
25	70	54	40
20	70	50	35

Mild programme

Woods which dry well with an initial temperature of 40°C and a final temperature of 55°C, resulting in a moisture content of 15 ± 2%.

MC (%)	Dry bulb °C	Wet bulb °C	RH %
Green	40	37	80
40	40	35	70
30	45	37	60
25	50	40	50
20	55	42	40
15	55	37	30

Equipment necessary :

- Experimental kiln

- Equipment required for air-drying tests.

2) Grouping of the species

Objective

To establish three groups of species in accordance with their mechanical properties.

Methodology

The strength of tropical timbers as measured in tests on sample pieces shows a marked correlation with the basic density. This characteristic makes it possible that this correlation could be used for grouping together the species into specific strength groups. Due to the fact that these correlations are not so significant in the case of full-scale beams as with small and defect-free test-pieces it is important to consider, for the purposes of this grouping, tests on elements of commercial size which have been stress graded on the basis of a rule for classifying defects.

The bases for effecting a grouping of species in accordance with design stresses will involve the following activities :

1) The anotomical and dendrological identification of the species under study.

2) Technological tests in the physico-mechanical area, using small defect-free test-pieces.

3) The development of a classification rule for defects in structural timbers.

4) Tests on full-scale beams.

5) Initial grouping for densities and strengths on the basis of the technological tests.

6) Definitive grouping on the basis of an analysis of the full-scale tests on stress graded beams.

Summary

Number of groups : 3

Quality grade : 1 (structural timber)

Density range : from 0.40 upwards

Values assignable to each group :

- Flexure,
- Tensile strength,
- Compression along the grain,
- Compression across the grain,
- Shearing,
- Minimum and mean moduli of elasticity.