STATEMENTS

FREEDOM IS A FUNDAMENTAL NEED THAT CAN BE MEASURED BY THE LEVEL ON WHICH OUR NEEDS ARE SATISFIED

FREEDOM IS A COMMODITY WE SHOULD NOT TAKE FOR GRANTED

TRUE FREEDOM CAN ONLY BE ACHIEVED IN A FRAMEWORK OF DEVELOPMENT

DEVELOPMENT IS A COMMODITY WE SHOULD NOT TAKE FOR GRANTED

SUSTAINED DEVELOPMENT CAN ONLY BE ACHIEVED IN A FRAMEWORK OF KNOWLEDGE

KNOWLEDGE IS A COMMODITY WE SHOULD NOT TAKE FOR GRANTED

NEW KNOWLEDGE CAN ONLY BE ACHIEVED IN A FRAMEWORK OF KNOWLEDGE, DEVELOPMENT AND FREEDOM

A MAN CAN DIE, BUT HIS KNOWLEDGE WILL BE INMORTAL IN THE DEVELOPMENT OF OTHER MAN AND THE FREEDOM OF MAN KIND

IF WE NEED TO SATISFY OUR NEED FOR FREEDOM, WE MAY NEED TO SATISFY OUR NEED FOR SHELTER

IF WE NEED TO SATISFY OUR NEED FOR SHELTER, WE MAY NEED TO BUILD A HOUSE

IF WE NEED TO BUILD A HOUSE, WE MAY NEED TO ACQUIRE CERTAIN BUILDING KNOWLEDGE

IF WE NEED TO ACQUIRE CERTAIN BUILDING KNOWLEDGE, WE MAY NEED TO DEVELOP SUCH BUILDING KNOWLEDGE

INFORMAL BUILDERS IN LIMA - PERU ARE DEVELOPING EMPIRICAL BUILDING KNOWLEDGE BASED ON THE USE OF EUCALYPTUS WOOD

IF WE UPGRADE THE DEVELOPMENT OF BUILDING KNOWLEDGE BASED ON THE USE OF EUCALYPTUS WOOD, WE MAY BE UPGRAADING THE LEVEL OF FREEDOM OF THEIR USERS

IF LIFE FULFILMENT IS TO RISE A CHILD, SEED A TREE, AND WRITE A BOOK, WITH THE DISSERTATION "LOW COST HOUSING BY MEANS OF EUCALYPTUS WOOD", I AM ACHIEVING THE LAST TWO THIRDS. I AM SURE THAT THE REMAINING THIRD WILL PROVE TO BE THE MOST DEMANDING ONE.
LOW COST HOUSING
BY MEANS OF
EUCALYPTUS WOOD

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To my son Adrian, with love
ACKNOWLEDGEMENT

I wish to acknowledge the help and assistance of all the persons who gave of their time to answer questions, and review fragments of the manuscript for this publication.

In particular, I want to thank Prof. ir. W. J. Beranek, Mw. ir. J. I. Zijlstra and, Mw. ir. I. S. Özsarıyıldız for their encouraging assistance, their willingness to help was always beyond my expectations.

I am deeply grateful to the former promoter of this dissertation Prof. ir. L. van Wilder for his inspiring tutorial, as well as to Prof. arch. F. Ramos G. and Prof. ir. A. Krijsman for their later intervention as promoters.

Finally, I would like to thank my wife, Antonietta, for all the hard work she has put into this research, that I must consider as our mutual work and achievement.

Guillermo Vásquez de Velasco de la Puente
SUGGESTIONS FOR OUR READERS.

The document you have in hands can be accounted as a research dissertation, bibliographic reference in several subjects, and/or building handbook. The following suggestions look forward to the optimization of your reading in accordance with mayor fields of interest and the time you are willing to invest on its review.

- **VERY FAST REVIEW**
  See table of content and read the Summary that can be found at the end of the dissertation.

- **FAST REVIEW**
  See table of content and read the main introduction as well as the introduction to each of the chapters of the dissertation, finally it is advisable to read the Summary.

- **REVIEW WITH A MAYOR FIELD OF INTEREST**
  **HOUSING**:
  Read main Introduction, and Chapter I regarding Global Considerations, the Informal Builders of Peru, Morphology of Informal Housing in Lima-Peru, and Low Income Housing Design Demands. It is also advisable to review the Summary.

  **BUILDING TECHNOLOGY**:
  Read main Introduction, and Chapter IV in full. It is also advisable to review the Summary.

  **EUCALYPTUS**:
  Read main Introduction. In Chapter I read The Wood of Eucalyptus and then move to read Chapters II and III in full. It is also advisable to review the Summary.

  **COMPUTER AIDED DESIGN**:
  Read main introduction. In Chapter I read Design Demands for an Eucalyptus Building Technology.

- **COMPLETE REVIEW**:
  Read the whole document on the same sequence as presented and move back and forward as required.

For further information on any subject mentioned in this dissertation, we must refer our readers to the Bibliographic Reference or to our offices at Delft University of Technology-Faculty of Architecture where intermediate reports, articles, and background information may be available.
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LOW COST HOUSING BY MEANS OF EUCALYPTUS WOOD

FOREWORDS

MINISTRY FOR HOUSING AND CONSTRUCTION MINISTER OFFICE

Housing is one of men's basic needs not only for protection but also for his social and cultural development.

Nevertheless, an appropriate housing supply is limited by the lack of financial resources in developing countries, making more necessary the search for alternative solutions specially oriented toward the needy.

In such sense, "Low Cost Housing by Means of Eucalyptus Wood" is a work that undertakes the popular experience of using the round wood of eucalyptus globulus, well-known and extensively grown in our country, and makes a proposal for its rational and systematic use by means of a building methodology.

Our country must give special acknowledgement upon the interest and help given by the Delft University of Technology to the author of this document, institution that not only ratifies its well-known international prestige, but its spirit of social sensibility and social projection, a fact that should serve as an example for other universities located in countries with great economic potential and high level on scientific and technological development.
Finally, I want to state that this work is a contribution toward the search of previously mentioned alternatives, and recognizes the effort and resources that studies and research in this field demand, therefore we must underline the hard and dedicated work of architect MDA Guillermo Vásquez de Velasco de la Puente, as well as his former promoter Prof. L. Van Wilder.

ing. Guillermo del Solar Rojas
Minister for Housing and Construction
Perú

MUNICIPALITY OF METROPOLITAN LIMA

Lima is a city with many problems, the problem of housing is among the most urgent ones.

The housing problem of Lima has gone through several stages, that previous municipal administrations have not faced properly, resulting on an accumulative deficit of overwhelming character.

The magnitude of the problem we must face today does not permit the application of conventional strategies, the municipality does not count with the resources needed for producing a housing stock of the required magnitude, and even less, with the speed demanded by the growing population of Lima.

In historical terms, the most important contribution towards low cost housing has been on hands of the homeless population that as a response to instutional limitations has adopted a self-promotional attitude that has been subject of critics, but nevertheless, has been necessary.

The squattering of land in Lima and its outskirts is not the problem, but a manifestation of the problem itself, the dynamic generated by informal builders in Lima holds a potential that, if properly oriented, can permit a supply of low cost housing on the magnitude and schedule that is required.

In the context of a municipal strategy that undertakes the popular
tendency towards self-promotion, it is of vital importance to count with building technologies that relate themselves with such tendency.

The research made by architect Guillermo Vásquez de Velasco, important and dedicated researcher in the field of housing in Perú, captures the spirit of a new housing tendency in Latin America and offers us a building technology based on the use of eucalyptus wood giving solution to its obvious limitations and upgrading it to a level of high performance.

Personally, it is very gratifying to see how a mature and brilliant scholar, comes to be a capable professional with a vision upon the future.

The Municipality of Lima welcomes this publication.

arch. César Díaz Gonzales
Director for Urban Development
Municipality of Metropolitan Lima
Perú

ITINTEC
INSTITUTE ON INDUSTRIAL TECHNOLOGICAL RESEARCH
AND TECHNICAL NORMS.

In the integral development of Peru it is of fundamental importance to stimulate technological research at all levels.

In the level of building technologies, the rescue of native dynamics of ancient origin and their improvement by means of modern technics is of vital importance since they insure adequate relations with a context of peculiar characteristics.

The Institute on Industrial Technological Research and Technical Norms (ITINTEC), has followed with great interest, during the last two years, the development of the research carried by arch. Guillermo Vásquez de Velasco de la Puente, at the Faculty of Architecture in Delft University of Technology, Holland, regarding the use of eucalyptus in the construction of low cost housing. Perú has over
100,000 hectares of eucalyptus forests that imply obvious economic and environmental advantages since its growth rate is considered to be among the highest of the world and, in mechanical terms, it has an outstanding hardness and resistance towards structural loads; nevertheless, we use it very little in construction due to the complex technological problems that the timber industry must face at the time of preserving, drying, and sawing the eucalyptus wood.

All such aspects have been subject of deep and rational handling by this work, which represents an important contribution to our country, not only due to the analysis of alternative solutions for methods on preservation, drying, and sawing eucalyptus wood, but basically, due to the criteria that is set forward and toward reaching appropriate solutions within the present economic situation of Peru.

All the technological problems of the eucalyptus wood have been subject of research by arch. Vásquez de Velasco de la Puente, as a preliminary stage toward its application in low cost housing, and offers us valuable recommendations toward achieving the complex technical control of this wood.

Ing. Benjamín Jarufe Zedan
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Lima - Perú
INTRODUCTION

In terms of housing, Latin America is one of the Third World areas where on the last fifteen years more research has been undertaken. Such tendency may be explained not only by the fact that Latin American researchers have achieved a substantial knowledge on research methods and technics but due to the fact that on many countries of the region it is quite notorious a massive "shelter self-supply dynamic" \(^1\) that has motivated the interest of researchers all over the world.

Popular dynamics has always pointed out the path through which professionals have developed their proposals in terms of appropriate building technology, mode of production, and housing design.

In such sense we have been witnesses of "improved traditional technologies" based on native building methods; self-help and mutual-aid modes of production in relation with popular modes of production, and finally, evolutionary housing design in relation to empirical housing design criteria.

Even though methodological research has been undertaken following the

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\(^1\) "Shelter self-supply dynamic" is a term developed by the author for identifying a process by which certain social sector undertake the task of supplying themselves with a housing stock.
most notorious native tendencies, there is one of contemporary gravitation where little integrated research has been done: the use of eucalyptus timber on low cost housing.

Most Latin American countries have considerable sources of eucalyptus timber that are used mostly as fuel or by the paper industry, eucalyptus wood is not often used by the formal building industry due to several limitations at the time of working with it.

Under such circumstances the "informal housing delivery system" of many Latin American countries have found in the unsawn eucalyptus timber an inexpensive and available material that is being used on the erection of structural frameworks of temporary shelters on squatted land. Thousands of dwellings are actually being built with this noble material and empirical building technics in combination with straw mats, tin sheets, plastics bags, and almost any available or affordable material.

Understanding the growing need for proper housing that most developing societies have to face on today's world and the potential feasibility of using eucalyptus timber where ever available to alleviate such urgent demand; the Faculty of Architecture of Delft University of Technology in Holland has sponsored the present research looking forward to the development of a building technology for low cost housing by means of eucalyptus timber.

The present document holds not only the intended technological know-how for building low cost housing using eucalyptus timber but an analysis of all the marginal factors that insure practical feasibility for its eventual application in Lima - Peru and by replicability in any other location with similar context.

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2 Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Chile, Ecuador, Mexico, Panama, Paraguay, Peru, Puerto Rico (USA), Dominican Republic, Uruguay, and Venezuela.
CHAPTER I

GLOBAL CONSIDERATIONS

In order to reach a solid base on which we can establish our initial statements, we must refer ourselves to facts well accepted by all scholars in the field of low cost housing and correlated technology.

In such sense we can take the fact that in contemporary terms and in world wide basis there is people facing a so called "housing problem" that can be defined as the complex of circumstances that determine access difficulties towards a "shelter" in accordance with individual or social expectations.

Most scholars will also accept the fact that even though it is possible to detect such housing problem within almost any society, it assumes dramatic proportions in those countries where the state is far unable to cover the very basic needs of an extensive homeless sector.

Since at this stage our aim is to perform a full feedback on the very basic premises of the research, we will first study the feasibility of
approaching a given "target group" in order to establish its general spectrum and then study the feasibility of exposing such target group to a building technology based on the use of eucalyptus wood.

THE TARGET GROUP

As we previously mentioned, the existence of a so called "housing problem" is a fact on which most scholars will agree but from such broad context we must establish a narrow spectrum of the phenomena, a target group with specific conditions we can study, and even more important a target group depending on contributions of the sort we are in conditions to generate.

In order to approach our target group we should divide the global phenomena through qualitative features evaluating the need for assistance and capacity to react that each of the following global target groups are likely to have.

First, we have the group of nations where a wealthy state based on highly productive means, important material resources or heavy taxation over its population, can take the responsibility of supplying "shelters" to most of its members. Under such social arrangement the housing delivery system is shared between private investors and the state that safeguards the welfare of any individual facing limitations on its eventual access to proper shelter.

Such societies do have members facing a real housing problem due to the fact that housing needs and standards evolve faster than the institutional capability to follow and upgrade the housing stock; in many instances, social behaviour has changed very rapidly generating a housing shortage; good examples are given by the always younger age in which children intend to leave their parents home and establish an independent address, same goes for the increase of divorces that some societies have experienced over the last decade.

Nevertheless, such societies have structured very complex state mechanisms to handle their housing problem in terms of investment and distribution, counting at the same time with the important contribution of the private industry in the production and development of building material and building technologies. Therefore this is not a target group mainly depending on the assistance we can provide.

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3 Term used for identifying a specific social segment subject of survey, research, and intervention. Mostly used on sociological and/or anthropological research.
Second, we can find a group of nations where the state has very limited resources of its own and can hardly demand, if not control, a taxation revenue from its population. The result in such cases is usually a state deficit and subsequent inflation as the only way to cope with the most vital responsibilities of the state in a priority structure where housing is left aside on hands of private investors and the needy people itself.

Within such societies it is possible to find large sectors that have already discharged the possibility of access to housing through the precarious state mechanisms or expensive private offer and have started a self-supply process with almost no professional assistance other than the know-how they develop in their day to day struggle to obtain a living space or shelter.

In such conditions it has been proved that the state is able to assist on a very limited range of affairs concentrating its efforts on developing certain legislation mechanisms that usually result in highly complex procedures, more expenses for the state and little help for the homeless population.

The informal housing delivery system that is generated within such specific target groups is an equally complex dynamic that has no proper articulation with the formal legislation of the state, formal building technology of the private building industry, formal design practice, and urban structure; resulting on an evident conflict that demands urgent alternatives of conciliation.

The informal builders of the societies we have just described are in general terms the target group we can compromise ourselves to assist, at least they seem to have the need for assistance and have the capability to respond actively.

Finally, we must face a group of nations in which the state counts with even shorter resources to cope with a housing supply dynamic and the population itself struggles to satisfy the essential need for food. Such nations are usually subjects of the aid that some wealthy nations can provide as means of subsistence. This target group has obviously the need for the assistance we can provide in technological terms but can hardly react actively since more urgent needs are still unsatisfied. We must not discharge the possibility of assisting such target groups with a given building technology, but in realistic terms, it seems quite theoretical at this moment.

In global terms, the ideal composition of our target group is based on the large group of people that are actually or potentially building their
own precarious shelters (informal builders) showing through such dynamic their need for technological assistance and capability of related action.

THE BUILDING TECHNOLOGY

One of the key factors generating and maintaining the so called "housing problem" is to be found within the relation of technical standards and building costs.

Technical standard is a term that has been openly used to imply the overall quality of a dwelling misleading to a complex and not always clear understanding of its real spectrum of variables. For us, technical standards implies a restricted spectrum of features directly related with the performance of a dwelling in relation with the environment and its user, such as acoustic performance, thermal performance, durability, fire resistance, shock resistance, etc. Other features as social acceptability, social impact, etc; should be handled separately.

On the other hand, building cost is sometimes understood as the overall cost that a given dwelling implies. For us, it only implies the costs related with the actual process of erecting a dwelling. Other costs, as those of land, maintenance, etc; should be handled separately. If we understand the fact that building a house is possibly the largest investment that any member of our target group will make during his life time, it becomes quite understandable that the decision making process leading to the election of an affordable technical standard is a very complex one.

Within most societies we can find a fix relation based on the so called "building codes" that imply a rigid technical standard that must be achieved through the use of formal building materials and technics, but unfortunately our target group is far from considering such relation as affordable.

Within the reality of our target group a new affordable relationship must be arranged by means of all interacting variables.

If we review previous attempts to arrange a new affordable relation for specific target groups of the kind we are working for, we can find several basic tendencies.

1. MANIPULATION WITH THE COST OF BUILDING MATERIALS

Building materials are market goods that respond by their price to
their cost of production, and the basic rule of offer and demand. The attempts to arrange a reduction on the price of conventional building materials has been through:

Increase of industrial productivity

In theoretical terms an increase on productivity would reduce production costs and modify the balance between offer and demand, but to do so it is needed to create confidence on investors and employers, thing that is not easy in developing societies where profits are hardly re-invested but exported towards more stable markets beyond taxation control. In some cases productivity has been increased in the direction of better quality increasing its marketing price instead of reducing it, in other cases a higher productivity has resulted in a large offer that has affected in a reduction of price, making more interesting the external market of exports, eventually internal shortage of building materials has reverted on price increases.

State control of prices

There have been attempts to control the price of building materials through a direct action of the state, but the reaction of the industry has always been the one of restricting any further investment and instead of following state regulations it has reacted violently resulting on strikes, personal cut-downs or the simple overstocking and creation of a black market for their product. Sometimes the state has intervened in the delivery system itself by buying and selling with subsidies, but such policy has been far too expensive to maintain for a long period of time.

Since obtaining a reduction on the price of conventional building materials has proved to be extremely difficult to achieve, many attempts have been made to develop non-conventional materials, obtaining a certain level of success.

Highly industrialized materials in the field of heavy and intermediate pre-fabrication have proved to result on a cut-down of building costs but because of been related with highly complex building technologies, its use has been limited to state housing programmes and the formal building industry with no impact on the informal builders that usually lack of technical assistance, sophisticated tools and heavy equipment.

Light pre-fabrication has proved to be more successful within our target group, specially if such materials have been used first by upper social sectors with careful professional assistance insuring their best behaviour. Such materials have eventually been used by our target
group but since light prefab components are sold with no correlation to an integral building technology or professional assistance on their application, the results have been precarious.

The development of upgraded traditional materials have also shown a certain level of success, the use of locally available materials is already an indicator of a possible cut-down on production costs. On the other hand, even though the low technical behaviour of such materials has been improved, a low social acceptability has strongly limited their use.

Through this short review of attempts to reduce the cost of building materials it is clear enough that the more promising tendencies are those on the direction of creating light prefab-components and development of improved traditional materials, however the need for technical assistance remains as a problem on the first category and social acceptability limits the second one.

Our approach should be in such case to rescue the positive features of each tendency making use of the good acceptability that certain light prefabs may have together with the low cost that improved traditional materials may achieve.

**2. MANIPULATION WITH THE MODE OF PRODUCTION**

The attempts to reduce building costs through manipulation with the mode of production have found a key feature on the so called "self-help dynamic".

A self-help mode of production implies the intervention of the user on certain building role replacing the cost of a given actor in the process, therefore it is possible to consider different levels of intervention.

Self-help can cover dynamics of very different characters, we can consider dynamics going from self-management to self-building implying different costs by mode of production. Even though the building costs may vary substantially, the process of capital accumulation remains intact as an ingredient of enormous importance for a target group as ours.

In societies with high un-employment rates or non-official un-employment, which is worst, people will greatly welcome the possibility of investing their un-used or under-paid working force in a process that will result on a good of clear aggregated value.

Our approach in relation to mode of production should undertake a self-
help tendency since it is already present as characteristic of our target group and indeed benefits the achievement of an affordable building cost.

3. MANIPULATION WITH TECHNICAL STANDARDS.

A reduction on the technical standard of a house will obviously be an important feature on achieving a lower building cost, but not necessarily a better relationship between such standard and its cost; for our target group a house is not only a good meant for consumption but a capital good and a low technical standard may result contradictory with their ultimate objective of financial consolidation.

It is possible to demonstrate that building technics resulting on an immediate high technical standard are not affordable due to the short term investment required, and houses with definitive low technical standards are not attractive to say the least.

An intermediate position on this regard has proved to be successful; actually, informal builders accept a very low standard dwelling as starting point on their process of self-building a precarious dwelling that is later replaced by a high standard dwelling that is built through a very slow and painful process.

On this case the praxis of informal building pin points which should be our approach to the subject; our proposal should involve a building technic able to perform evolutions from the generation of a low technical standard dwelling to a house of high technical standard through an addition of events instead of a chain of replacements with an obvious misuse of materials; we should also intend to reduce the consolidation process in terms of time.

4. MANIPULATION WITH HOUSING DESIGN

Housing design has always been the first target of those compromised on offering an affordable house for low income target groups, fact that is quite understandable if we consider that on 1980 more than 60% of the scholars working in the field of low cost housing had a background on architecture.

Housing design theories for low income target groups have developed

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4 Field surveys have shown that self-help adventures imply an average of 20 years before final consolidation is achieved.
5 Data based on research personnel of housing related institutions in Lima - Peru.
through many years of experimentation; the initial theory of "minimal built areas" has been complemented by those of evolutionary growth, high flexibility index, and transitory structures.

Most contributions have proved to be successful to a certain extent and it seems likely that through the application of a blended theory it may be possible to achieve a 100% of impact on our target group.

On global terms we should concentrate on the development of a building technology based on the following criteria:

A. A blending of improved traditional materials and light prefabricated components.
B. A mode of production based on self-help building methods.
C. A technical standard able to perform evolutions from low to high by addition of events on an affordable span of time.
D. A housing design theory based on rational use of built area, evolutionary growth, high flexibility, and transitoriness.

Our target group and intended building technology have been defined on global terms; now we must narrow our horizon on both aspects to achieve a spectrum of homogeneous characteristics and more specific correspondence.

It is clear that we are searching for a low cost traditional building material that could be subject of a substantial improvement on its performance and a target group within the informal building sector of certain developing country with local access to such material.

Stone and wood have been well known building materials since the most ancient times, this is a fact that needs no demonstration since our daily life is constantly confronted with extensive evidence, furthermore, we can find that most of the so called traditional building technics that have survived until our days do make use of related materials.

Wood is a building material of un-disputable convenient behaviour due to its versatility and availability, but actually not all kinds of woods have been considered appropriate for building purposes, among those, perhaps the eucalyptus wood is one of the most abundant.

On 1955 the area covered by eucalyptus trees was considered to be approximately 700,000 hectares; but due to their high adaptability, strength, growth speed and other features we will discuss on further detail in other sections of this dissertation, the eucalyptus population.
OVER: E. Globulus forest growing on top of a garbage dump at the outskirts of Lima
OVER: Shanty town on early stage of consolidation at the outskirts of Lima

UNDER: Informal trading of eucalyptus poles and straw mats at the outskirts of Lima
SIDE AND UNDER:
Stock of E. Globulus in deposit of building materials at Lima
has grown to well over 4 million hectares (1981) and distributed over 58 countries.  

The eucalyptus wood is mainly used for other purposes but building, actually 85% of the reserves are used for fuel, paper, and other industrial purposes, 10% for poles of several dimensions and 5% for sawn timber.

The reason for avoiding the use of eucalyptus timber in the formal building industry is to be found on several inconvenient features of its workability, for instance: growth tensions, drying contractions, tendency to crack, and twisted fibbers.

Nevertheless, there are several traditional building technics that make use of eucalyptus poles as structural members; many rural communities have used such technics in the Andes mountains of South America, and today, there are some how used them for the building of precarious shelters in squatted land on the outskirts of Latin American cities.

If we assume that it may be possible to improve the workability conditions of eucalyptus wood without implying an overwhelming increase on its production cost; its potential availability, price, and acceptability gives us full support to assume that such material may be used for the development of an appropriate technology for an important section of our global target group.

The fact of finding a tendency towards the use of eucalyptus timber as building material in Latin America is not a matter of coincidence, actually the largest reserves of eucalyptus are located in Brazil with over 1 million of hectares and Iberoamerica holds more than half of todays world reserves.

Among the many species of eucalyptus that have found proper settlement outside their native Australia, the Eucalyptus Globulus subspecies Globulus is the most extended one with an area of almost 1 million hectares; its wood is highly appreciated for straight poles, railway sleepers, paper and fuel.

The largest reserves of E. Globulus in Latin America are located in Peru with an area of about 100,000 hectares; Argentina, Bolivia, Colombia, Chile, Ecuador, and Uruguay also have reserves of E. Globulus.

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6 Sources: FAO records.
Blending the facts that Iberoamerica is the group of nations with more extensive plantations of eucalyptus, Latin America shows a clear tendency on the use of eucalyptus as a building material. E. Globulus is the most extensively planted species providing good straight poles and that Peru holds the largest Latin American reserve of such species, we can say: "The horizon of our research will be specific on the study of the wood of Eucalyptus Globulus subsp. Globulus as building material on the production of affordable housing for the informal builders of Peru".

I.1 THE INFORMAL BUILDERS OF PERU

Historical, cultural, and geographical conditions are a strong link among human societies that have defined common patterns of development. Latin America is one of such group of nations that can be considered as an analytical unit for overall social studies.

Having a common historical heritage within the Iberian colonial structure of the 16th century, Latin American nations have developed a quite similar social structure that can be traced through their social manifestations and maybe the most notorious of such manifestations are their cities.

Actually, if we want to describe with a single word the common physiognomy of many Latin American metropolis, maybe the one nearest to a consensus would be "anarchy". Overcrowded and decaying downtowns, proliferation of slums and shanty towns with unarticulated distribution of activities are the common features that any visitor will notice as the tip of an iceberg that has been building up very rapidly and eventually will continue to grow at an accelerated rate during the incoming decades.

The apparent chaos that the citizens must face on their day to day struggle to make a living seems to control the urban scenario and most of the activities it was aimed to support, trade and industry, recreation and housing, to mention a few, have became activities of a very peculiar social context that is far from the former context they originally had.

But the citizens of Lima, Bogota, Guayaquil, Caracas, Santiago, Buenos Aires, and others, are not strangers to the "new state" of conditions; as a matter of fact the "new citizens" are the main promoters of a "new system" developed in accordance with their needs and limitations, a complex that is very different from the one of the "former citizens" and their "status quo".

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We must face the fact that Latin American cities are witnessing the conflict of two societies moving in parallel, sharing a common geographical environment that is being transformed as they struggle for supremacy and a better position on the relations they necessarily develop. The coexistence of this two societies and their correlated activities are generating a new Latin American social and therefore urban order that scholars are starting to study and understand as the formal and informal faces of an unitarian reality.

The informal sector in Latin America is historically generated by a coincidence of circumstances that go far back in time but became physically notorious about 40 years ago when unprecedented rural-urban migrations started to be evident. Latin American societies are dramatically changed from an agricultural historical tendency to a urban economy that is not able to cope with the speed of changes. Peasants in the rural areas are confronted simultaneously with a poor environment characterized by lack of profitable jobs, basic services, and expectations of improvement on their quality of life, at the same time that cities showed themselves to be the land of opportunities and eventual prosperity.

Rural-urban migrations in the Latin American context have been deeply studied ever since the phenomena was detected, scholars have developed quite detailed studies of the subject pointing out the triggering motivations of the process; we have done such kind of analysis as part of the research entitled "The Peruvian Process of Urbanization as a Tool for Development in Lima", study in which the dramatic uneven distribution of wealth and services is shown based on the specific case of Peru and its capital city, therefore we will only state here that such migrational phenomena is the result of a complex decision making process and not an arbitrary decision as many have suggested in the past.

The important fact for our present study is that the presence of rural immigrants in Latin American cities was not welcome, on the contrary, the legal system of the formal urban society took a hostile position pretending to ignore what was a notorious reality and later trying to detain a process that was inevitable according with the context that same formal order had generated.

The states neglected on supplying proper shelter and job opportunities for the incoming and growing population; the army and state bureaucracy was increased in order to absorb a relatively small

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7 Master's degree dissertation by Guillermo Vásquez de Velasco / University of Toronto - Canada

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proportion of the un-employed and reinforce their control mechanisms over the rest of the population up to a limit in which that same legal complex left no other possibility but to develop new ways of satisfaction at the margin of the legal and formal system.

In such way the informal sector starts to develop and grow in the latin american context, giving its back to the society that rejected them and the hostile legal system that rules their discrimination. The informal sectors are left on their own, counting only with their imagination and working force, with little economic capability other that the one they can generate and rotate, no technical skill other that the one they can develop at the time of facing the uncertainty of making a living without the protection that the formality offers to the rest of the society.

Even though the manifestations of an informal system have been present in the latin american panorama for a long time, it is only a few years ago that scholars have acknowledged its importance and need for in-deep understanding; measurements of the informal share in latin american economies have been made finding that maybe the most dramatic development of the system is taking place in the context of the peruvian society where a 47% of the national economy has proved to be informal.

Since we have already identified our specific target group within the informal sector of the peruvian economy, we will concentrate our analysis in such specific context on search for relevant variables.

HISTORICAL EVOLUTION OF THE INFORMAL SECTOR IN PERU

The historical evolution of the informal sector in Peru can not be explained in isolation from the social, political, economic, and legal evolution of its formal sector, actually it has been demonstrated that the rigidity of such order is ultimately the overall generator of the exceptional strength that the informality had to develop in order to co-exist in a shared environment.

The geographical context in which peruvian history is based has been subject of a very peculiar sequence of formal structures aimed to rule the social, political, economic, and legal life of an extensive territory.

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8 Target group identification procedure can be reviewed in this document under the title "Global Considerations".
9 In-detailed demonstration of such statement can be found in the book "El Otro Sendero" (See bibliographical reference)
On 1100 A.C. the city of Cuzco was centre of the Inca Empire and its political-religious order, a complex of formal structures able to conquer and control a huge territory and population was developed. With the arrival of the Spanish conquerors such formal structures were transformed into an even more rigid order aimed to rule over all Spanish possessions in South America, the city of Lima became the centre of such order in a urban network intended for the recollection of wealth and its transfer to Spain.

Three centuries later the Latin American war of independence resulted on sovereign republics but the role of Lima remained to be the one of wealth gathering centre, a wealth that was not longer transfer to Spain but to the capitalist empires of the world and the ruling elite of former citizens that support the sustenance of such order.

In such way Peru never had an economy of production, actually its economy is more the one of social market based on the redistribution of wealth and not the generation of it. The State had to follow a game by which legislation was aimed to gain the favour of small pressure groups and against the interests of the majorities that were left at the margin of their share of wealth.

The system was not only immoral but un-efficient since its complex legal structure was a strong limitation for the formal development of productive means at the same time that it reinforced the proliferation of non-productive activities and a parasitising bureaucracy.

The rural activities had to take the heavy load of producing most of the wealth that was to be distributed in a city of precarious industrial development, and get very little in return; the gap between quality of life in the city and country side was stressed to a limit that finally resulted on massive migrations from the rural areas into the cities.

In such way the urban population was increased at a rate beyond precedent; on 1700 the population of rural areas was the 85% of the national population, on 1876 it was 80%, and on 1940 about 65% but on the last 50 years the figures have been inverted and today only 35% of the national population remains in the country side.¹⁰

The growth of the population in Lima shows the most dramatic figures since migrations were specially directed towards such city, and further more, the natural growth of such population was increased on more than a double; on straight figures Lima had 602,000 inhabitants on 1940 and today holds more than 5 million souls.

¹⁰ Sources: Peruvian National Center for Statistics
The reaction of the system towards the incoming population was hostile to say the least, actually the formal system was designed so the city could live from the productivity of the rural population, population that was abandoning the fields and migrating to that same city with the goal of making a living out of it.

For a city of precarious industrial development and decaying economic revenue from the country side it was very difficult to fulfill its obligations of providing jobs, housing and services for such increasing population. Immigrants had to find their own way of coping with an environment and system that gave them no opportunities of prosperity and in such way they had to develop a different system far from the formal one but fully coherent with their expectations, skills and limitations; an informal system started to grow and develop until becoming a complete structure covering all activities of a modern metropolis.

Every urban activity has been duplicated by the new system, and further more, formal and informal people have developed relations of mutual benefit within a complex structure where there is no 100% formality or informality.

The formal industry saw the development of an informal industry that started to buy semi-processed goods from them, at the same time that they found out that other informal industries were able to offer them the same kind of deal in competition with formal suppliers; in such way, for instance, a textile industry was selling fabrics to an informal clothing industry and buying parts from an informal metal-mechanic workshop. Relations have been sometimes of direct competition, for instance, one of the most notorious cases has been seen within the shoe industry forcing the formal sector to re-structure themselves.

Formal commercial activities were also subject of informal replica, the primitive street vendor has evolved not only into areas of permanent fairs but into commercial centres of formal appearance; informal traders are supplied by formal and informal industries in the same way that formal shops are supplied by merchandise of both origins. Banks are confronted with informal money lenders and hundreds of money exchange brokers that operate on a "formal black market" 11 basis.

Police is replaced by community self-defense and justice is exercised.

11 "Formal black market" is a term developed by the author for identifying a black market structure that operates under implicit state recognition.
on a community basis as well, on extreme cases murderers are put on hands of formal authorities but crimes like child abuse are punished by death in a country where there is no formal death penalty.

Urban transport is almost completely informal making most of the urban activities dependent on such powerful informal union.

Informal people offer all kinds of services, health is supplied by means of exotic herbs at the same time that doctors work within the informality of their homes to avoid taxation, education on many subjects is available in informal establishments and even bureaucratic procedures within government and institutions of legality are linked with sub-structures of informal red-tape professionals.

Informal services imply fixing a dripping pipe in the sink of your kitchen, lending you money to buy a Volvo truck or building for you a new house in a formal or informal urban development scheme.

The fields in which informal activities have developed more strongly are those in which formality has neglected an affordable coverage of the market; for instance the formal commercial establishments used to work with high overhead costs as result of their formal status and high profit index in compensation to a limited demand resulting from a society in which middle class has a very low purchasing capability; middle and low income groups of the population were lacking of an affordable offer and only informal traders with almost non overhead costs were able to reach such affordable levels.

In the field of urban transport and housing, not only the formal practice but the state neglected an affordable offer on price and magnitude leaving a large proportion of the population with no other offer than the one provided by informal activities.

In order to give our readers a more complete picture of the context in which our target group is involved we will continue to analyze the structure of the informal practice in the fields of commerce and transport as main economic sources of the global target group and follow to the study of the informal builders and urban developers as specific targets.

INFORMAL COMMERCE

The history of informal commerce in Lima has been a long and painful one that started with street vendors of fruits, flowers and other very specific products going from door to door in the wealthy neighbourhoods of the colonial city.
The charisma of such traders was not rejected by the formal society and actually it was accepted as a convenient service from needy people, even a kind of cultural patrimony that was captured by painters 12 and writers 13 in the early republic.

The attractive price at which ambulatory commerce was making its trade resulted on a growing concentration of the activity in the poorest areas of the city allowing at the same time a certain diversification of the trade.

The activity grew with little changes in its dynamic until the 1940's when rural immigrants started to overtake the activity on a more aggressive way, the magnitude of ambulatory commerce reached a point in which it was not possible to continue with a door to door approach that was creating discomfort on the consumers, limiting the assortment of products to be offered and eventually creating conflicts for trading jurisdictions; in such way the original ambulatory commerce took the streets, plazas, and parks establishing their business on a static fashion.

The formal society went in conflict with this new approach and ever since the authorities have not been clear on their position, some have undertake repression and other have supported them, the state government and municipality have played a sort of tennis game with a situation neither of them understands fully and finally no one has faced the social and political cost that explicit actions necessarily imply.

As result of an ambiguous position of the authorities, on 1953 the municipality stated a tax called "sisa" that gave the informal traders no right over the street but do gave eventual license for their operations; such tax gave informal traders the certainty they needed for expanding further and create informal unions for the protection of their implicit right over specific locations generating a change of use and value in certain streets.

Today, informal traders with base on the "sisa" tax payment and union organization can rent, sell and even arrange mortgages over their specific locations in the streets of Lima.

The municipality on 1984 was receiving by concept of "sisa" a rent that was 70% higher than the one it was obtaining from the formal sector of traders; in the context of a very needy municipal government is very unlikely a return to repression.

12 Water colours by Pancho Fierro.
13 Publications by Ricardo Palma.
On 1986 it was estimated that more than 400,000 inhabitants of Lima were directly dependent of ambulatory commerce. There were 91,455 registered street vendors and almost 80,000 informal establishments in 274 informal markets and fairs.

In average, an informal trader earns 38 times more than a formal worker under basic salary, therefore it is not surprising why ambulatory commerce is growing so rapidly.

Informal trading is a good business for merchants, consumers and the municipality; the system has found a structure of mutual benefit on depredation of the formal sector that has to compete on an unfair position or move into a different market as it is happening already.

INFORMAL URBAN TRANSPORT

The participation of the informal sector in the field of urban transport in Lima has been overwhelming and implies a peculiar experience that must be understood as an example of informal evolution.

Urban transport in Lima has evolved more in accordance with historical circumstances than with technical planning, therefore, it has been subject of a kind of free enterprise approach that left open doors to the informality.

Historically, massive urban transport is first established by means of rail-wagons pulled by horses on very basic routes that were followed by electric trams; such normal and coherent development was confronted with the overcoming of motor cars and a explosive expansion of the city that soon resulted on formal enterprises giving public service on adapted trucks.

The cost of extending tram routes at the rate in which the city was growing in simultaneous with an already notorious state deficit, evolved towards the political decision of leaving the tram infrastructure on its own for self-destruction and change the state role of supplying transport into the one of controlling the transport private enterprises in operation.

The political intervention of the state in such enterprises, its control on tariffs, and inefficient support on return was disastrous for the formal sector that started to lose ground at the time of competing with an emerging informal sector of individuals making public transport on sedan cars.

14 Sources: In-field survey by the author.
Informality started to grow very rapidly following the disappearance of formality in the sector and the accelerated growth of the city, informal people got organized in "comities of route" in order to improve their productivity arranging frequencies, buying parts in block transactions, owning fuel stations, and mechanic workshops.

A union and national federation of urban transporters was created as a very powerful structure to allow the informal transporters a direct negotiation with the government, and obtain its support on aspects related with the import of larger units and fuel subsidies but on counterpart the state started to pull the unions into a bureaucratic and political structure they were not aimed for.

On 1980 the negotiation between government and unions resulted on an agreement by which informal transporters obtained a "sui generis" legal framework that was supposed to solve their limitations, but implied all sorts of controls; from 1980 to 1984 the tariffs were reduced on real terms about 15% below those of 1975-80, at the same time that their international debt by concept of new units was affected by a devaluation of 1676.5%.

Unions were forced to a cannibalistic practice in order to maintain operational units on the streets, at the same time that further extensions on the routes were required; a new deficit on the transport offer was generated and as usual informality was there to cover the demand at margin of any legal form.

A new generation of informal transporters emerged under the denomination of "pirates"; conflicts for the exploitation of routes and standard of the service are issues still pending over such informal practice as the "pirates" follow to grow and undertake the role of the former informal transporters.

In Lima the informal transporters operate in total more than 16,000 transport units covering 91% of the offer; the replacement value of their units is of 620 millions US dollars which means about 40% of the national budget for public works, and their infrastructure has been evaluated on over 400 millions US dollars.

INFORMAL HOUSING AND URBAN DEVELOPMENT

During the four last decades, Lima has grown on a 1200% in order to match the requirements of its always increasing population, but the amazing fact is that such growth has been mainly based on informal urban development.
Informal urban development is an old practice in the context of Lima but its dynamic has evolved on an unprecedented way transforming the initial approach into a expanding activity that has become strongly popular.

Historically, all started at the turn of last century and even before the peruvian republic was known as such; plantations on the outskirts of the colonial city had to supply housing for their workers and to do so they used to build lineal quarters of very restricted privacy that were soon left for independent precarious shelters made by the workers themselves.

The owners of the land had no complains since the former quarters were left to house more workers, but the dynamic did not stop there, it continued to expand into further developments by which relatives and friends of the workers started to build on land of the plantation as the formal growth of the city got nearer to their location.

This structure of "slow invasion" of private land was not subject of repression, the owners of the squatted land did had complains but the state was not ready or willing to make a political decision on such regard.

On 1932 a flood of the Rimac river destroyed an informal settlement that had been growing based on slow invasions, the state had to react by relocating the population on the slope of a near mountain. The relocation was supposed to be temporary, but the implicit acknowledgement that the state had to make about such invasion was a triggering event, that not only resulted on the permanent settling of that population but a change of attitude among potential squatters; at such time, 4 out of every 100 houses were informal.

Ever since, the state has maintained an undercover relation with squatters in order to capture their political support; they have played a game of giving and not giving, generating a situation in which both parties study their moves as in a chess board.

On 1945 the first wave of violent invasions hit Lima squatterizing state owned land, the approach was quite simple and the population relatively small, the process of invasion took several days before gathering a minimal critical mass of people that usually had conflicts among themselves for delimitation of "seudo-properties" 15; certain

15 "Seudo-properties" is a term developed by the squatters of Lima for identifying their individual plots before any legal property recognition is granted.
level of repression was exercised, but on the balance 9 out of every 10
invasions resulted successful. On 1954, 28 out of every 100 houses in
Lima were informal and 7 years later the figure was increased to 41.

On 1961 the state made its first real move towards incorporating
informal dwellers into a structure of legality, but the approach far
from reaching its goal of bringing the informal dwellers into formality
and limit further developments of the dynamic, was a stronger
acknowledgement of informality that gave a higher certainty of
success to more potential squatters. On 1968, 57 out of every 100
houses were informal.

Between 1968 and 1970 a "Military Junta", that took control of the
state breaking a precarious constitutional order, undertook the
approach of strong repression against squatters, 80% of all invasions
were suffocated by force. The approach resulted on a new generation
of squatters that had to organize themselves in more sophisticated and
complex ways in order to be successful on their enterprise.

On 1971 the largest invasion of peruvian history took place in an area
known as "Pamplona", the repression over tenths of thousands was
unsuccessful resulting on 1 death and many injured, a catholic priest
came in support of the squatters and made a mass for the soul of the
victim, the authorities followed to put the priest in jail but soon
found out that the measure had been so unpopular that they had to
release the priest, request the resignation of the minister in charge,
and promise a convenient relocation for the squatters. The failure of
the state on understanding the phenomena of invasions brought down all
its defences; more invasions followed almost immediately and on
1975, 62 out of every 100 houses were informal.

In parallel to violent invasions over state owned land, the same
military government undertook an agrarian reform that was badly
introduced among plantations on the outskirts of the city; the former
owners of agricultural land started to sell their properties at margin
of legality, and associations of potential squatters started to buy at a
low price and simulate invasions that were not repressed since the
land was still private and the owners never made strong complains; in
such way more than 3,400 hectares of agricultural land have been
subject of informal urban development and more than 260 associations
have operated illegal transactions on the undercover of simulated
invasions.

On 1979 the state approved a law by which informal settlements could
become formal neighbourhoods of the city, stating a complex
bureaucratic procedure that informal dwellers have learned to handle
on their behalf as a fully economic and social activity.

On 1984 the municipality of Lima undertook the experiment of guiding an invasion in an area called "Huaycan", the authorities tried to manipulate the dynamic but on the process they did not evaluate properly the critical mass of potential squatters generating over-invasions and disputes among former squatters and late squatters; usually, on the original dynamic, late squatters are welcome to reinforce the minimal critic mass against repression, but on this case since repression was not likely the population has returned to primitive fights for the seudo-property of plots.

Today it has been calculated that 70 out of every 100 houses in Lima are informal with an average replacement price of 22,000 US dollars per unit; this means that informal dwellers have invested about 8,319 million dollars at the same time that the government has invested 173 million dollars on low cost housing; on other terms, the housing delivery system directed towards our target group has been covered on a 98% by the informal sector.

Further from understanding the magnitude of the dynamic in which our target group is involved, as we develop an appropriate building technic for their practice, it is essential we understand the peculiar process through which they achieve their objectives.

The invasion of state owned land or private property is key and common feature of all informal urban developments, and it has been proved that it starts long time before the actual invasion takes place. The dynamic is motivated by the need of proper housing and a private patrimony on one hand, and the convenience of investing a spare or underpaid labour capability in a process able of adding value to a certain land and construction materials.

In the beginning, a group of people strongly motivated by any of the previously mentioned reasons and with some kind of previous relationship (people of a given slum, people living as tenants in an old shanty-town, people of a common rural origin, people working together on any given activity, people that have been involved on previous invasions) will get together and identify a piece of land suitable for invasion or marginal negotiation.

In order to achieve a minimal critical mass able of performing an

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16 Sources: In-field survey by the author, part of the Master's degree dissertation "The Peruvian Process of Urbanization as a Tool for Development in Lima" (See bibliographical reference)
invasion, they will consider the participation of an architect, engineer, or student on any of these disciplines that will make a basic plan of the site with a given subdivision of plots, and open a list in which all the people interested on taking part on the invasion will register themselves; usually there is a registration fee that has to be paid for common expenses but the fact that such fee is increased as they reach the minimal critic mass points towards understanding that the whole dynamic has a speculative business-like approach.

On the case of an association intending to buy illegally a given agricultural site, registration implies strong payments aimed for negotiation with the owner of the land but until the association reaches a minimal critic mass they operate as a kind of cooperative that gives loans and makes a profit at the same time that gives them a legal platform over which they are entitled to issue "notes of deposit".

The registration list is a document of enormous importance implying the individual extra-legal right over the land to be invaded and can be considered as the relation of parties in a "contract of invasion". Once the minimal critic mass is completed, the directing committee will determine a specific date for the invasion (usually a civic holiday), the name of the new settlement (usually the name of a civic personality), and notifies all its associates on a basis of 24 hours in advance.

Some times the services of lawyers are used in order to make an official request for legal adjudication of the land to be invaded, and present such document at the municipality some hours before the actual invasion. The invasion usually takes place after 10:00 pm and is started by the arrival of men with specific functions, some will guard on the limits of the site armed with eucalyptus poles, some will make lines with a solution of white paint that is poured in tins specially provided of holes for a fast delimitation of plots, and others will build precarious shelters of eucalyptus poles and straw mats that will insure a common place for cooking, keeping the youngest children, and meeting with any visiting politician or authority.

The rest of the population arrives some time later in trucks, cars and any imaginable mean of transportation bringing some of their belongings, eucalyptus poles, and straw mats in order to build their initial houses; each family moves directly to "their" pre-assigned plot and starts building, while some women take care of the children of the whole settlement and maintain a constant flow of warm drinks, among

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17 24 hours was the time margin used for giving notice to the author during an actual invitation in which he acted as an observing-squatter. According with a later survey it was considered as an average margin.
them the "rooster", blended of coffee and Coca Cola that maintains them awake and on dynamic attitude.

Next morning the site presents a peculiar morphology of precarious dwellings but clear distribution of plots and streets, the media has been informed, and the directing committee is ready to receive the visit of the authorities holding on their hands the relation of former squatters, a formal request for legal recognition, or even better, a copy of a request already presented to the municipality, and a home-made feasibility study for water, sewerage, and energy networks. A squad of men carrying small eucalyptus poles maintains the good order and prevents any external repression.

In the case of invasions over state owned land, new squatters are welcome if they agree with the "invasion contract" increasing the critic mass, and the whole population maintains a busy attitude until it is agreed that no repression or relocation will be undertaken. From that moment and on, the directing committee will be engaged on a long process of legal and bureaucratic procedures in order to obtain first a global recognition as "Pueblo Joven" (Young Town), and final individual property. At the same time, the population will start to replace the initial house of eucalyptus poles and straw mats for one of brick and reinforced concrete using to do so a self-help mode of production that in average takes about 20 years to be completed.

Through the time of consolidation, people will sell, rent or even arrange mortgages on peculiar ways over the house on constant process of construction; it is well understood that the house is private property even if it is located on land of the community.

A growing sector that at the same time is involved in the organization of the invasion has found a way of self-employment on the dynamic. Their specific trade is to first arrange and promote a certain invasion, build a precarious shelter on the back of the plot where their families will live while they build a house in the front; as soon as the first floor is finished, they will move in and rent the shelter of the back at the same time that they start building a second floor for other tenant. As soon as the 2 levels are finished and the neighbourhood has been improved, the house can be sold and the process will start all over again in a new settlement but with a certain capital that will insure a faster process on a revolving dynamic. On extreme cases an informal housing developer will have more than one house in construction based on the capital he can supply to a neighbour squatter that will give his name for the registration list and build a house on a partnership basis.

In an overall view, we can say that our specific target group is not
only committed to a housing self-supply dynamic, but immersed in a process of informal urban development and informal housing development that results on an affordable housing offer for our global target group.

1.2 MORPHOLOGY OF INFORMAL HOUSING IN LIMA - PERU

Most professionals in the field of housing will recall the common said "a house is the face of its owner", and in a certain way such said resumes the fact that a house is not only a good intended to satisfy a basic need for shelter, but balance of the expectations and limitations that an individual or its family may have at a given time.

Sociological studies have shown that most people tend to hide their reality from society as a mechanism of self-defense, achieving less vulnerability and projecting themselves in accordance with their expectations more that with their present limitations.

For instance, clothing has proved to be a lot more than a respond to a basic need, its sociological need as a tool for manipulating with our image has proved to be efficient and up to a certain extent inexpensive as well. Cars are also items that fall in the category of "image generators" but due to their price this are goods more difficult to manipulate with; ultimately, houses are maybe the goods that we can more hardly manipulate, and therefore represent more vividly our reality.

Our target group is part of an emergent sector as we previously explained, their attitude towards housing is extremely rational regarding their day to day expectations and limitations, in a process of fast changes that are physically expressed on the materials they use, the functional arrangements they develop, and formal language they intend.

For our informal builders, a house is not the product of a stationary reality but a product resulting from its evolution in time, a constant feedback of expectations and limitations that drive them from a homeless position to a house owner status.

We must understand that our task is not only the one of identifying a morphological housing pattern and insure its feasibility through the building technology we are developing; our study must also concentrate on the sequence of decision making processes that take place in the 2, 3 or 20 years of consolidation that finally results on a
fully developed house, and make ourselves sure that our technology can
cope successfully with every stage giving a rational alternative to
every requirement of a complex decision making sequence.

In order to make somehow predictable the decision making events
through which our technology must prove to be appropriate, we will
review in detail a stressed sequence of decision making events that
experience have proved to be frequent, and analyze the expectations
and limitations that result on the most common physical answers that
our target group tends to develop in terms of building materials,
functional organization, and formal expression.

PRE-INVASION

As we previously explained, the first decision making process that
individuals must face as potential informal builders is the one of
taking possession of a piece of land through a process of violent
squatterizing or illegal transaction concerning agricultural land. In
either cases the main concern will be on obtaining a large and well
located plot prevailing over any other factor; at this stage, other
decisions such as form, kind or basic characteristics of the intended
house are considered of secondary priority. Nevertheless, they have a
foggy image of the house they intend to build and usually it resembles a
middle class single house with front and back gardens, plastered
walls, two stories high, and sloped roofs.

The only real decision making process at this stage involves variables
such as location of the plot and its dimensions, always making sure
such factors will not limit their potential access to the ideal house.

As a result, informal settlements are subdivided on relatively large
plots that will hardly limit the most ambitious building developments;
actually, it has been proved that average plots are not used to the
limit of their building potential due to economic restraints and other
uses are introduced generating domestic farms and crops before a
further densification process takes place, and the land reaches a
conventional density as urban area.

When by any reason an informal settlement has been subject of
relocation, the authorities have found very difficult to achieve the
acceptance of less convenient locations or smaller plots and had to
offer compensations (usually service networks) before reaching a
pacific concert of interests.

18 Conventional density is referred to those specified by regional land use codes.
In average an informal settlement will consider individual plots of about 200 square meters with a building potential of 300 square meters in accordance with residencial-unfamiliar codes; considering that the family composition of our target group is of 5 members the consumption index will result on 60 square meters per person. We understand this is a high index for low income sectors but at the same time we must be realistic and understand that we are not facing a consolidation process guided by certainty and therefore informal settlements must be prepared to evolve properly not only to the ideal single middle class house but to farm-houses, factory-houses, and even multi-family houses in a process in which maximum flexibility is compulsory.

Large plots may respond to the need of flexibility we mentioned but at the same time they result on a horizontal growth of the city, and costly extensions of urban networks that the government must face; the conflict of interests regarding the issue is clear, informal builders intend large plots while the government authorities pretend high density developments, it is a fact that given time the informal settlements will reach higher densities and that the government will expand urban networks to serve such areas, but before such concert is reached government and informal builders are confronted on a vivid conflict that may take years before it is solved.

We believe that a solution to the problem is not to be found on a change of attitude by any of both parties; informal dwellers will not settle over smaller plots, and the government will hardly face the expenses of network extensions over a vast area in order to serve a small population with low level of consolidation and little capability to exercise pressure on them; but, if by technological means we can speed up the process of consolidation and densification in informal settlements, the government respond will also have to be faster and the period of conflict will be reduced substantially; it is even possible that due to the speed of consolidation and densification that informal settlements may cover the dynamic will be properly understood and gain support from the government itself.

INVASION

The actual process of invasion implies necessarily the building of a shelter in the squatted plot as an explicit gesture of possession, at the same time that helps to support the activities that the squatters will have to undertake on the date of invasion and following days.

At the time of performing an invasion the expectation is to gain control of the land by means of establishing themselves in the squatted plot,
in straight forward terms, this could mean that the people will move in with all their building materials and start building their ideal house, but in reality the limitations implied on this stage are a restriction that transforms the physical expression of a theoretical straight forward dynamic.

The first limitation to be considered is the uncertainty of repression by the authorities, the possibility of having to be relocated, or simply be expelled from the site. If repression is violent the squatters may loose all their possessions, therefore the squatters will choose very inexpensive building materials to build the "invasion shelter", materials they can afford to loose if needed.

Another important factor that is taken into account is the fact that the invasion must be fast and difficult to detect, the building materials they can use must be light and easy to transport by any means; large trucks may be too notorious and a massive delivery of bricks, cement, and other formal building materials will rise questions they can not answer without setting in danger the effectiveness of the adventure.

Finally, economic restrictions are also important, the action of performing an invasion is costly on terms of time; the squatters will have to remain in their seudo-properties until it is sure that repression will not take place, and this means that for a hardly predictable period of time they will have to rely on the precarious savings they may have; it is almost compulsory to save all the money they can to insure their capacity to support a long period of uncertainty.

As a consequence of the limitations we have just mentioned the informal builders will not start building the ideal house immediately; their approach is to build a basic shelter made of straw mats with the form of an igloo or a camping tent, able to cover some mattresses where they can sleep, and a few belongings needed to support the family through the initial stage. Most family activities as for instance cooking, eating, washing, and children care are performed in a community context using temporary shelters on the form of a straw mat roof supported by a structural frame of eucalyptus poles.

In addition to the straw mats and eucalyptus poles the initial shelters may make use of other elements that are brought at the time of the invasion or immediately after; for instance, old furniture, carton boxes, steel drums, plastic bags, and tin sheets are also incorporated as building materials on a peculiar composition that sometimes reaches the form of a room with one door.
On the case of informal builders making a simulacrum of invasion after buying illegally a piece of agricultural land, the limitations are notoriously reduced; repression is less likely and they can afford the risk of moving in the site with more materials and build from the very beginning one or two rooms with straw mats, tin sheets, and eucalyptus poles.

![the igloo](image1)

![the tent](image2)

![the one room shelter](image3)

![the two rooms shelter](image4)

**ILLUSTRATION 1.2.1**

Straw mats and Eucalyptus poles are the materials more frequently used due to their low price, light weight, and possible recuperation if repression takes place; on basic terms we may say that the "invasion shelters" make use of unitarian components for the structure and laminate light pre-fabs for the enclosure. The functional performance of the shelter is reduced to the activities of sleeping and storing in the case of real squatters; illegal buyers of agricultural land may also consider activities of cooking and eating within their shelters. The formal expression of the shelter responds directly to the functions it will support and basic conditions of the materials that are used.

**TRANSITORY CONSOLIDATION**

Our target group will remain on the stage of invasion until some indicator will give them more certainty of not having to face the repression of the authorities and consequent expulsion or relocation; sometimes such indicator will come on the form of a legal recognition.
as informal settlement, but usually informal builders are hardly able
to maintain an invasion stage until such recognition is granted. The
most common possibility is that a less specific indicator, as for
instance the supporting visit of any authority or politician, will
trigger their transit to the next stage; sometimes the simple fact of
not having to face an immediate repression will increase their
confidence and push some squatters to consolidate their presence in
the seudo-properties.

The decision making process at this stage usually takes into account
that it may still be risky to invest a substantial amount of money in
the seudo-property, actually the kind of investment that is
traditionally needed to start building the ideal house is quite large. If
we consider that informal settlements may be located on areas of low
mechanical resistance and foundations for heavy brick constructions
able to cope with earthquakes can represent up to 30% of the global
building cost.

On the other hand, the living conditions offered by the invasion shelter
can not be maintained for a long period of time, and even though they
do not have sureness of permanency their certainty is reinforced with
every day of occupation.

Usually the approach is to consolidate a transitory house that follows
the basic patterns of an invasion shelter but can cope with a more
demanding functional scheme.

The building materials remain to be the same, low cost and lightness
are still key factors; besides, they can handle this transitory
consolidation in extension to the invasion shelter modifying its use or
re-using its materials for a new arrangement.

The most common arrangement is of 2 or 3 rooms with a cross-through
circulation, a specific area is reserved for sleeping, and the rest of
the dwelling is assigned to functions of storing, eating, and cooking if
the climate limits them to cook out on a back covered terrace.

A specific place is arranged for washing based on the supply of water
that informal tank trucks will deliver once a week into individual steel
cylinders, and a latrine is fixed usually on the back of the plot. (See
Illustration 1.2.2)

It is important to mention that informal builders involved on the
illegal purchasing of agricultural land may neglect this stage and link
almost directly the stage of invasion with the one of definitive
consolidation.
ILLUSTRATION 1.2.2

DEFINITIVE CONSOLIDATION

The stage of transitory consolidation finds its end when the uncertainty of such and previous stages is removed and replaced by the certainty of some kind of legal recognition over the squatted land; on many instances a global recognition may be sufficient.

Informal builders will feel it is finally safe to invest on building the ideal house and are confronted with the decision of choosing the materials to do so. The basic expectation, as we previously explained, is to build a house resembling a traditional middle class single family house and therefore their decision is somehow pre-established, and no matter the cost and technical complexities of the system they will almost directly decide for brick and reinforced concrete as the materials and correlated technic to be used.

It is important to mention that even though the decision of building with brick may seems almost arbitrary and resulting from only a pre-established picture of the ideal house, the concept is far more complex and takes into account the good marketing possibilities that a brick house may have, its soundness as guaranty for bank loans, and over all technical performance.

Usually, the first action on the consolidation process is to buy bricks as expression of the eagerness accumulated during the long previous
stages of uncertainty, and store such materials fixing dry walls (without mortar joints) in addition to the transitory dwelling; this practice beyond its psychological effect on the family, permits certain security over an area of the transitory house, but has been strongly criticised due to the danger it may imply if an earthquake hits the area, nevertheless it remains as a popular practice.

It is not unfrequent that the action of buying a lot of bricks may consume the savings of the family, but nevertheless the works directed to build a basic house unit with "formal materials" are immediately undertaken starting by the excavation of foundations and the calibration of aggregated materials to be mixed later with cement mortar. Work within the plot is usually shared by all members of the family on a joyful climate but it is frequently hold-down by the need of materials such as cement and steel.

Foundations are usually over-dimensioned consuming a great deal of money, laybour, and time, but informal builders do not hesitate; scholars have tried to determine if the reason for such over-dimensioning is to be found on an empirical process of following someone's instructions, and start escalating on dimensions as the original instructions move further from their origin, or if it is fully intentional on prevision of further developments the house may have. According to my own experience the reason is blended by both approaches, technical assistance is mostly empirical and the fear to earthquakes may stress empirical security factors every time they are applied, but cost is a constant constraint that should limit the escalation of structural specifications; on the other hand, the always clear intention of achieving a maximum flexibility and avoid engaging the dwelling to a certain limitation may explain why they do not hesitate on an initial heavy investment.

The building process is slow and almost directly related to their financial capacity to buy cement and steel; foundations are followed by brick walls, reinforced concrete columns, and finally a load bearing concrete roof that shows clearly the intention to build a second story in the future.

On morphological terms the permanent house is not finished before the family moves in and discharges the transitory dwelling; doors and windows will be incorporated but no plastering or painting will be done. Electrical and sanitary facilities are foreseen but not fully installed until urban networks are finished.

At this stage the housing unit made of formal materials is almost a replica of the previous transitory dwelling holding a very similar
functional organization but does supply security against robberies and severe weather conditions.

ILLUSTRATION 1.2.3

This process of consolidation may take little as 3 months or as much as 5 years depending on the economic condition of the household and its experience on the process; in many instances we can find informal builders, coming from a previous consolidation process in squatter land, that have more solid resources and building skills, generating a fast process and sharing their knowledge in the neighbourhood. The growing percentage of experienced informal builders is on global terms speeding the process of consolidation in new informal settlements and improving the building standards of the dwellings.

FURTHER DEVELOPMENTS

After going through the stage of permanent consolidation, the gained experience of building in formal fashion will have proved to be very demanding in terms of money and labour; informal builders will realize that achieving the ideal house will still demand further efforts and for those making their first process of consolidation the fulfilment of expectations will seem extremely far.

Several alternatives are considered before continuing with a further development of the building, the most common ones may be:
A. To continue working at a similar speed on search of the ideal house.
B. To build, in annex to the house, a small area on support to some kind of economic activity that may help speeding up the construction of housing extensions; usually a small shop or workshop is built for such purposes.
C. To build, in annex to the house, a temporary shelter for renting purposes and use the rent to continue building more areas either for rent or as extensions of the main house.

As time goes on, the improvement made on the environment and the supply of urban networks play a very important role that is also evaluated before any further development of the dwelling is made; such factors may result on the possibility of selling the house just as it is, cashing all the efforts made until then and move towards other invasion with a profit in hands, that will insure a faster consolidation within a new enterprise.

As a result of the many alternatives available at this final stage, informal settlements develop on very diversified morphological patterns; some basic housing units will be finished and sold, others will continue to be develop on search for the ideal house, some will incorporate productive areas, and many will transform the intended ideal house into a bi-familiar or multi-familiar dwelling that gains building speed.

Usually, any further developments of informal housing will be on brick and reinforced concrete by self-help methods, professional assistance will be used only on special circumstances and mostly referred to structural aspects as the dwellings expands.

Functional organisation is quite complex at this stage as new activities are some times introduced; the house will usually incorporate rooms on 1 or 2 levels until satisfying the family needs but due to the nature of its origins, social, intimate, and services areas may be multi-functional at any given time. Circulation usually remains to be lineal and centrifugal on essence but as the dwelling grows its flexibility is limited and at a certain stage unclear and extensive circulations may be incorporated to achieve new functional links.

In formal terms the picture of the ideal house is hardly achieved, shops and workshops are usually built on top of the intended front gardens, roofs are normally flat on prevision of vertical extensions, and, as we already mentioned, plastering and painting is hold until the end of the process.
ILLUSTRATION 1.2.4

Due to the formal appearance of informal houses, neighbourhoods will give the impression to be under construction even though the major consolidation process might be completed.
1.3 THE WOOD OF EUCALYPTUS

The common believe that the botanical order "eucalyptus" is native from the australian continent is partially true, actually it is native of not only Australia but of numerous islands to the east of the so called "Wallace Line", an imaginary line that goes across the Madagascar gap.

From such isolated part of the world the eucalyptus has expanded its population over more than 58 other countries, and all continents, at an amazing growth rate; on the last 20 years the population of eucalyptus has been multiplied by 5 and today more than 4 million hectares are covered by numerous species of eucalyptus 19.

The reason for such extensive proliferation is not only to be found in its practical value; perhaps, the main reason is that the species and sub-species of eucalyptus are highly adaptable to any intermediate or low latitude, altitude and soil, at the same time that grows at high speed and has extraordinary resistance towards external damage.

In Australia 95% of all natural forests are composed of eucalyptus trees, this is not a matter of coincidence but the result of a historical practice by which the ancient hunters of such regions used to set fire to the forest in order to increase their opportunity of a good capture; most trees were killed by the fire, but the eucalyptus had developed unusual mechanisms of defense on the form of a regenerating bulb below the ground surface; an organ of the former plant that is able to generate one or more new individuals if the former tree is destroyed.

Eucalyptus trees have quite a few peculiar growth characteristics that can partially explain their success at the time of expanding over areas where other species may have failed.

One of such characteristics is to be found on the small size that the seeds of most eucalyptus have (sometimes smaller than 1 mm); this can be a disadvantage if we consider the small amount of reserve material that each seed may have, but on the balance the large amounts of seeds that a single tree can produce insures its proliferation. At the same time, small seeds can find easy protection against the sun covered by leaves or any depression of the soil, can germinate with small amounts of moisture, and eventually be transported by air or other means to a large distance where over-all conditions may support new colonies.

Other important feature of many eucalyptus species is the development

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19 Sources: FAO records
of a defensive mechanism called "ligneous tubercle" in the meeting point of the stem and the root, this organ of the plant is at first generated over the ground surface but tends to bury itself at an early stage accumulating reserve material and substances; the ligneous tubercle will remain on a stand-by condition if the tree suffers no damage, but if by any reason the eucalyptus tree is destroyed, cut, or heavily damaged, the ligneous tubercle will be activated accumulating any remaining reserves and producing young shoots that can eventually be more vigorous than the original one.

Above ground level, the tree has growing mechanisms such as the "undefined shootings" that are intended for a continues growth along the stem and branches of the tree generating its peculiar "telescopic" growth, and the "nude buds" that are situated on the axilla of each leaf and can generate branches of a second order or assume functions of a main shoot if the leading apex of growth is damaged by any reason. In addition to this two main growth mechanisms the tree has "accessory buds" that are situated next to the nude buds and can undertake their function if they are eventually affected by insects or birds, at the same time that a fourth kind of bud called "epigenous bud" is left along the branch with the function of giving a new shooting if the growing end of the branch generates any defect and dies.

In such way an eucalyptus tree has a built-in system composed of 5 growing mechanisms that insure its survival and constant growth at the same time that regulates itself. If the tree is not affected by external damage, most of such mechanisms will remain on stand-by and the tree will grow in height maintaining a constant top crown holding 4 or 5 orders of branches that will insure the filtration of sun over the forest land.

The forest land will receive a constant input of organic nutrients supplied by the tree itself; eucalyptus trees are greatly appreciated for their natural lost of decaying branches and leaves, which means not only a benefit for the soil but a very convenient feature on reducing maintenance costs within a plantation. On a similar way, the bark of some eucalyptus trees tends to go loose and falls periodically leaving a straight clean stem that is extremely convenient for handling.

The self disposal of decaying components such as old branches, leaves, and bark also represents a important saving of "growth energy" that the tree translates into a vigorous growth rate. It has been shown that the eucalyptus species can produce in 30 to 50 years an ornamental individual that would take more than a 100 years for most of other botanical species; actually, commercial trees of about 10 cm on diameter can be achieved on an average time of 3 years with proper
care.

Among the many eucalyptus species that exist all over the world, the one of Eucalyptus Globulus Labill is of special importance because it is within this species that we can find the sub-species Globulus which is abundant not only on a world-wide basis but in the geographical context of our study.

E. Globulus sub-sp. Globulus was the first eucalyptus well known outside Australia and for a long time it was a synonymous of the whole eucalyptus botanical order, it has been considered as the most abundant species with a share of about 1/4 of the total population of eucalyptus trees; Peru has the third largest reserve in the world after Portugal and Spain.

Regarding its growth, this species is considered as the most vigorous one, in India specimens of 90 years old have reached heights of 76 meters and diameters of 1.80 meters, it can produce seeds at a very early age (5 years old); its wood is very appreciated as firewood and raw material for the production of coal, paper, and agglomerated panels, but its fast growing rate generates stresses that are hard to handle on the production of more elaborated and valuable items; nevertheless, straight poles, and small items like parket tiles can be produced with its strong and hard wood.

In environmental terms, it is very convenient for fast reforestation programs, it behaves well on the control of erosion and can co-exist with the breeding of cattle since its leaves are not subject of browsing; at the same time, it is highly adaptable to different soil conditions and altitudes; in Peru it is grown from sea level to well over 3000 meters in the locality of Cuzco.

According with a working paper of Hector Castilla and Phillip Cannon, the wood of E. Globulus has been used as a traditional material on the building of rural houses in the Andes region of Peru, considering that 90% of the housing stock in such areas make some use of the material.

In anatomical terms, the wood of E. Globulus is considered as a hard wood of complex structure based on a relatively thin alburnum or albura and massive duramen that can represent 85% of its cross section.

The vascular system is based on oval pores with densities that can reach 12 pores per square millimetre.

In average, the wood of E. Globulus has a moisture content level of
96%, but eventually can be as high as 141% ; its basic density is of 0.62 gr./ cm³ (dry to 12%).

The wood of E. Globulus is a strong and hard one, it can eventually provide structural members of relatively small dimensions in relation to average housing structural needs; if compared with traditional structural woods, E. Globulus will show structural advantages. For instance:

### Elastic Module on Flexion (perpendicular to the fiber) 20

<table>
<thead>
<tr>
<th></th>
<th>tons/cm²</th>
<th>kn/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus Globulus</td>
<td>147</td>
<td>14.41</td>
</tr>
<tr>
<td>Mahogany</td>
<td>94</td>
<td>9.22</td>
</tr>
<tr>
<td>Cedar</td>
<td>72</td>
<td>7.06</td>
</tr>
<tr>
<td>Ishpingo</td>
<td>94</td>
<td>9.22</td>
</tr>
<tr>
<td>Cypress</td>
<td>69</td>
<td>6.76</td>
</tr>
<tr>
<td>Pinus Radiata</td>
<td>65</td>
<td>6.37</td>
</tr>
<tr>
<td>Oak</td>
<td>123</td>
<td>12.06</td>
</tr>
<tr>
<td>Douglas Fir Pine</td>
<td>121</td>
<td>11.87</td>
</tr>
</tbody>
</table>

### Elastic Module on Compression (parallel to the fiber) 20

<table>
<thead>
<tr>
<th></th>
<th>tons/cm²</th>
<th>kn/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus Globulus</td>
<td>96</td>
<td>9.41</td>
</tr>
<tr>
<td>Cypress</td>
<td>86</td>
<td>8.43</td>
</tr>
<tr>
<td>Pinus Radiata</td>
<td>66</td>
<td>6.47</td>
</tr>
<tr>
<td>Poplar</td>
<td>68</td>
<td>6.67</td>
</tr>
</tbody>
</table>

### Maximum Resistance to Cut (perpendicular to the fiber) 20

<table>
<thead>
<tr>
<th></th>
<th>Kg/cm²</th>
<th>n/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus Globulus</td>
<td>133</td>
<td>13.04</td>
</tr>
<tr>
<td>Mahogany</td>
<td>68</td>
<td>6.67</td>
</tr>
<tr>
<td>Cedar</td>
<td>58</td>
<td>5.68</td>
</tr>
<tr>
<td>Ishpingo</td>
<td>52</td>
<td>5.10</td>
</tr>
<tr>
<td>Cypress</td>
<td>58</td>
<td>5.68</td>
</tr>
<tr>
<td>Pinus Radiata</td>
<td>51</td>
<td>5.00</td>
</tr>
<tr>
<td>Oak</td>
<td>120</td>
<td>11.77</td>
</tr>
<tr>
<td>Poplar</td>
<td>51</td>
<td>5.00</td>
</tr>
</tbody>
</table>

20 Sources: Average of recorded tests on specimens of peruvian diversified origin (dry to 18%)
SIDE AND UNDER:
E. Globulus timber frame as tested by ININVI
(National Institute for Research on Housing)
SIDE AND UNDER:
Overview and detail of housing prototype as proposed by ININVI
(National Institute for Research on Housing)
**Hardness (parallel to the fiber)**

<table>
<thead>
<tr>
<th>Wood Type</th>
<th>Kg/cm²</th>
<th>N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus Globulus</td>
<td>635</td>
<td>62.29</td>
</tr>
<tr>
<td>Mahogany</td>
<td>298</td>
<td>29.23</td>
</tr>
<tr>
<td>Cedar</td>
<td>273</td>
<td>26.78</td>
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<tr>
<td>Ishpingo</td>
<td>358</td>
<td>35.11</td>
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<tr>
<td>Cypress</td>
<td>240</td>
<td>23.54</td>
</tr>
<tr>
<td>Pinus Radiata</td>
<td>178</td>
<td>17.46</td>
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<tr>
<td>Oak</td>
<td>505</td>
<td>49.54</td>
</tr>
<tr>
<td>Poplar</td>
<td>129</td>
<td>12.65</td>
</tr>
</tbody>
</table>

This last factor, together with a cross section hardness of at least 730 Kg/cm², is far from being an advantage and can be considered as a limitation since it affects the productivity of labour on a drastic way; a worker nailing a piece of Oregon Pine will have to hammer only 2 times to achieve its goal, but working with E. Globulus he will have to hammer at least 12 times; this fact together with an specific weight of 620 Kg/m³ for E. Globulus (compared with 430 Kg/m³ of other structural woods) must be of important consideration.

Growing conditions resulting from plantation and exploitation methods, together with processing conditions deriving from drying and preserving methods, do have a substantial impact on the mechanical behaviour of the wood of E. Globulus. The values previously mentioned should not be considered as fix or standard values applicable to structural dimensioning since other specific sources of timber may show a different behaviour.

**I.3.1 EUCALYPTUS PLANTATIONS**

Eucalyptus trees can be found in natural forests and commercial plantations, but actually the proliferation of reserves is based more on commercial plantations than natural colonies.

The practice of plantations with the eucalyptus botanical order must be understood as a result of not always very specific motivations; until the last century, plantations were essentially motivated by the enthusiastic hope of developing endless fuel resources, its straightness and growing features were overwhelming criteria that in many cases triggered large plantation programs.

With the turn of this century, motivations were some how modified by

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\[21\] Sources: Average of recorded tests on specimens of peruvian diversified origin (dry to 15%)
the use of other fuel resources and even dow firewood and vegetal coal were still important uses for the eucalyptus wood, a fast process of deforestation and need for fast and inexpensive reforestation gave new reasons to expand eucalyptus plantations.

Today eucalyptus are grown with clear understanding that they represent an affordable way of stopping land erosion and an economic benefit on the balance. Its relatively low cost per hectare makes it commercially feasible even dow the resulting production reaches a low unitary value in the market of woods.

In the business of growing trees for wood, it is usual to consider a long span on the investment return index, most botanical species demand an average of 10 years before any representative return of investment takes place, as a consequence the investment needed is not only large but for long terms as well.

World-wide cross sections have shown that eucalyptus plantations are not only inexpensive on annual terms but offer the bonus of a fast return index; a plantation of eucalyptus may demand an average investment of about 450 US$ per hectare until the third year in which a considerable return of the investment can be obtained, to say the least.

A grower of eucalyptus can achieve a low unitary price for its production but a large volumetric output together with a small investment per hectare, in addition, a fast return index is a collateral benefit in countries with constant financial shortages.

Eucalyptus seeds are usually inexpensive due to the large production that can be obtained from natural forests, previous plantations, or specific plantations for such purpose; furthermore, seeds of eucalyptus can be stocked for long periods of time in well controlled environments and even in uncontrolled conditions can retain their germination potentiality for well over 2 years. The offer of seeds is usually larger than the demand.

The small size of the seeds and its high germination potentiality makes possible the technic of broadcasting by hand at the time of sowing, but in order to obtain a higher productivity growers prefer a nursery technic even dow it is more costly.

First, the seeds are put in germination trays with sterilized soil and fertilizers, the composition of the soil can vary a lot in accordance with the specie of eucalyptus that is being seeded, kind of soil where they will be transplanted, and density of the seeding which can vary on
itself from 3000 to 10000 seeds per square meter. A normal expectation is that at least 50% of the seeds will germinate during the first week and will produce small plants holding 2 or 4 young leaves by the fourth week.

From the germination trays the small plants are pricked out into individual containers made of a large variety of materials, experience has shown that polyethylene cylinders are technically and economically advantageous; again, the sizes of the containers and composition of the soil used are variables that the grower must analyze carefully and specially at this stage since the investment needed for containers, proper soil, laybour, and control may be considerable. Under good conditions the small plants should develop into young plants of about 30 cm high on the next 3 to 6 months, time at which they will be finally transferred to the fields; if the over-all conditions of the region demand stronger plants this stage can be extended even to a double until the plants are well over 50 cm high.

The field must be sterilized before stabilising a young forest of eucalyptus, and the distribution of the future trees must be carefully planned considering the slopes needed for proper draining of the land and a network of roads that will allow the future exploitation of the forest; in average each hectare can support a population of about 1100 individual trees. A normal expectation is that at least 90% of the plants will progress without any problem, 10% might face problems demanding special attention, it is usually advisable to maintain a reserve of about 10% in case full replacement might be needed.

A large number of factors may modify the timing previously described, the growers must always understand the process that takes place during the first year of operations and judge with total objectivity if any alterations are of concern; experience may be in most cases the ultimate guide-line.

1.3.2 EUCALYPTUS EXPLOITATION

In a world that is today threatened by deforestation and its collateral effects on the environment, the eucalyptus order is one of the few on constant expansion; actually, its peculiar characteristics of growth and ability to expand have shown through the last 10 years that eucalyptus plantations can produce almost 60 million cubic meters of wood 22 per year without a reduction of reserves.

For the first 3 or 4 years a plantation of eucalyptus is very much alike

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22 Sources ::FAO records
any other plantation of trees, but as soon as its exploitation starts it is transformed into a kind of wood factory in which due to its natural growth mechanisms each tree resembles to a giant asparagus that can be cutted and will immediately produce a new spear.

Eucalyptus trees can re-generate themselves over the base of its stub making possible a periodical rotation of the plantation without having to repeat the costly process of the first year.

Experience has shown that it is possible to hold rotations every 4 to 10 years and repeat such rotations 3 or 4 times before the mortality of the stubs makes necessary its extermination and reforestation.

The trees must be cut if possible with a chain saw at about 12 cm over ground level, leaving the stub intact so it will produce several new shootings that will finally result on 1, 2, or more successful stolons. Each rotation will result on about 5% mortality among the stubs if the diameter of the trees are between 10 and 20 cm on diameter at the time of the rotation; when trees are below or over such diameter a higher index of mortality is likely to occur.

If the planter wants to produce very straight trees, at about 18 months after a rotation, he can make a selection of stolons leaving only 2 per each stub and use the extraction for firewood; 2 years later he can cut down 50% of the trees leaving only one per stub and use the extraction for small poles. Each cut will result on a revitalization of remaining trees and constant output of products from the plantation.

If a diversification of diameters is desirable a plantation can be partially rotated every 7, 12, 17, and 22 years, maintaining certain specimens for a single rotation when they reach 45 to 50 cm on diameter and are suitable for the production of sawn timber.

At the time of making a rotation, it is important to consider the possibility of peeling the bark of the trees when they are still standing, in most cases marketing conditions are better if the product is sold peeled and this activity becomes complex if the tree is cut down before. The best method to peel an eucalyptus tree is to perform an incision all around the stem at about 25 cm over ground level and pull of the bark from down to upwards, in such way the workers will be sure of not damaging the stub.

The green wood of eucalyptus is extremely heavy for handling and transport but such initial weight is dramatically reduced as it becomes dry. The green wood may contain more than 100% of water content, percentage that must be reduced to not less than 18% in humid
environments and 5% for very dry ones. It might be advisable to dry the wood for about one month before considering its transport, on one month the wood may lose about 25% of its total weight and will be easier to handle, but on the other hand great care must be put on controlling the speed at which the wood loses water avoiding drastic loses and eventual cracking of the timber.

According with marketing conditions the grower of eucalyptus trees might have to face the challenge of preserving and drying the wood before turning it into the market; preserving and drying eucalyptus wood is not a simple process due to peculiar conditions of the wood that make it extremely difficult to control, this might be one of the reasons why most growers prefer to supply the market of firewood and vegetal coal where preservation and controlled drying is not required.

1.3.3 EUCALYPTUS DRYING

Trees, as any other living organism, have a cellular structure dependent on its water content to perform its multiple functions; therefore, wood is a material holding considerable proportion of water that it is not convenient for its performance as a building material.

For instance, dry wood is less heavy than wet wood, it has better structural behaviour, it is dimensional stable, it is more resistant to the eventual attack of organic depredateurs, and it achieves better thermo-acoustic performance; all this reasons have motivated men to develop methods in order to dry all kinds of woods with higher or lower levels of success; unfortunately the wood of Eucalyptus Globulus is among the less successful subjects.

Wood is a hygroscopic material that exchanges moisture with the environment and becomes stable or "dry" as soon as it reaches a balance with it, such balance depends on the climatic conditions of the locality where the wood is aimed to perform, usually ranging between 18% in humid environments and 5% in air conditioned interiors.

On general terms wood holds 3 different kinds of water: free water (water of capillary condensation) that fills the vascular network, cellular water contained within the cellular walls, and water of chemical constitution that is only liberated when the wood burns; all the free water and most of the cellular water is due to be eliminated before we consider a wood as dry or in hygroscopic balance.

When a log starts to dry it will first lose its free water reaching what is known as the "saturation point". During such period of the drying process there is no special task other than controlling drying.
speed, so to avoid the risk of a case hardening if the drying is too fast or rooting if the process becomes too slow.

A case hardening can eventually occur when the outer layers of a log are dried to fast exceeding the saturation point while the inner layers remain holding free water, on such case the inner water will be cased-in and eventually generates a focus of rot; this phenomena is unfrequent when natural drying is performed, but nevertheless direct exposition to sun rays should be avoided. On the other hand, if a slow drying process is intended, sanitary measures on the drying site should be stressed to avoid the development of fungus or rot.

The real technological task is to be found on the drop of moisture that takes the wood from its saturation point to its hygroscopic balance, through such stage the wood will loose part of its cellular water implying dimensional changes and stresses, that should be carefully controlled; on the case of woods with simple anatomy and uniform contractions the task is somehow less complicated.

On the case of the wood of E. Globulus we find a wood with complex and variable anatomy, high content of water, and uneven contractions, that is considered among the most difficult woods to dry.

The wood of E. Globulus can present a water content ranging between 65% and 141% depending on the growing conditions of its given location and origin, for instance plantations of high growing speed rates usually produce timber holding well over 100% water content. We must carefully evaluate the economic and technological implications of stimulating plantations of high growing speed that may reach high productivity levels, but result on products extremely difficult to dry or preserve properly.

Besides its high water content and complex anatomy, the two main problems involved on the drying of E. Globulus wood are based on the fact that the albura and duramen have very differential drying speeds, and that the contractions resulting from the loose of cellular water are also quite different regarding the longitudinal, radial, and tangential axis of the wood.

The vascular network of the duramen is heavily blocked by substances such as gums, resins, glues, etc, that eventually retard its drying fluency; as a result the albura normally dries before the duramen increasing the risk of leaving cased-in water in the duramen, or forcing us to prescribe an extremely slow drying process that affects its rentability and increases the risk of degradation through the process.
On practical terms, the difference between the drying speeds of alburna and duramen can be minimized by washing or deeping the wood in clean flowing water that will dissolve part of the duramen blocking substances; such process was traditionally performed in rivers making use at the same time of natural flowing water resources for the transport of the wood from forests hardly accessible by roads. Modern eucalyptus plantations are usually accessible by roads and therefore the process of washing out the undesirable substances of the duramen is neglected.

According with laboratory tests of E. Globulus in Peru it has been established that the hygroscopic balance for its use in Lima and other coastal areas is 18% +/- 1%, while in the Andes region of lower atmospheric humidity the balance is achieved at 15% +/- 1%; on the other hand, it has been found that the wood of E. Globulus meets its saturation point at about 30% of moisture, this data is of extreme importance because it allows us to identify the range of "critical drying" for our wood. For instance, on the case of wood giving service on the coastal region the critical range can be of 12% while in the Andes region it can be stressed to 16%. If a stock of wood is aimed for a coastal market it should not be unnecessarily dried down to a hygroscopic balance of 14% or less stressing the possibility of undesirable deformations, unfortunately this is a common practice on pursuit for lower freight costs.

The critical drying range on the wood of E. Globulus is directly related with its deformation by contractions; the larger the critical drying range is, the more dramatic dimensional changes will occur and on our case the phenomena is stressed by different contraction rates along the 3 axis of the wood. On the longitudinal axis, the contractions are minimal rating at about 0.1%; the contractions along the radial axis are more severe rating at about 6.8% and the tangential contractions can be of about 13.2%. It has also been observed that contractions tend to be more dramatic on young specimens.

When a log is being dried within the critical range its structure will react trying to maintain an equilibrium of internal stresses; the tangential contractions will be more dramatic than the radial contractions, and as a result the external fibbers will be subject of tensions tending to extrangulate the inner fibbers that will respond against the outer pressure by working under compression; such internal stresses are not visually notorious if the log remains in balance, but if sawn the resulting pieces will be out of balance and will tend to bend or twist accordingly with the triggered stresses.

The cross sections of a log are the areas where the wood will dry more
OVER: Stock of E. Globulus trunks drying at an in-forest location

UNDER: Stock of E. Globulus trunks after an unsuccessful drying programme
OVER: Preservation tests using pentachlorofenol achieving penetration only at albura level.

UNDER: E. Globulus trunks (right) showing signs of case hardening and radial crack.
quickly reaching its hygroscopic balance, such drying speed is directly related with the speed in which the tangential fibbers will have to develop the tensions their higher contraction demands; sometimes however, the drying speed of the wood overcomes the tension capacity of the tangential fibbers and eventually they collapse one after the other on radial direction as the wood continues to dry, the result is visually notorious as radial cracks that start on the cross sections of the logs and eventually can extend themselves along the longitudinal axis of the log.

The cross section cracks can be partially avoided by deeping the cross section areas in tar and in such way reduce the drying speed of such areas, but since the drying process as a whole depends on a 75% of longitudinal flow, such protective measure retards not only the drying of cross sections but the drying of the log as a whole with little flexibility on controlling it; a more flexible controlling measure is based on the periodic wetting of the drying logs and wire lacing near the cross sections, but eventually the wire lacing will loose pace with the contractions of the wood and become useless.

Regarding artificial drying, several programmes have been successfully tested but always within rigourous speed limits that in economic terms are only feasible for highly priced products; for instance, artificial drying of large logs has produced very good parket that is usually exported at top market prices.

I.3.4 EUCALYPTUS PRESERVATION

Wood is a building material characterized by its strength on ratio with the loads it can structurally handle, but at the same time, and due to its organic constitution, it is also characterized by its need for protection against organic and inorganic agents that may generate its degradation. The technological answer of men to such need for protection is to be found on preservation substances and preservation technics we will review on search for parameters suitable for the wood of eucalyptus and its use on the building of low cost housing.

As a starting point we must remember that on the cross section of a log, beside the internal and external crust, the xilema is divided on an external ring of albura and inner duramen; the first one (albura) holds the function of transporting water and mineral salts from the roots to the leaves, while the second one (duramen) supplies the structural support of the living tree; such difference on function implies a difference on the wood structure that is important to understand since.

23 Sources: FOPEX (peruvian association of exporters)
it affects its possible preservation.

On the natural growing process of a tree, the cambium generates material for the alburna on the inside and the crust on the outside; the alburna due to its function is structurated by a vascular network oriented in parallel or spiral along the vertical axis of the tree, such structure is very convenient for the introduction of preserving substances since the network used for the former transport of water and salts can be used as preserving network. On the other hand, the same growing process that generates alburna layers generates other substances such as oils, resins, glues, etc., that tend to block the vascular network of the alburna developing the inner duramen; as a consequence, the vascular network in the duramen becomes useless for the transport of nutrients and it is difficult to penetrate with preserving substances as well.

In the specific case of the Eucalyptus Globulus, the constitution of the alburna and duramen is not only coherent with the characteristics already mentioned, but extreme; the high rate of growth of the E. Globulus demands an alburna able to transport large amounts of water and salts to the top of the tree where it is distributed through the branches towards the leaves, as a consequence the alburna contains an expanded vascular network with fibbers under tensional stresses that presents little natural resistance to the attack of organic depredators; nevertheless, such expanded vascular network represents an advantage at the time of preserving the alburna wood that can be conveniently penetrated through the same network with inexpensive preserving substances and non-complicated methods.

The characteristics of the duramen are also stressed on the case of E. Globulus, the structural requirements of a tree that grows rapidly on height are obviously enormous and do demand for a duramen able to cope with the resulting flexo-compression stresses; on such regard, the fibbers under tension of the alburna are of enormous help on absorbing part of the flexo-stresses but this also means that the duramen has to assume by itself all the load generated along its vertical axis and perform at high compression.

The duramen of E. Globulus can assume densities of about 1.2 gr/cm³ (green timber) by heavily blocking the vascular network of the former alburna, in such way it can achieve the structural strength required, but makes it very difficult to penetrate with preserving substances; nevertheless, many of the substances the tree uses to block the vascular network are toxic to organic depredators and the wood achieves good natural resistance under normal exposure.
Tests made in Peru and Ecuador have shown that the albura of E. Globulus is not resistant to the action of insects and common fungus (polyporus versicolor, p.sanguines, ganoderma applanatum, etc) but the duramen has a good natural resistance; nevertheless, untreated duramen or albura should not be used on exposure to wood depredators. At the same time the two countries have carried tests on the potential penetration of preserving substances on both albura and duramen of Eucalyptus Globulus, the outcome of such tests shows that the albura is easily treatable with all preservatives achieving retentions of 95% and more, but the duramen is hardly treatable no matter the preservant or method used.

This limitation on the possibilities of treating the duramen of E. Globulus explains why it is not frequently used for sawn elements and mostly left as round timber, condition in which a dressing of treated albura protects the inner duramen from exposure to wood depredators.

It is under such circumstances that we must introduce and use the concept of "preservation by use"; if Eucalyptus timber must be used maintaining a protective dressing of treated albura, but on the other hand elements of circular cross section are physically and technologically difficult to handle on housing construction and design, we must evaluate the possibility of partial sawing as an alternative of "preservation by use".

The albura of E. Globulus represents 10 to 15% of the xilema, this means that in a log with diameter of 10 cm. we could sawn about 0.5 cm. on orthogonal planes and still maintain a fully protected duramen, the resulting flat faces will offer convenient contact areas needed to insure a safe and easy handling of the logs as building elements.

Regarding the preservation of the albura, the choice for a certain preserving substance and method depends largely on its economic feasibility; in our specific case the importance of such factor is overwhelming.

WOOD PRESERVING COMPOUNDS

Wood preserving compounds can be soluble in oil or water, but in the case of those soluble in water, only catalytic salts can be used, otherwise environmental water sources such as rain may wash-out the preserving substances even long after the wood has been put into service.

Sources: Junta del Acuerdo de Cartagena (Pacto Andino)
Among the oil soluble preservatives, maybe the best known of all is the creosota oil that gives good protection against common insects and fungus; nevertheless, it is not the best protection against the soft rot which is particularly dangerous for most eucalyptus species. The creosota oil must be warm-up to about 70 degrees C for application and may irritate the unprotected skin of workers, reason why safety measures should be adopted at the treatment site.

The pentaclorofenol is another well known preserving compound that has proved to be far more efficient than the creosota on the control of soft rot, but needs the addition of certain specific insecticides (specially against the comejon); the pentaclorofenol is a stable compound but its toxic condition demands rigorous safety measures at the treatment site. On general terms the pentaclorofenol is more expensive that the creosota oil, and its use is specially recommended in countries that are self-sufficient on their oil supply.

Oil soluble preservatives are considered to be incompatible with fire retarding substances and even dow the creosota oil may supply a certain fire protection, any further treatment against fire must be performed as an independent procedure. The methods used to preserve wood with oil soluble substances demand that the wood should be dry in advance, so the possibilities of developing an unitary procedure for drying and preserving at the same time is somehow unlikely.

Among the water soluble preservatives, the compounds of copper-chrom-arsenic (C.C.A) and copper-chrom-boro (C.C.B) are the best known of all; both products are commercially available in powder or concentrated past and are easily soluble in water, such factor is of considerable importance in economic terms since transport and stock costs are minimal. The wood treated with C.C.A or C.C.B is non-toxic, but the first one (C.C.A) due to its content of arsenic is poisonous and some countries have restricted its use.

Water soluble preservatives as those mentioned above supply no special fire protection to the wood treated with them (nevertheless an untreated piece of wood will ignite more easily than the one treated), but the question of whether they can be mixed with fire retardation agents such as zinc, tetraborato of sodium and boric acid will demand our future attention; on the other hand, preserving methods using C.C.A or C.C.B may be relatively simple, and in specific terms, some of them can and actually must be performed before drying the wood; as a consequence the possibility of achieving an unitary process for preserving and drying can be fruitfully explored.
PRESERVING METHODS

The convenience of using certain preserving compounds can not be judged in isolation, the complexity and expected cost of the correlated preserving method is key factor.

Preserving methods can vary from very simple and inexpensive procedures to extremely complex and costly ones achieving different levels of protection, the search for the most convenient method must take into account the kind of preserving compound that is used, the kind of skills needed on the personnel charged of the process, the operational costs involved, and the results each method is expected to achieve.

In the case of E. Globulus wood, testing has shown that the albura is easily treatable while the duramen is hardly treatable at all; as a consequence, the analysis of highly sophisticated and therefore expensive methods, that may achieve good penetration of albura and nevertheless unsatisfactory penetration on the duramen, can be considered as a technological misuse. Furthermore, our working context is of extreme economic constrain limiting on beforehand those methods implying costly operational inputs as for instance costly equipment.

After a preliminary review of conventional and non-conventional preservation methods and their confrontation within our parameters of simplicity and low operational cost, we can evaluate on further detail the following 4 basic procedures or methods:

1. SINGLE IMMERSION:

This preserving method is frequently used on empirical way by traditional users of eucalyptus poles; the characteristics of the procedure have been transmitted from user to user with limited understanding of its scientific background, but as on many other traditional practices extensive experimentation has resulted on a quite efficient method.

The method is based on the immersion of the green eucalyptus logs in a pool containing a mild solution of lime salts where they are left for about 2 days; the deeping of logs on popular argot is called "desangrado" ("dibleeding" in English) and has several implications: first, the water and nutrients filling the vascular network of the albura tend to flow out into the lime solution and are replaced by the blended substance, this slow loose of vascular content and its replacement by a fluid of lower density results on a liberation of
tensions on the albura and make less critical the contractions and deformations expected as the wood dries. After the deeping stage the wet logs are suspended over the pool for a slow drying stage in which they are frequently washed with the same solution and finally left alone to dry as the pool evaporates.

This popular preservation method gives a moderated protection to the albura that due to its mineral content becomes less vulnerable to the action of insects but it is frequent to find that certain sections of the logs (specially at the centre of its length) receive little penetration of lime salts. The interactive drying process has amazingly positive attributes.

2. SUBSTITUTION OF SAP:

This is another simple preserving method that is frequently used for eucalyptus logs and is based on the sucking attributes of their vascular network.

In operational terms, the logs are positioned on a sloped framework with the bottom end deeped in a solution of C.C.A or C.C.B preservatives, as the water in the vascular network is evaporated the preservatives are sucked into the hydraulic columns of the vascular network, when 2/3 of the expected penetration has been achieved the position of the logs is inverted to complete the treatment.

In preserving terms, this method is far more efficient that the one of single immersion but it involves the danger of neglecting treatment over areas where the hydraulic columns may have been interrupted by cross section cuts or wood internal defects.

Regarding the side effects of this method, we must mention that the collateral drying process that takes place simultaneously is usually too violent and difficult to control generating the unwanted contractions and deformations that are so typical on eucalyptus timber.

3. DEPLACEMENT OF SAP:

This method can be considered as of intermediate complexity since certain specific equipment is necessary to perform it, but after the initial investment its operation can be relatively inexpensive.

This method is commonly known as the "boucherie system" and is based on the use of pressure generated by gravity and transferred over the cross section of a log, in such way the sap within the vascular network of the albura is pushed out by C.C.A or C.C.B preservatives that
are at the same time pushed in by pressure. In terms of infrastructure, a modular preserving plant may require a metal or wooden framework of about 5 meters high, a tank of about 950 liters of preservant, a mixing deposit with mechanical pump, a pipe distribution network, and 6 rubber helmets for connecting the cross section of eucalyptus logs to the pipes distributing the preserving substances.

This system is very efficient in relation to the speed of treatment and the uniform penetration it can achieve, but as on the method previously described (substitution of sap), any cross section cut, perforation, or defect on the wood may result in vascular interruption and limitation on the further penetration of preservatives.

The side effects of this preserving method are somewhat how minimal since the preserving substances can push the sap out of the vascular network and do not depend on the evaporation of vascular content; therefore, the log can retain its crust through out the whole process insuring no violent drying will take place simultaneously, but implying the necessity of handling a separated drying process after the preservation is complete.

4. HOT-COLD IMMERSION:

This preserving method gives the possibility of using oil or water soluble preservatives and is based on the principle of generating a vacuum within the vascular network of the alburna.

The eucalyptus poles are first deeped into a hot immersion pool that forces the air within the vascular network to expand, such air expansion is then forced to a radical contraction by transferring the log into a cold immersion pool containing creosota oil or C.C.A or C.C.B preservatives; the air contraction generates a vacuum effect that sucks the preservant into the vascular network saturating the whole alburna structure.

This method is somehow the most reliable approach towards the complete saturation of alburna wood with preserving substances, but it implies the operational cost of warming the content of the hot immersion pool.

Regarding the possibility of developing an unitary process for preserving the wood, protecting it from fire (fire retardation), and drying it, there is no evidence pointing toward major obstacles.
1.3.5 EUCALYPTUS SAWING

Modern men is by all means more familiar with commercial sawn timber that with the unsawn round logs from which it is obtained; actually, our daily life in cities is surrounded by the predominant presence of sawn timber. Our buildings, furniture, and utensils are very often made of sawn timber making us forget that even large and roughly processed pieces of sawn timber are the product of men’s technology, a product that should not be taken for granted.

The dimensional transformation of wood implies a process that is not always simple; for instance, soft and regular woods can be sawn quite easily, but the sawing of some hard and complex woods is still a technological challenge that must be faced.

Because of formal technological and economic reasons, wood is usually sawn into square or rectangular cross sections, sections that due to marketing conditions are some how standardized.

In technological terms, square or rectangular elements are ruled by geometrical considerations that are far more simpler than those ruling circular or curved forms, as a consequence, wood users tend to feel more comfortable whether building or designing with rectangular components they can easily digest on intellectual terms or handle and manipulate on a physical basis.

In economical terms, timber of square or rectangular cross section can be efficiently transported, handled, manipulated, or stored resulting on clear economic advantages for those in the trading field. Such economic advantages are equally valid for wood users.

Regarding the wood of eucalyptus, less than 10% of the world’s production finds destiny in the market of sawn timber, and in particular the wood of E. Globulus is considered among the most difficult sub-species for sawing; the already discussed limitations on preserving eucalyptus duramen, hardness of its wood, inner stresses of the wood, and its typical drying contractions, may be accounted as the main reasons why technicians tend to avoid its sawing.

On a retrospective view over our discussion on wood preservation, we must remember that the duramen of eucalyptus wood is hardly treatable, and as a consequence, a key alternative for its overall preservation was found on the potential possibility of avoiding the sawing of the wood through out the untreated duramen, and instead, to saw only through the albura on parallel planes maintaining a protective ring of treated albura. The question of whether this alternative of
SIDE AND UNDER:
Evidence on the complexity of handling building details by means of round timber
OVER: Precarious solution for a large span roof using E. Globulus round timber
"preservation by use" is operationally valid, depends on the real feasibility of performing such partial sawing, and its interaction with the process of drying the wood, preserving its alburna, and using the resulting component in a correlated building technology.

The hardness of eucalyptus wood must also be evaluated at the time of considering its sawing; in general terms, the softer a wood is, the more easily it can be sawn with common equipment, but if we compare the hardness of some structural woods with the one of eucalyptus we will find that this last one is at least 50% harder to cut.

The natural resistance of a wood to the stresses of sawing is proportional to its drying condition; actually, a traditional sawing process considers wood with a high content of moisture not only because the drying of small section elements will be faster, but because green wood offers lower resistance to the sawing blades, demanding less sophisticated tools and smaller mechanical power.

Other important consideration at the time of evaluating the sawing potentiality of eucalyptus wood is to be found in the inner stresses of the wood, such stresses are undesirable consequence of the eucalyptus natural growing process and uneven drying contractions that on the balance may result on the bending and twisting of the sawn timber.

According with conventional sawing procedures, a cut on a round log of eucalyptus timber breaks the equilibrium of stresses it holds and forces a recovery of equilibrium that can only be achieved by deflections on the resulting elements, such deflections follows the direction and characteristics of the stresses that are left out of balance and since such stresses are typical we can also predict the following typical deformations. (See illustration 1.3.1)

1. External longitudinal fibbers that are hold under tension will tend to pull in and generating a concave external axis
2. If longitudinal fibbers are not parallel to the main longitudinal axis of the log the previously mentioned concave curvature may be stressed with a lateral twisting effect describing a spiral.
3. External tangential tensions will also pull in and generate a concave external axis in tangential direction overlapping the previous mentioned deformations.
4. The inner compression stresses of the log will still try to react against the outer tension stresses, but since the fibbers of opposite vocations are not longer bounded by its original concentric system, there may appear tangential cracks between areas of tension and compression.
Wood stresses can be minimized by the washing of logs before preserving, drying, or sawing its timber; nevertheless, the magnitude of deformations that can be still expected from the conventional sawing of green eucalyptus timber is considerable. Until now the only 2 ways known by us for achieving acceptable sawn timber out of eucalyptus, are:

1. The first sawing technic consists on sawing green logs of large diameter in such way that the inevitable deformations will respond to circular arcs of large radios that will be less notorious in small sawn elements. The sawing of green wood is then followed by artificial drying and a re-sawing down to the final marketing dimensions. This method is quite convenient in the sense that most of the heavy sawing is done on green timber, but nevertheless, it implies the costs of artificially drying and a second sawing stage on hard-dry wood.

2. The second sawing technic is somehow similar to the first one in the sense of selecting only logs of large diameter, but in this case, an artificial drying process takes place before any mayor sawing is done avoiding the two sawing stages of the previous method. Yet a single heavy sawing of hard-dry wood down to elements of very small dimensions, as for instance parket, is necessary.

In accordance with the economic restraints of our target market for eucalyptus wood, neither of both sawing technics seem to be appropriate. On such regard, our sawing alternative may be found on the feasibility of performing the intended "partial sawing" of eucalyptus logs considering the need of maintaining a constant equilibrium of stresses through out the sawing process; therefore, we must evaluate the feasibility of performing symmetrical and simultaneous cuts by means of double blades on the sawing machinery to be used.

In basic terms, we should test the possibility of sawing simultaneously on parallel planes maintaining a central element on constant geometrical equilibrium; it is predictable that the pieces of timber we cut out of balance will react with the always dramatic deformations we previously explained, but the main central element will retain balance with the only possibility of tangential twisting if longitudinal fibbers follow a notorious spiral axis that can be more easily corrected by a convenient and realistic evaluation of its impact on the correlated building technology. (See illustration 1.3.2)

Sources: UNA (Universidad Nacional Agraria del Peru)
In order to achieve a 100% utilization of the wood subject of the intended sawing procedure, we must prevent that according with our initial calculations, the process may produce about 5% to 8% of bent and twisted pieces of wood resulting from the parallel cuts of external albura and that such material should find a destiny within our intended building technology achieving a closed and self-dependant circuit on the exploitation and utilization of resources.

On such regard, there is sufficient evidence pointing towards the fact that unappropriated products of the sawing process and actually any product of eucalyptus plantations that is not appropriate for sawing due to its dimensions, form, or quality, can be converted into wood wool or wood chips used for the production of agglomerated panels; among such panels those using cement as binding agent may result economically and technically coherent with our target context.

I.3.6 EUCALYPTUS COMMERCIALISATION

In commercial terms, the plantations of E. Globulus are used on a 85% as supply for firewood, vegetal coal, and raw material for the industrial production of paper and agglomerated panels, a 10% finds destiny as round poles, and only a 5% is sawn into square timber.
OVER: Production of E. Globulus wood wool

UNDER: Filling of forms for the production of wood wool and cement slabs
OVER AND UNDER: Piling and storage of wood wool and cement slabs
The destiny of eucalyptus wood is, in percentage, inverse to the common use of other commercial woods due to additional conditions we will analyze on this section; actually, most of the eucalyptus wood reaches a low unitary price.

**FIREWOOD**

Firewood has been the former use of eucalyptus wood in most countries and as a matter of fact all reports are very specific on stabilising that their expectations have been fulfilled on such regard. Eucalyptus wood burns well and leaves a small amount of ashes, needs only about 8 months to dry up to acceptable combustion levels, and can produce a minimum of 19700 kilo julios (4700 kilo calories).

The energetic value of a wood at the time of burning is directly related with its density and eucalyptus wood has proved to have a relatively high density at a short age; for instance, a tree of 9 years can hold a density of about 500 kg/m$^3$ while a 34 years old can achieve a density of about 750 kg/m$^3$; this means that a plantation under system of rotations can produce a very substantial energetic value in short term, fact that is very convenient not only for growers but for surrounding communities that are constantly supplied of firewood at low price.

Even if the main objective of a plantation is not to produce firewood, the trees will be constantly loosing dry branches that are optimum material for firewood; at the same time, after each rotation of the plantation the owner will have to select its new generation of trees and in the process discharge a considerable number of stolons that are also suitable for this purpose.

The best eucalyptus for firewood are E. Camaldulensis, E. Tereticornis, E. Globulus, E. Grandis, and E. Saligna; that at the same time happen to be the most abundant.

The firewood market implies no need for drying, preserving, or sawing the wood, and makes it attractive for small growers even dow the volumetric value of the product may be low.

**VEGETAL COAL**

The eucalyptus wood can produce very good commercial coal, and even dow the wood will loose about 2/3 of its energetic value on the carbonization process, there are other reasons that make it commercially attractive. Eucalyptus coal can produce a higher energetic value per kg (28000 kj) if compared with firewood and its

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26 *Sources: FAO country reports*
transport and stocking costs are lower.

Coal burns without smoke release, can reach high efficiency even in precarious stoves, can be used for b.b.q. cooking, and its combustion can be more efficiently controlled than the one of firewood.

Finally, eucalyptus coal is a source of reactive coal with high level of pureness that is used on the metallurgic and chemical industries; in operational terms, it can make feasible the production of high quality steel at small scale. This has attracted the attention of many developing countries that are interested on medium and small steel industries.

PASTE AND PAPER
In technical terms the wood of eucalyptus is not the best material for producing paste and paper due to its short fibbers, but in economical terms, it has proved to be feasible and it is actually used very extensively in combination with other woods that provide the needed long fibbers.

Each year more than a million tons of paper are produced with base on eucalyptus wood and countries with important reserves of eucalyptus like Portugal, Spain, and Australia are known as important exporters of paper and printed matters.

AGGLOMERATED PANELS
Eucalyptus wood is a very good raw material for the production of agglomerated panels due to its low commercial value. The wood is shaved or smashed into ribbons or particles respectively and then agglomerated with resins or cement.

It has been estimated that each year not less than 9 million square meters of panels are produced based on eucalyptus wood and the figures tend to increase sharply, specially in developing countries.

WOOD FOR BUILDING INDUSTRY
Only 15% of all the eucalyptus wood is used for this purpose and most of it never reaches the state of sawn timber, the reason for such limited use is not to be found on the availability of the material or its mechanical performance; actually a plantation of eucalyptus can produce vast amounts of straight poles of proper diameter and the mechanical strength of its wood can easily cope with the most demanding stresses we can expect in conventional structures.

27 Sources: FAO / "El Eucalipto en la Repoblación Reforestal" (See bibliographical reference)
The real reason for its little popularity in the formal building industry is to be found on the several problems that one must face at the time of preserving, drying, and working with eucalyptus members, as we have already point out in this same chapter.

COST

The eucalyptus wood is a relatively inexpensive resource not only because of its low production cost if compared with other forestry products, but due to its limited access to markets of high unitary value. Eucalyptus wood is difficult to preserve, dry, and saw; therefore, the commercial value of its unsawn wood is usually 1/4 or 1/5 of the price of other sawn woods.

On its present condition, eucalyptus wood is a low cost material that must be transformed into a low cost building material, even dow such transformation may necessarily imply a variation of price.

1.4 DESIGN DEMANDS FOR AN EUCALYPTUS BUILDING TECHNOLOGY

The search for appropriate building technologies for low cost housing has a long history through which scholars have proposed a wide range of alternatives; heavy prefabrication undertaken by the state, light prefabrication by self-help, high technologies, and even intermediate technologies that had little success on achieving replication form low income target groups; millions of dollars have been invested on window projects that remain as isolated testimony of mistakes we are starting to understand.

In design terms we have concentrated our efforts in the development of evolutionary housing patterns to be implemented by means of many different materials and technologies, but on the balance, low income target groups remain building with brick and reinforced concrete even dow the task may demand a lifetime of labour and investment.

The choice of building with brick and reinforced concrete can be explained through a wide range of criteria, but in design terms, it is a fact that such material can be used for building a relatively modest house as well as the most overwhelming residence.

Brick as a building material can be technologically used at a hi-tech or low-tech level and therefore the choice of using it involves no contradiction with the hopes and expectations of emerging stratus like our target group.
As a result of such simple but crucial observation, the concept of appropriate technology covers a new perspective in which we must speak of a basic technology that should be able to work within expensive building systems, as well as within low-cost building systems, adapting itself to a very wide spectrum of design requirements.

Therefore, the designers of new building technologies should not concentrate their efforts on the task of developing a fixed package of technologies restricted for use among a single target group, but a flexible technology able to participate on as many technological packages as possible covering the building needs of a wide social spectrum.

Our methods for identifying design requirements to be fulfil by new building technologies should be also reconsidered; conventionally, the designer tends to develop a first draft of the pretended technology and with such tool on hands performs a design exercise in order to test its actual performance, but in such foggy process architectural and technological criteria get blended on an unit in which facts and variables can not be any longer set apart from each other, and the resulting product is perhaps more a consequence of technological limitations than architectural needs.

On the other hand, such design exercises are undertaken in a conventional fashion on which the designer's mind, paper, and pencil face the task of simulating a building process that is, by definition, a 3-dimensional process; such conventional practice often result on the neglecting of fundamental design criteria and overall misunderstanding of findings and conclusions.

Having such concepts in mind, this section of the research will undertaken two design exercises; the first one aimed towards the construction of a low-cost house, and the second one focussing towards the construction of a high-class residence on search for a wide range of design requirements that our "eucalyptus technology" must fulfil.

For both projects, technics of Computer Aided Design have been applied. For the project on low-cost housing, a CAAD programme has made possible for the first time, the accurate simulation of a peruvian informal building enterprise step by step avoiding in such way

28 ARIADNE software, developed by the TUDARC Research Team (Faculty of Architecture - Delft University of Technology) in cooperation with the Darmstadt University of Technology and the KONDAR Institute of Germany.
the conventional distortions of design criteria previously mentioned. For the second project, a complete 3-dimensional design exercise aided by the same computer software has achieved a clear break-down of design steps, in which the introduction of technological criteria can be subject of continues feedbacks without the risk of distorting design aims.

1.4.1 LOW INCOME HOUSING DESIGN DEMANDS

Even dow a design process in architecture is by definition a 3-dimensional intellectual exercise, its conventional instrumentation by pencil and paper often derives to a bi-dimensional scope; in such way designers tend to render the global 3-dimensional design components and accumulate graphic information on top views, cross sections, and elevations.

The fragmentation of 3-dimensional concepts into bi-dimensional representations is in fundamental terms an alien approach towards the goal of simulating an actual construction process by a design exercise.

For our target group the practice of design and actual construction is blended as a unitary process, design is undertaken on the construction site positioning building elements on a constant feedback process that is at all times affected by the circumstances they go through; invasion considerations, search for primary shelter, evolution of priorities, fragmentation of investment, material physical behaviour, etc, are criteria of a decision making process that is very difficult to duplicate through a conventional design process as described above.

On the search for a design method able to simulate the design-construction practice of our target group we hereby make use of a 3-dimensional CAD (computer aided design) program that operates following a construction-like process. In specific terms, the Ariadne program will allow us the creation of 3-dimensional replicas of construction components as available in the market of building materials, it will also allow us to manipulate such components in the same manner it will be done on an actual building process, duplicating every major construction step and therefore simulate a design-construction practice as the one performed by our target group.

On the other hand, previous study on the characteristics and pattern behaviour of the target group will allow us to take, in theoretical terms, the role of an informal builder and describe the criteria involved in the related decision making process for its direct evaluation and later formulation as findings.
STAGE 1:

After taking the decision of squatting a previously selected piece of land, my first concern is to choose the very few things I can transport during the night of invasion. Due to the characteristics of the intended action, there is no place for heavy items I may find difficult to transport, neither for expensive things I may not be willing to risk and lose if an unlikely violent repression takes place.

For making a temporary roof aimed to protect my family from the sun, I can take a large piece of fabric, maybe an old curtain or bed sheet and some wood pieces from an old drawer or table to make a sort of tent structure, but such arrangement may result on a very small shelter insufficient for my wife, children, and belongings.

This is not the best choice by itself since such low level of consolidation may encourage certain police undertaking; for strategical reasons I will better buy one or two straw mats (esteras) in order to make a larger shelter able to house all my family, and a eucalyptus pole where I can nail a Peruvian flag as statement of my rights. Experience has shown that such level of consolidation may be high enough for this stage and as corroborated by the fact I can find both items in any of the many informal stores that offer almost exclusively the "esteras" and eucalyptus poles.

Carton boxes are light and expendable, they can come in handy to store some food and clothes; a pile of boxes filled with stones or sand can work as a temporary wall, and on such regard, it might be also a good idea to take some empty flour or fish mill bags that may be used in the same way.

STAGE 2:

After squatting the chosen land and making myself sure that no violent repression will be undertaken, I must support our global request for official recognition and improve our living conditions by arranging a more elaborated shelter that shows a higher level of consolidation. I do not want to build another temporary shelter with materials I will have to discharge on a later stage, but if my choice is to start building a permanent dwelling through any of the conventional or non-conventional building technics available at the moment, it will mean I must start by making a costly foundation or at least a concrete slab that represents a strong investment at a moment in which uncertainty is still present. Furthermore, making a concrete foundation for structural needs I can not predict, it can result on misusing my very limited investment capacity, obtaining no immediate
habitation benefit, and achieving a consolidation level that is only visible by a close look.

Under such circumstances my best choice will be to start building a house with materials traditionally considered as temporary but with the intention of achieving a dwelling that may evolve as the circumstances towards a permanent status.

First, I will buy eucalyptus poles, of the largest length (6 meters) and smallest diameter available (4 inches); I am not interested on a strong structure but a very notorious one. Since I pretend to use eucalyptus as permanent building material I will be willing to pay an extra bonus for poles that are dry and preserved.

![Eucalyptus Pole Diagram]

**ILLUSTRATION 1.4.01**

I know that joining together round wooden elements on a permanent basis may be very complicated, but on the other hand I also know that sawing a hard wood like eucalyptus can be very laborious. In a pole of 10 cm on diameter the soft and preserved alburna will be of about 10
mm thickness, giving me the possibility of chiseling by hand 5 or 6 mm on perpendicular and parallel planes achieving flat surfaces of about 4 cm along the pole without exposing the un-preserved duramen.

![Eucalyptus Pole After Chiseling](image)

**ILLUSTRATION 1.4.02**

Taking the maximum length of the poles as structural module I can fix two 6 meters span frames into a 6 x 6 meters cuboid structure with concrete footings for only the four corner columns. I can also fix additional columns and cross beams as I try the structural behaviour of the frames under the load of a straw roof. Straw mats can be nailed to columns and beams to stabilise a temporary enclosure. (See illustration 1.4.03)
HIGH SPAN STRUCTURE  
ILLUSTRATION 1.4.03

As my budget recovers from the investment for the high span structure, I may start thinking on replacing the straw roof by a more heavy but resistant material, specially towards eventual light rains of winter (garuas), but to cope with the new structural demand, I must first introduce some wall panels made of the same eucalyptus poles and supported by a concrete foundation as load bearing elements, transforming the high span structure into one of short span frames; the roof structure will also be reinforced by secondary beams every 1.2 meters to hold tin sheets, or wood-wool and cement slabs of 1.5 to 2 inches on thickness. (See illustration 1.4.04).

If at certain moment in the future I want to build a second floor on top of my present "short span frame structure", I can do so by introducing a sequence of load bearing panels along the structural walls, transforming the short span scheme into a "modular framed load bearing wall system" able to cope with the structural demand of introducing more beams at every 60 cm, a ceiling, and floor tiling on the second level.

Depending on my order of priorities, I can maintain straw mats as coverture for the wall panels or start replacing them by wood-wool and cement slabs that can be nailed to the structure by one or two sides, and finally plastered them achieving a wall of conventional appearance; but to do so, I must be sure of official recognition since the plastering of walls makes impossible the recovery of materials if a relocation...
process results compulsory.

MODULAR FRAME STRUCTURE
ILLUSTRATION 1.4.04

STAGE 3:

In my case, I know that going for a premature vertical expansion of our house will be a strong statement in terms of consolidation level, but without having an alternative shelter the process of building a second story over our heads may be very disturbing.

My priority is for a larger living space and the possibility of an alternative shelter while our present living module is developed further or a second story is erected.

Most theories of evolutionary housing do point out the convenience of building from the back of the plot towards the front in order to avoid the eventual problem of transporting aggregated materials through the already erected and inhabited dwelling; I know about that recommendation, but as most of my squatter fellows, I have built my first stage shelter at about 6 meters from the front of the plot in order to control a back area where I have some chicken, a storage, and a latrine under a shaft made with straw mats. Besides, a building near to the front of the plot is more accessible and makes a stronger
statement in terms of consolidation appearance.

Nevertheless, I always had the idea of a possible lateral access to the back of my plot and prevented it by living about 1 meter gap to the right of my house, this gap should be maintained but I must built the totality of the left side gap, about 3.6 m, in order to gain further privacy and control over the back of the plot.

Following the same criteria used to build the first housing module, I will add a structure holding two rooms over the left side closing the gap previously mentioned, and move further to the front in order to achieve certain volumetric vibration that is characteristic of many middle class and high class houses. As a result, I will be almost duplicating my living space, having now the possibility of a private bedroom for me and my wife, and a semi-private bedroom for my daughter.

SECOND MODULE
ILLUSTRATION 1.4.05

STAGE 4:

Now that I have built an alternative shelter and before my family gets use to a larger living space, it is advisable to move them into the second module, re-arrange the roof of the first one in order to make it load bearing, introduce some more panels under the main beams, and
undertake the construction of a basic module on the second story.

I know that in order to speed up the future development of my house I need an additional income; therefore, the second story module will be for rent. I have many relatives willing to pay a modest amount for it without any legal complication.

First I will make a staircase for access to the second level; using the volumetric vibration of my present facade, I will locate the stairs in parallel to the first floor entrance in such way that it will be completely independent but integrated on volumetric terms.

The construction of the second story module will be almost identical to the one of the ground level, with the exemption of overlapping the corner columns with those coming from the first level making a structural unit with the initial high span frame and later evolving into a short span structure as I introduce some load bearing panels.

I am not sure if my tenant will need in a future a vertical expansion over his second level structure, a flat roof seems to be the most flexible alternative.

THIRD MODULE
ILLUSTRATION 1.4.06
STAGE 5:

My family is at this stage making use of two housing modules with a total area of about 70 m²; my tenant is housed in a module of 36 m² with patio facilities on top of my second module and access to my latrine through the one meter gap I have left at the right side of my house.

I have achieved an income increase by means of my up-stairs tenant, the extra money can help me with some new expansions but my savings are almost gone by now and if I pretend to maintain my present building speed my next investment must be of a productive nature; on such regard, I will build almost a replica of the second module next to it but towards the back of the plot with the idea of moving the bedrooms there and transform the former bedrooms into a shop or workshop with door openings over the street. This is a simple arrangement since I can remove a few panels from the former bedrooms, make doors, and move such panels into the new bedroom.

FOURTH MODULE
ILLUSTRATION 1.4.07
STAGE 6:

As expected, my tenant needs additional living space for his always increasing family and has agreed on a strong rent increase, paying 6 months in advance for a horizontal and vertical expansion of his dwelling.

I have been able to build a second story by reinforcing the structure of the first level transforming it first from a high span scheme into a short span scheme and later into a modular frame structure able to cope with the load increment; now the second story should be reinforced in the same way before I undertake the erection of a third level.

FIFTH & SIXTH MODULES
ILLUSTRATION 1.4.08

I am almost sure that the modular frame structure of 2 levels can cope with the vertical load of a third story and its conventional housing over-loads, but Lima is frequently subject of earthquakes that create horizontal stresses I must prevent by an additional reinforcement of
vertical elements.

Following empirical criteria I will reinforce the 4 corners of the third level not only by overlapping them with the poles of the second level, but in addition to it, I will add a 6 meter long pole on each corner reaching down to ground level insuring an unitary vertical behaviour of all 3 units.

In functional terms, a maximum flexibility of use is intended; therefore, I will arrange a module on top of my shop that may be used as bedroom as well as workshop with direct access possibilities from the staircase. On the remaining area I will fix a circular staircase going from the second floor to the third level and a drying patio. The module on third level will be an almost identical replica of those beneath it, but in this case the entrance will be set to the inside area allowing a larger arrangement of bedroom, and even a future bathroom with shower.

The roof of the third level can be flat but I always wanted a house with sloped roofs as those of middle class single family houses.

STAGE 7:

The legal recognition of our squatter settlement is taking longer than expected, it always does; but due to my building approach while my squatter fellows remain living in a temporary shelter afraid of risking an investment on bricks and not willing to expand with temporary materials they will have to discharge later, I have achieved not only to house my family but to increase my income by means of a tenant and a workshop. I can continue building additional bedrooms on the back of my plot on one or two levels around a patio as I wait for a legal recognition that will trigger my final investment. (See illustration 1.4.09).

STAGE 8:

Our squatter settlement has been granted with legal recognition and soon infrastructure works will be undertaken. Triggered by the certainty of not having to move towards a new location, my neighbours are slowly dismantling their temporary dwellings; in my case the situation is different, I already have a complete temporary dwelling to be upgraded to permanent status.

First, I will bury p.v.c tubes reaching towards the toilet and kitchen areas; 4-2 inches tubes will later be connected to sewerage collectors from my collector box and 1/2 inch tubes will transfer fresh water.
from a main gate box in front of my plot into the dwelling. Vertical pipes will be installed in sanitary columns reaching to my tenants kitchen and toilet.

As soon as pipes are properly buried I can pour concrete slabs making the floor of rooms, patios, and paths; eucalyptus horizontal frames will work as forms for the concrete allowing me a room by room investment. A thin steel grid over the wood-wool and cement slabs of my ceiling will be arranged before I pour a thin layer of concrete on top of them, making the permanent floor of my second and third levels.

The straw mats on walls can be plastered with mud or replaced by wood-wool and cement slabs on one or two sides of the eucalyptus panel frames and then plastered with a sand-cement mortar covering all wood works; I can even plate some walls with decorative brick.

At the end of this stage my house can look like a conventional brick house of white walls and tiled roofs; far more, walls will be about 20 cm thick with good acoustic and thermal performance. (See illustrations 1.4.10, 1.4.11, 1.4.12)
STAGE 9:

My tenant wants to buy my house based on a soft governmental loan and become landlord of a new up-stairs tenant. My plan at this stage is to sell and squatter two plots on a new invasion area, my building knowledge and gained capital will insure a profitable adventure as informal housing developer.

The exercise of direct 3-dimensional design on low cost housing developed within this section has derived towards the following findings:

1. The decision making process regarding building materials of potential squatters is strongly practical within foreseen circumstances; under such scope the use of straw mats and eucalyptus poles is a pattern fully consistent with the process.

2. A building technic aimed to cope with squattering stages can not suggest the building of conventional concrete foundations or slabs since such works are on conflict with the criteria of temporality.

29 In - field survey has shown that such decision is becoming very popular among un-employed segments of the target group.
and maximum consolidation appearance that rules such stages. Costly concrete works within the building process can only take place when legal recognition is granted.

3. A building technic that demands a pre-evaluation of final structural needs is not realistic within the context of our target group; an appropriate building technic must be able to change its structural framework in accordance with changing structural demands on an evolutionary process.

4. In a process of direct 3-dimensional design, as the one our target group is used to undertake, there is a natural tendency towards the repetition of previous arrangements in a process ruled by a very few original compositions and many additions of modified replicas, suggesting an empirical vocation towards the handling of flexible but large design components.

5. The eventual possibility of developing a 3 story-high structure can be an important attribute for any building technic claiming to be appropriate for our target group.

6. In functional terms, tendency is clearly towards cuboid spaces inter-related by doors. Relations between social spaces and bedrooms are solved by means of an open patio of hispanic tradition but no longer used by middle classes that tend to replace it by a so called "family room". Housing activities are usually linked to functions of productive or commercial nature, privacy between landlords and tenants is strongly desirable as well as between each housing area and its related productive or commercial areas.

7. In formal terms, an architectural style known as "chicha" results from the imitation of local styles used by the higher social segments but adapted to bi-familiar schemes mixing different finishes and decorative features even dow they may not be compatible within former styles.

8. Evolutionary criteria should not limit themselves within a functional scope; integral evolution taking into account structure, function and form must articulate a consistent process clearly divided on temporary and permanent stages. Temporary stages should stress the use of labour over a relatively long time span.

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30 The "chicha style" is a well documented tendency among members of our target group (See bibliographical reference under the title Huaca/Las Urbanizaciones populares)
while permanent stages hold those works demanding a heavy investment that is only feasible after legal recognition of land ownership.

1.4.2 HIGH INCOME HOUSING DESIGN DEMANDS

As described in previous sections of the research, the level of acceptability that low income target groups may offer towards new building technologies depends at large extent on the acceptability that higher social stratus may have put on evidence; therefore, if we want to insure proper acceptability of a low cost version of the eucalyptus basic technology by low income target groups, we must first make feasible a hi-tech version that higher social stratus will accept and use for the erection of their houses.

The present section holds a design exercise guided by a hypothetical architectural commission aimed as tool for the identification or additional technological requirements the eucalyptus basic technology should fulfil in order to be an feasible building alternative for intermediate and high social stratus.

1. THE HYPOTHETICAL COMMISSION

1.A- REGARDING THE CLIENT

Mr. and Mrs. X are middle age urban professionals with a family of two children of opposite sex aging 12 and 9 years old. At present they live in a flat apartment where the two children share a single bedroom, the living room is too small for their booming social lives, and the main bedroom lacks of private bathroom; after a first meeting we have arrived to the following statements of needs:

SOCIAL NEEDS: The family needs an "area-space" 31 for holding meetings of social and/or professional nature, it should be an integrated space divided in an implicit way into a living room with a chimney, a dining room, a flexible studio, a solarium for winter gatherings or sunday breakfast, and a back garden porch that could be on a future complemented with a small swimming pool.

SERVICE NEEDS: Conventional household needs should be performed in a one car garage with workshop attributes, a small washroom including a w.c. for visitors, a kitchen, and a laundry room for washer

31 "Area space" is a term developed by the author for replacing the term "area" which has an obvious 2-dimensional connotation and would be inappropriate in the context of 3-dimensional architectural design.
and dryer. Servant quarters have not been considered necessary.

PRIVATE NEEDS: The private needs of the family should be solved by one master bedroom with complete bathroom, two secondary bedrooms, and a secondary bathroom unit including a sauna cabin. All bedrooms should consider built-in closets.

OTHER NEEDS: On addition to the already stated needs, the family will like to count with a reception area where the main entrance will be allocated, a hidden safe closet for domestic appliances (tv set, hi-fi system, etc) to be use during summer holidays, and a gardening closet for mechanical tools.

The clients have no problems on using a two story dwelling in order to achieve a larger back garden, neither have fixed ideas regarding the aesthetic appearance of the house but will hardly accept an extremely unconventional statement.

1.B. REGARDING THE PLOT

The plot Mr. and Mrs X have bought for building their new house is located on the outskirts of Lima city in a housing development area of recent creation. The plot has a rectangular form of 14.40 meters by 37.80 meters with a total area of 544.32 square meters making corner between a main avenue and a secondary street.
In topographic and mechanical terms, the plot is flat and even, but has low mechanical resistance with a reading of 1.5 kg/cm² and sandy composition (usual in Lima's outskirts).

The building code of the area stabilises a frontal margin of 6 meters and lateral margin of 1.2 meters, the maximum building factor is set on a value of 1 and maximum dwelling height on nine meters.

2. THE DESIGN EXERCISE

Having a statement of needs offered on explicit or implicit way by the client, the architect must face the design process itself.

In modern terms, design can be a methodological process that makes use of a sequence of tools aimed for blending the client's needs with variables and concepts that the architect puts forward; within such methodological process the elaboration of a "space-functional graphic" and an "area program" is of fundamental importance.

2.A. AREA PROGRAM

The process of developing an area program is based on the ability of the architect to translate a statement of needs into a list of functional spaces, and to perform their antropometric analysis in order to stabilise the area each space must account.

An antropometric analysis can be performed as a gabinet or field analysis; for complex activities as for instance those taking place in a surgery room, a gabinet analysis plus field feedback may be compulsory, but as the architect gains experience on a given subject of design, he/she can almost automatically state areas and show their clients into other dwellings designed by him or her in order to obtain a fast confirmation or readjustment of the "area program".

For our design exercise we are stabilising an area program based on previous commissions where the client's life style matches the one we have hypothetically defined. (See Illustration 1.4.14)

2.B.-SPACE FUNCTIONAL GRAPHIC

For the elaboration of this graphic we undertake the list of functional spaces stated in the area program as functional units, and stabilise through lines the links or relations such units may have among themselves. A proper understanding of family routines is fundamental at this stage, as well as the architects ability to avoid graphic conflicts on the distribution of functional units.
### AREA PROGRAMME

#### SOCIAL WING

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIVING ROOM</td>
<td>+ chimney</td>
<td>18.00</td>
</tr>
<tr>
<td>DINING ROOM</td>
<td></td>
<td>12.00</td>
</tr>
<tr>
<td>STUDIO</td>
<td>+ chimney</td>
<td>12.00</td>
</tr>
<tr>
<td>SOLARIUM</td>
<td></td>
<td>12.00</td>
</tr>
<tr>
<td>BACK PORCH</td>
<td>only roof</td>
<td>5.00</td>
</tr>
</tbody>
</table>

#### SERVICE WING

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GARAGE WORKSHOP</td>
<td>for one car</td>
<td>30.00</td>
</tr>
<tr>
<td>VISITORS WASHROOM</td>
<td></td>
<td>3.00</td>
</tr>
<tr>
<td>KITCHEN</td>
<td></td>
<td>15.00</td>
</tr>
<tr>
<td>LAUNDRY ROOM</td>
<td>for household</td>
<td>6.00</td>
</tr>
<tr>
<td>GARDENING CLOSET</td>
<td>for manual tools only</td>
<td>1.50</td>
</tr>
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</table>

#### PRIVATE WING

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASTER BEDROOM</td>
<td></td>
<td>12.00</td>
</tr>
<tr>
<td>MASTER BATHROOM</td>
<td>bath tube + shower</td>
<td>12.00</td>
</tr>
<tr>
<td>CHILDREN BEDROOMS</td>
<td>2 units</td>
<td>30.00</td>
</tr>
<tr>
<td>CHILDREN BATHROOMS</td>
<td>incl. sauna cabin</td>
<td>12.00</td>
</tr>
</tbody>
</table>

#### OTHERS

<table>
<thead>
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<th>Area</th>
<th>Description</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECEPTION HALL</td>
<td>staircase is not included</td>
<td>6.00</td>
</tr>
<tr>
<td>SAFE CLOset</td>
<td></td>
<td>1.50</td>
</tr>
</tbody>
</table>

**FUNCTIONAL TOTAL**

| Total                   |                     | 188.00    |

**20% INTERNAL CIRCULATION**

| Total                   |                      | 37.60     |

**TOTAL**

| Total                   |                      | 225.60 m² |

**ILLUSTRATION 1.4.14**

Space-functional graphics are sometimes very complex networks of inter-relations that tend to cross each other as result of traditional pencil and paper graphic technics; in our case we have made use of a
bi-dimensional program for computer aided design as an advanced tool for achieving a clean network of relations that can be almost directly translated into a zone chart; the convenience of such instrumentalisation will be more evident on the case of complex functional requirements as for instance those of a hospital, but this small exercise already puts on evidence its convenience.

SPAC-E-SC-NCTIgLAR GBJIRACI। 1.4.15

2.C.-ZONE CHARTS
On the process of translating bi-dimensional information into three-dimensional schemes, the first step is to blend our space functional graphic (2D information) with the area program (3D analytical

32 The CAD programmes used for this specific case have been: STAD running on an Atari PC and MACDRAW running on an Apple Macintosh PC.
information) making on the process some preliminary decisions about the dimensional proportion of spaces.

For our purposes, we will define cuboid spaces of square or rectangular base with a height of 3 meters and place them in accordance with the distribution suggested by the space-functional graphic.

At this stage we will make use of a three-dimensional program for computer-aided design as a tool for the creation of 3D models (boxes), that as such, can be manipulated in space with complete freedom.

DIRECT REPRESENTATION OF SPACE-FUNCTIONAL GRAPHIC + AREA PROGRAMME

ILLUSTRATION 1.4.16

ARIADNE software / reference footnote 28
As we start manipulating the models, we feel the need of arranging them in two levels so to reduce the plot area that the dwelling will demand, and make feasible a larger back garden. Working in this direction, we will lift the whole private wing over the service wing at the same time that we spin its referential distribution on 180 degrees in order to leave the master bedroom over-looking the back garden and the children bedrooms over the front margin of the plot. A final adjustment of spatial locations results on dimensional consistency between models on first level and those on the second one, as for instance between garage and children bedrooms, master bathroom and kitchen, as well as between the master bedroom and the dining room; at the same time, with this arrangement we concentrate wet areas of the dwelling and reduce plumbing costs.

MANIPULATION OF FUNCTIONAL UNITS
ILLUSTRATION 1.4.17
As we continue manipulating the models, we see the need of filling gaps between spaces; on such regard, some try-outs show the possibility of introducing the reception between the studio, dining room, and service area; in such way, the reception can still be in contact with the exterior and may work as well as a distribution area among wings, it can even hold a staircase for access into the private wing. On parallel to this arrangement, we also try to fit the safe closet on direct relation with the reception; there are several alternatives of solution but the one of fitting it at the side of the laundry and visitor’s washroom seems very clean on volumetric terms.

VOLUMETRIC INTEGRATION
ILLUSTRATION 1.4.18

Finally, in order to achieve a volumetric unit, we will move the models on an assembly motion. Some models will collide with neighbouring elements and call for volumetric penetrations of the spaces hold within; in the case of the living room, its cuboid space will mutate into a prismatic, one as well as it is dilated to a height of 5.25 meters together with the studio. The reception is also dilated in order to master the volumetric composition and link the two levels of
The volumetric unit or spatial object made out of spatial models can be visualise from any point of view in order to test its good volumetric balance and equilibrium, we must also place it on a related scale with a model of the plot in order to visualise its referential position regarding frontal and lateral compulsory margins. (See illustration 1.4.20.)

So far we have achieved a volumetric unit that makes possible a proper functional arrangement of the house, but before going further on the design, it is wise to make a fast feedback with the clients checking possible distributions of furniture, links between spaces, and some special features on a conventional layout sketch.
For such purpose, we will dump the 3D information developed so far into a 2D CAD program taking top view sections of it and placing at proper scale the internal walls, roof projections, and basic furniture.
With the approval of the clients, the design development stage is undertaken. The first question on the development of the project is the identification of a structural technology able to cope with the explicit demands of the dwelling, and suitable in accordance with the environmental conditions of the site.
LOW COST HOUSING BY MEANS OF EUCALYPTUS WOOD

On forehand, we know about the low mechanical resistance of the plot, this factor implies that conventional structural technologies such as reinforced concrete and bricks will demand costly foundations that even high income clients will try to avoid.

On search for non-conventional structures, a timber technology may appear as appropriate due to its light weight, and on specific, an eucalyptus timber structure may result even more convenient considering its availability and structural strength.

For a two story house that will be erected through a lineal construction process we can choose between a timber frame technology or a load bearing timber skeleton wall technology, but in our case the almost complete lack of internal walls in the social wing, due to space integration, makes this last alternative clearly inconvenient.

On the development of a timber frame structural technology using eucalyptus resources, a fundamental step is to design a systematic for structural joints.

According to our design, the maximum free standing height of columns is 5.25 meters and maximum free span of beams is 5.85 meters; such demands can not be satisfied with single eucalyptus poles that have a common commercial diameter of 10 cm, the structural demands clearly point towards the need of some kind of lamination technology.

From our previous research sections we have learned about the sawing limitations eucalyptus timber implies, the idea of sawing such timber into 1 or 2 inches slabs for conventional assembly of laminated components is not commercially feasible, but the possibility of using short eucalyptus poles of 2 inches on diameter for the assembly of non-conventional laminated-like components should be explored.

Considering a conventional dimensioning of structural members, square columns of roughly 4 x 4 inches and rectangular beams of 4 x 6 inches are initially considered as sufficient for the most demanding structural needs of the dwelling.

Regarding the structural joints, a conventional steel plated fixation might demand heavy bolting that on the case of eucalyptus timber can be hazardous, for that reason, timber penetrations are advisable in order to cope with most of the cut stresses of the joint, while steel

35 Conventional dimensioning is based on structural abacus for tropical woods of category A. Sources: Acuerdo de la Junta de Cartagena (See bibliographical reference)
plates are mostly used for maintaining all members in place and absorb torsion stresses; nevertheless, the joint is still heavily plated.

STRUCTURE ASSEMBLY / ALTERNATIVE 1
ILLUSTRATION 1.4.24

At the time we look forward into the blending of such structural alternative with a partition technology, the following alternatives can be foreseen.

PARTITION TECHNOLOGY / ALTERNATIVE 1
ILLUSTRATION 1.4.25
From the first alternative we can evaluate a panelling technology similar to the one peruvian producers of wood wool & cement boards 36 tend to suggest, such approach offers the possibility of showing the timber structure wherever partitions or roofs are not present, but results on walls of 9 cm thick that are highly unconventional and of doubtful acoustic performance.

The second alternative offers, beyond doubt, a better acoustic performance due to a built-in air chamber in the walls, it also offers the possibility of walls with 15 cm thickness which are not so unconventional as those of 10 cm, but the level at which plaster is applied suggests the need of covering the timber structure as well. This alternative might be a good solution for clients seeking a dwelling of 100% conventional appearance. Regarding engineering procedures, the structural technology hereby evaluated may put forward some assembly difficulties at site due to the complexity of three different timber penetrations in each structural joint, demanding careful planning on the position each head of beam should take; on the other hand, solid-like beams may demand careful handling wherever electrical or plumbing pipes have to cross them.

Due to the technical difficulties just explained, it is advisable to consider other structural alternatives before we make the attempt of arranging a structural framework for the house; on such regard, we will now explore an structural alternative that blends a laminated-like technology with ingredients of high-inertia timber structures. (See illustration 1.4.26)

In this alternative the cross section of columns and beams is the same; on regard to the previous alternative, the new cross section has about the same mechanical capacity but a higher geometrical inertia that gives them more efficiency in an environment where earthquakes loads are likely to occur.

The structural joints do consider the need for timber penetrations, but unlike the previous alternative, the configuration of beam's heads is identical in all cases. The joint still requires the presence of steel fixation plates, but in this case the timber penetrations can be seen adding a hi-tech beauty to the joint.

Regarding the blending of such structure with a partition technology, the following details can be foreseen. (See illustration 1.4.27)

36 Sources: Department of Technical Assistance / FIBRACEMIENTO SA, Lima - Peru
From alternative 1 we can evaluate walls of about 15 cm thick that are quite acceptable on their acoustic performance, nevertheless, as in all alternatives involving interstitial air chambers and thin panelling, the owner will have to be careful at the time of introducing large nails into such walls.

Alternative 2 makes use of two wood wool & cement slabs that are introduced within the structure itself, simplifying its fixation with no
need of additional timber strips at the same time that achieves an outstanding acoustic performance and rigidity. The use of 2 independent wood wool & cement slabs instead of a single thick one generates a vibration barrier that absorbs shock impacts as for instance when someone knocks on the walls. Both alternatives offer the possibility of showing the timber structure but if desirable such same details can be complemented with plastic or metal fittings for additional protection of the timber.

Electrical and plumbing installations can run along the structural elements using the geometrical cavities between the eucalyptus poles, eventually removable fittings can allow the inspection of networks.

Hi-inertia timber structures like the one proposed by these two last alternatives have been frequently criticised regarding the large amount of exposed timber area they imply; such characteristic has a controversial impact on maintenance cost and fire protection features, but their advantages in building terms, as well as structural and aesthetical terms, points towards the need of technological developments aimed to overcome such limitations; in specific terms, chemical fire retardates, epoxic finishing, pvc or other plastic dressings, and the eventual blending of timber with other materials are technological alternatives to be considered.

Having defined a structural technology as well as a compatible partition technology, we can go further into the design of the structural framework of the house, to do so, we go back to the three-dimensional object achieved so far and by means of the several representation alternatives the 3D CAD program offers, we produce a "wire skeleton" of the object that will guide the process of structural assembly.

The structural framework achieved by the substitution of graphic lines for 3D columns and beams is then complemented by the addition of several other structural elements for the support of internal balconies, partition, and fenestrations; the resulting 3D framework can be then plotted or printed on 3D or 2D representations and sent to the timber contractor for the actual production of all structural components of the dwelling. (See illustration 1.4.28)

As we move forward on the design process, every step is subject of immediate feedback by a 3D updated view of the house under design; for instance we can analyse its simulated erection on the following steps. (See illustrations 1.4.29 and 1.4.30)
volumetric unit

wire-frame representation of volumetric unit

beam

column

column

DISTRIBUTION OF STRUCTURAL ELEMENTS
ILLUSTRATION 1.4.28

AXONOMETRIC DRAWING 1
ILLUSTRATION 1.4.29
At this step, the studio and living room is covered by a 3D space structure made out of short poles of eucalyptus fixed together by steel knot-like joints, the flat roof on top of such space structure is made out of wood wool & cement slabs working as permanent shuttering for a thin reinforced concrete slab, the final covering may be of asphaltic tiles.

The reception area will be covered by a timber spider supporting a glass roof. Due to environmental conditions we can use single glassing for such roof, but it must be water proof. Rain levels in Lima are extremely low and therefore a top sprinkler should be fixed on the summit of the spider providing water over the glass roof, such feature will help to maintain clean the outer face of the glassing in a dusty environment.

The solarium and a lateral strip of the living room will be also covered by a glass roof made out of small pyramids resulting from a timber space framework, internal parasols fixed to the same framework will provide the needed climatic control on such areas. The master concept guiding the location of glass roofs in the dwelling aims towards providing a glass roofed transit that runs from the main entrance all the way through the dwelling and finally reaches towards the back garden porch.
The front porch and back garden porch will have a partial coverture made out of a timber space frameworks and textile parasols.

In order to achieve an adequate operational speed on the computer production of drawings, we must substitute the in-detail models of such roofs for a simplified version made out of lines, but the contractor will receive in-detail independent drawings like the following sample:

As we continue, first floor internal partitions are loaded into the 3D object. (See illustration 1.4.32). The second level floors and internal partitions can follow on the 3D loading of the object. (See illustration 1.4.33)

As we progress on the process, we can concentrate on the design of some internal elements like the chimney and the stair case.

The chimney will be made out of copper cylinders and steel bars following a spatial pattern compatible with the timber space frame roof above it; as in previous cases, the contractor will receive
AXONOMETRIC DRAWING 3
ILLUSTRATION 1.4.32

AXONOMETRIC DRAWING 4
ILLUSTRATION 1.4.33
independent in-detail drawings while we use simplified versions for the global assembly of the 3D object.

The staircase will be made of conventional laminated timber (hard wood) for the steps and thin eucalyptus poles for the hand-rails.

The following drawings show in-detail models of the chimney and the staircase; as well as the incorporation of such elements into the 3D object.
At this stage all features of internal design have been sorted out, with the exemption of certain elements like internal blinds that should be later undertaken in relation with an integral decorative design process. Our next step is to design the exterior walls of the dwelling and final arrangement of facades.

On such regard, it would be very time consuming to test on 3D level every facade alternative, therefore we will make a 3D dump of information into 2D representations of the frontal, lateral, and posterior views of the object; then with the assistance of a 2D CAD programme we can start testing several facade alternatives as shown by illustrations 1.4.37 and 1.4.38.

The possibility of a post-modern grammar on study case 1 can be clearly confronted with a hi-tech grammar on study case 3 from which the hi-tech alternative results more consistent by the use of security.
glass on the windows; in an environment where house owners are confronted with the possibility of robberies, the option of using security glass is an attractive one.

Study case 5 offers the appearance of conventional brick work and plastered walls, this may be an attractive option for clients seeking for an inconspicuous statement but our hypothetical clients are young professionals that do search for certain individuality on their property.

Within a hi-tech grammar, study case 4 offers the use of glass-box windows that imply further volumetric vibration on one hand, and additional internal exposure of columns on the other. A parapet that partially hides the reception glass spider helps to integrate such feature with a basic cubic language at the same time that protects it from intentional damage. On the balance, study case 4 has better attributes towards becoming our best choice.

AXONOMETRIC DRAWING 6
ILLUSTRATION 1.4.39

For the final approval of the client we can replace some of the simplified models for the in-detailed ones in the global 3D object, and produce a set of internal and external perspectives as follows:
PERSPECTIVE VIEW FROM THE STUDIO
ILLUSTRATION 1.4.43
PERSPECTIVE VIEW FROM THE RECEPTION
ILLUSTRATION 1.4.44
PERSPECTIVE VIEW FROM THE LIVING-ROOM
ILLUSTRATION 1.4.46
PERSPECTIVE VIEW FROM SECOND LEVEL BALCONY
ILLUSTRATION 1.4.47
PERSPECTIVE VIEW TOWARDS ROOF OF RECEPTION AREA
ILLUSTRATION 1.4.48
TOP VIEW PERSPECTIVE - FIRST LEVEL
ILLUSTRATION 1.4.49
TOP VIEW PERSPECTIVE - SECOND LEVEL
ILLUSTRATION 1.4.50
TOP VIEW PERSPECTIVE - ROOF LEVEL
ILLUSTRATION 1.4.51
The exercise of hi-tech housing design developed within this section has derived towards the following findings:

1. The decision making process regarding building materials for middle and high cost houses is shared between the clients and the architects, but on the balance, technical considerations put forward by the architect do have important gravitation on the decision.

2. Not even high income clients are willing to "bury" large amounts of money in costly foundations.

3. Most of the new housing development areas of Lima are set on the sandy outskirts of the city where mechanical conditions of the soil do demand costly foundations.

4. The alternative of building with timber on plots of low mechanical resistance is attractive due to the important reduction of foundation costs it implies.

5. Timber construction is traditionally considered as expensive if handled at a hi-tech level, and implies a high income status.

6. The mechanical strength of eucalyptus timber, in relation to its weight and its low cost as a raw material, makes it an attractive building material for hi-tech, high-cost-like houses.

7. A fashionable search for space integration in high cost houses makes compulsory the use of a middle span frame structure technology able to cope with large openings between rooms as well as between the interior and exterior of the dwelling.

8. Structural joints of eucalyptus timber components must take into account timber penetrations able to cope with cut efforts and use steel plating or bolting only as fixation elements of restricted mechanical demands.

9. It is possible to develop laminated-like components as well as hi-inertia components with eucalyptus poles of small cross sections.

10. It is possible to develop space frameworks based on short eucalyptus poles and metal joints for use on large span roofs, glassed roofs, or textile roofs.

11. An eucalyptus structural technology may be compatible with a wood wool & cement partition, and roofing technology, as well as with conventional finishing technologies.
CHAPTER II

TECHNOLOGICAL IMPROVEMENT OF THE MATERIAL.

Raw materials are subjects hardly suitable for building purposes, as a matter of fact, raw materials should be transformed into building materials through a process that improves their natural behaviour in the direction of stressing their building attributes.

In the case of eucalyptus wood, our first chapter has shown a raw material that is being used as a building material without much improvement on its natural building attributes; actually, many would hardly call it a building material since only its marketing and empirical use corresponds roughly to this category.

At present, eucalyptus forests are mainly seeded for erosion control and fuel supply, implying locations and layouts that are not the most convenient for the production of trees that will find their final destination within a building process. In the same way, exploitation methods tend to address a fuel or industrial market that has no special regard on the quality of the output and stresses the convenience of large volumetric production at low price.
Regarding the drying and preservation of products offered as building materials to an empirical building market, little has been done to improve methods that may result in achieving a performance competitive with other woods specially treated as building materials; on the balance, the high level of acceptability that eucalyptus timber may have at this moment among informal builders in Peru mostly stands on its availability and low price, a condition that reverts on its use as "temporary" building material.

This chapter will review all aspects relevant to the production of eucalyptus timber as a building material considering not only present reserves but new ones, safeguarding the integrity of existing dynamics in the context of the study.

II.1. PLANTATION METHODS.

The present reserves of eucalyptus Globulus in Peru are quite considerable as we have already mentioned in our previous chapter, but such reserves should not be considered as an available resource for the dynamic we intend to create; as a matter of fact, present reserves are already accomplishing functions that should not be disturbed by the sudden introduction of new dynamics that may dismantle ecological and collateral systems.

In specific terms, forests that are at present accomplishing functions of erosion control and local supply of fuel should not be distracted from such essential use, not only because of the impact such action may have in environmental terms, but because most of such forests grow on mountain slopes and therefore produce woods that are not the most suitable subjects for achieving the quality of product we look foreword to develop.

Our proposal considers the feasibility of using only valley forests that may be at present committed to the production of straight poles for the informal builders of neighbouring cities, as starting point for a dynamic that must develop its own specific reserves in which every possible technological improvement should be properly implemented.

In the process of developing new E. Globulus reserves and upgrading those existing reserves that may be in conditions of applying improved plantation and exploitation methods, we consider it will be convenient the creation of an "Association of Eucalyptus Growers" as a non-profit organisation in charge of stimulating existing and potential growers towards the application of the set of recommendations we hereby intend to state, as well as the know-how they can develop themselves.
as product of specific lines of research, and/or feedback from the actual activity of growing and exploiting their plantations.

On the development of a set of recommendations for plantations interested in the production of eucalyptus timber for building purposes, we must tackle all plantation aspects on a systematical order that may well follow the same order of activities in a plantation operation.

SEEDS

A very first step on improving the quality of E. Globulus timber for building purposes is on hands of plantation owners, at the time of selecting the stock of seeds to be used. Usually, the market of seeds is handled with prime concern over the germination level a certain stock may have, this is often clear by putting forward the unitary weight of the stock as indication of such germination level, but the origin of the stock itself is not always clear.

The eucalyptus botanical order relies mostly on inductive polinization for the production of fertile seeds, this means that in a single capsule of seeds the chance of having seeds with different parents is quite high, and eventually the possibility of generating hybrids would be of special concern.

Stocks of seeds coming from natural forests or plantations surrounded by the first ones do imply a high risk of containing hybrid seeds, that will generate hybrid specimens within a plantation that becomes therefore unreliable on its own production of seeds.

New plantation owners should be very careful on their buying choice, germination levels are important but an analysis of the origin of stocks should not be neglected.

A first task for the suggested "Association of Eucalyptus Growers" could be on the identification of safe seed origins that may guarantee a certain standard; furthermore, the association may eventually perform block purchasing of seeds, offer a fix standard to all its associates, and in such way contribute towards the eventual standardisation of eucalyptus Globulus wood as building material.

Another important activity for the "Association of Eucalyptus Growers" could be found in the field of research on genetic engineering; the possibility of developing a specific hybrid of E. Globulus for building purposes should be explored in terms that it may supply not only a clearly defined standard on the final product, but an upgraded specimen stressing its building attributes beyond those of the former.
specie itself.

The handling of seeds can also be improved, it is true that eucalyptus seeds can be easily stored for over 2 years without special care and still retain considerable germination capacity. But if we intend to develop plantations with a fixed seed standard and if possible make such plantations self-sufficient on their seed supply, it may be necessary to store seeds for longer periods of time; for such purpose, it is advisable to store seeds in hermetic containers far from the reach of moisture, light, and insects; temperature should also be controlled and maintained if possible between 1 and 4 °C, this can perhaps be achieved by introducing the containers deep underground or by more sophisticated but still natural means as the one shown in the diagram.

![Diagram](image)

**SEED STORAGE**
**ILLUSTRATION 2.1.1**

Plantations specially aimed for the production of upgraded seeds may need artificial cooling devices in their storage chambers in order to have a more accurate control of temperature; as for instance "Thermo King" units that are actually quite inexpensive to maintain and can eventually be run by wind and/or solar generators in accordance with local conditions.

**NURSERIES**

According with present conditions, a E. Globulus grower should consider that only 40% to 50% of the seeds he plants will germinate
under optimum conditions, this means that direct broadcasting in the field will not only produce a smaller level of germination but a forest of almost unpredictable and uneven density that can be hardly corrected; this practice can only be recommended in complementary plantations of natural forests broadcasting from a helicopter or a small airplane.

Under present circumstances the best method we can recommend is the creation of nurseries at 2 levels. First, seeds can be planted in small trays of about 50 x 20 x 5 cm that would contain sterile soil or sterile compounds like vermiculite or perlite, the trays would then be kept under proper cover from the sun-rays and receive constant watering as well as a fertilising solution 2 times per week; seeds should start to germinate within one week and under proper conditions at about 4 weeks the small plants may hold 2 to 4 pairs of leaves and be ready for transfer into individual containers.

Large plantations or growers, specially commited to the production of nursery plants, can perhaps afford artificial control of their nurseries; this may imply the construction of green houses, with proper parasols, artificial temperature control, artificial light control, chronometer-base watering systems (frequencies of 5 to 10 seconds of watering by fog jets every 10 minutes may for instance be arranged), and air filters, that can not only insure an optimum germination level but reduce the time span necessary at this nursery level.

The second nursery level would be based on individual containers where the small plant will spend about 5 month before they are ready to live the nursery and be finally transferred into the field.

Individual containers made of poliethilene cylinders are strongly recommended for this purposed. A poliethilene cylinder of about 10 to 15 cm on diameter can be supplied in a roll that the grower must fill with a mixture of soil (soil from, the field itself is recommended) and about 25% of animal fertilizer, and then cut into containers of about 25 cm on length.

The containers, holding one small plant each, should be placed on top of a clean soil surface protected from direct sun-rays and receive the same watering routine they had during the first nursery level for about one week more; changing environmental conditions towards achieving the final field conditions can take about 2 months, nevertheless, direct wind and animal access to the nursery area should be prevented at all times.

This research must strongly recommend the creation of * regional
nurseries * supplying young plants to local growers in order to achieve economic feasibility on the investment of special nursery infrastructure, that can result on an improvement of plantation productivity in terms of cost and quality.

PLANTATIONS.

It is very important to evaluate field conditions before establishing a commercial plantation of E. Globulus, and even more important if the objective is to produce timber for building purposes as we intend to do.

The site must have a mild slope of not more than 8% if possible, in such way that floods may be prevented but convenient absorption of rains may be achieved; plantations located on sites with slopes over the recommended percentage will produce trees of slower growth rate, harder wood, and a vascular system less suitable for its future preservation.

If possible, the site should be located on an area protected from strong radical winds in order to avoid the generation of uneven structural stresses in the trees, that may result on different tensions on the outer fibbers of the log itself, making more difficult its future sawing. Eventually, a wind barrier of E. Globulus trees not aimed for wood production complemented with a belt of lower bushes in between, may provide sufficient protection.

In the same way and whenever possible, the grower should avoid selecting sites located next to natural eucalyptus forests, specially if they stand on the way of prevailing winds, this measure will help to avoid the generation of wild specimens within the homogeneous plantation and safeguard the eventual production of hybrid seeds.

Regardless the kind of soil, the field must be clean of waste material at plantation level, and if possible, a turn over of soil at 50 cm in depth should be performed improving the distribution of nutrients and oxygen content; this operation can be performed only along the intended plantation lines avoiding unnecessary costs. If the land has been previously used for growing crops of any other nature, it is advisable a careful lifting of left over material and sterilization of plantation lines with chemical products in accordance with manufacturer specifications in order to avoid the germination of unwanted material. This practice is of particular importance at the time of starting a E. Globulus plantation and during the first 4 years of operations, later the grower may consider attractive to develop a in-forest crop but always careful evaluation of operational costs must be performed before introducing such practice in a forest intended for
periodical rotations, as we will see in the section of exploitation methods.

Regarding the location and climate of the intended plantation site, there are little limitations; in terms of latitude, the site can be almost anywhere within the Peruvian territory, actually we can find successful plantations north in the locality of Cajamarca as well as in the south in Cuzco and altitudes ranging from sea level to 3,366 meters above sea level. Temperatures along the year can fluctuate in a range of about 15 °C in averages and 30 °C on extreme, in any case, Peru has plantations in areas where average maximum temperatures are well over 20 °C in summer and other areas where average minimum temperatures may drop under 8 °C in winter. Rain falls may vary between 500 mm to 1500 mm per year with dramatic differences between dry and rainy seasons, as in Cuzco where January can have an average of 158 mm and July as little as 1 mm.

The lay-out of the plantation must also consider not only the growing practice itself, but the future exploitation of the forest; for growing purposes we must advice a plantation density not higher than 1,400 trees per hectare and plantation lines oriented on perpendicular direction of the main slope of the field, avoiding the eventual erosion of the soil; a lay-out of 3 mts by 3 mts may be advisable in terms of making feasible a free expansion of roots, a generous supply of nutrients, and sufficient sunlight penetration; in exploitation terms, the suggested distance between plantation lines may permit the introduction of vehicles moving perpendicular to the main slope of the field with obvious advantages; in addition, special service roads of 4 mts to 5 mts can be left clear every 10 plantation lanes for the transit of heavy equipment and placement of service installations as well as eventual drying areas.

With the arrival of the rainy season, plantation work itself must be performed taking into account several important details; the polyethylene bags holding the mass of roots of the young plan must be cut at about 5 cm from the bottom, discharging root sections that may have grown twisted, in the same way, side walls should be cut and if possible taken out so that roots can have immediate contact with the field soil and can expand on radial direction without any obstacle.

Plantation holes must be properly dimensioned allowing an easy introduction of roots, avoiding eventual twisting of terminals towards the surface; the filling of holes must be performed exercising a gentle pressure that must insure good contact between soil and roots, and supply consistent stability for the young plant.
During the first 3 month after plantation the grower must take special care on evaluating the progress of the young plants within the new environment; it is possible that a certain percentage, not more than 10%, may show adaptation problems that may result on the need for replacement; therefore, the grower must maintain a certain stock of nursery plans for quick substitution in the field. The addition of natural fertilizers near the stem of decaying plants and selective watering may save a considerable number of plants from having to be replaced.

The application of the suggestions we have stated must make possible the achievement of substantial improvements on present plantation methods, in particular, we can look foreword to the generation of forests that can produce trees of homogeneous quality as a step closer to the standardization of the material itself; at the same time, we can predict that the quality of the timber coming from forest applying such improvements will be far better oriented towards drying, preserving, and eventually sawing processes, resulting on a building material competitive not only on virtue of its price but technical performance as well.

The original idea of promoting the establishment of an "Association of Eucalyptus Growers" at national level and smaller units at local level, can be of great importance on the optimization of plantation costs; such organizations can offer not only advantages on the purchasing of products and equipments, as well as on the production of upgraded seeds and nursery plants, but become sponsors of further research capturing national and international funding. In particular, recent agreements between the governments of Colombia, Bolivia, Peru and the United States of North America for the substitution of coca crops can offer an outstanding opportunity for canalising investment into the expansion of E. Globulus reserves by beans of upgraded plantations; it may be important to remember that the areas used today for coca crops in Peru were traditionally used for timber production, holding considerable infrastructure that can be set operational again, as well as human resources with considerable know-how on forest exploitation, timber production, and marketing.

II.2. EXPLOITATION METHODS.

As we have already explained in Chapter I, a E. Globulus forest can be exploited by a sequence of rotations based on the natural ability of most eucalyptus trees to re-generate themselves after being cut. This exploitation method should be performed with substantial care and knowledge in order to achieve good productivity not only on the first
cut but on future cuts as well; the present section will suggest a set of recommendations regarding the way in which we can improve the methods used for the exploitation of E. Globulus forests.

**SELECTION OF THE HARVEST.**

In conventional E. Globulus forests aimed towards the production of wood for fuel or industrial use, the selection of the harvest is a decision making process mainly guided by 3 factors: market demand, volumetric value of the output, and logging feasibility.

In terms of market demand, we usually find a sustained and almost even demand for firewood from local communities that hardly triggers full-scale logging operations, as a matter of fact, such demand tends to be covered by farms holding small forests for self-consumption that sell part of their stock in order to achieve a sustained cash flow, or by the output of waste material from larger plantations. Full-scale logging operations are usually triggered by the industrial market that operate on the basis of global contracts that can compromise fixed volumetric amounts or fixed forest areas.

In terms of volumetric value of the output, growers tend to harvest plantations as late as possible; such tendency can be easily understandable when we realize that one rotation over a period of 14 years can produce 6 times more wood in volumetric terms than 2 rotations over the same period of time without the cost implied by the rotation itself.

In terms of logging feasibility, the location and lay-out of conventional E. Globulus forests imply limitations on the size of trees that can be turned down and transported out of the forest.

On the balance, the most common decision among E. Globulus growers is to establish two simultaneous logging operations; the first one is at small scale and short-term achieving a sustained cash flow that covers the cost of maintenance operations and financial costs, the output is offered within the fuel market or to the industry as an out-of-programme supply for immediate delivery that is usually welcome and well paid. In second one, growers will try to establish a contract with the industry for a full-scale logging operation at long term, achieving a high volumetric output and applying open-forest logging technics in order to bridge limitations implied by the high density and uneven lay-out that plantations may have.

The present supply of E. Globulus poles for the building market is derived from the operation already explained, and implies no specific
selection of the harvest but sorting of trunks already harvested, distracting certain amount of wood from its original volumetric market and introducing it into a market of unitary value.

From our viewpoint, prevailing criteria for the selection of harvest imply two major concerns; first, open-forest logging technics on sites of potential erosion of the soil may account towards a constant deterioration of forest growing conditions that must be avoided, and second, the logging of trees under 10 cm on diameter and over 25 cm on diameter may result on high mortality among E. Globulus talons that may demand for partial replacement operations, increasing growth unevenness in plantations and subsequent increase on talon mortality as new open-forest rotations are performed.

Even though our main task is to establish guide-lines for the selection of a harvests aimed for a building market within new plantations of E. Globulus, we must hereby recommend growers aiming fuel and industrial markets to avoid cutting trees under 10 cm on diameter during their short term logging operations, as well as trees over 25-30 cm on diameter during their long term contracts, preventing the increase of talons' mortality, and to apply sorting logging technics instead of open-forest logging operations on sites where erosion of soil is likely to occur.

Regarding new plantations aimed towards the production of timber for building purposes, growers must select their harvest considering their own market demands, unitary value of output, and logging feasibility.

In terms of market demand, there is an already existing demand and offer that should not be changed, but complemented towards the establishments of a standard.

Present dimensional standards within the informal building practice we have already described in Chapter I, have been fixed on poles of roughly 3 to 6 meters long and 4" to 8" inches on diameter, that should not be changed since it is consistent with metric as well as imperial modular coordinating patterns, in an environment where both dimensional standards are almost evenly used.

In terms of the output value, we must also refer ourselves to the already existing dynamic that implies the determination of unitary value instead of volumetric value, making feasible the offer of an assortment of dimensions with equal benefit for growers.

In terms of logging feasibility, the introduction of improved plantation methods with special care on the suggested maximum slope in forests,
density, and lay-out should not imply any limitation on the optimum selection of the harvest.

As we can see, the decision making process leading to the selection of the harvest is strongly determined by the pursue of dimensional standards on the output, task that already implies certain complexity that growers must handle with efficiency; the idea of cutting down a tree of 10 cm on diameter and reach the market with a building component of 10 cm on diameter is not only simplistic but mistaken.

As a first step, growers must have a clear view of the marketing product to be achieved, and the dimensional changes that can be foreseen, in order to define their harvest triggering dimensions range.

Regarding the marketing products, we can undertake 3 basic concepts:

1. Present marketing conditions tend to suggest a dimensional standard ranging between diameters of 4" to 8" inches, and lengths of 3 to 6 meters. In qualitative terms, components must be peeled (only Xilema), hold hydroscopic balance with the environment (18% water content), and should be preserved.

2. Building considerations tend to suggest the need for sawn planes within albura margins in a morphological tendency to square the circular cross section of components.

3. Natural growth conditions imply that within optimum exploitation range (10-25 cm) trees will gain about 1" inch on diameter for every 1.5 meters in high resulting on the following range of potential products.

<table>
<thead>
<tr>
<th>Commercial Diameter</th>
<th>Length</th>
<th>Metric prod.</th>
<th>Imperial prod.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>3.0</td>
<td>1, 1.5, 3</td>
<td>1.2, 2.4</td>
</tr>
<tr>
<td>0.125</td>
<td>4.5</td>
<td>1, 1.5, 3, 4.5</td>
<td>1.2, 2.4, 3.6</td>
</tr>
<tr>
<td>0.150</td>
<td>6.0</td>
<td>1, 1.5, 3, 4.5, 6</td>
<td>1.2, 2.4, 3.6, 4.8, 6</td>
</tr>
<tr>
<td>0.175</td>
<td>6.0</td>
<td>1, 1.5, 3, 4.5, 6</td>
<td>1.2, 2.4, 3.6, 4.8, 6</td>
</tr>
<tr>
<td>0.200</td>
<td>6.0</td>
<td>1, 1.5, 3, 4.5, 6</td>
<td>1.2, 2.4, 3.6, 4.8, 6</td>
</tr>
</tbody>
</table>

Regarding the dimensional changes to be expected, growers can calculate diameter reductions as follows:

A) The harvest triggering diameter (x) will first loose its bark (b) and reach the status of peeled diameter (d_b); bark thickness can be introduced in the calculation as a percentage of the harvest.
triggering diameter. The dimensional change at this stage can be calculated by:

\[ x = \text{harvest triggering diameter} \]
\[ b = \text{bark thickness (\% of } X) \]
\[ d_b = \text{peeled diameter} \]
\[ d_b = x - (b/100)x \]

B) The intended sawing operation is likely to be performed when the wood reaches saturation level in order to avoid its seasoned hardness. Cuts will be always performed in parallel planes along the direction of the fiber, and within a range (20\% to 80\%) of the thickness of the sapwood, insuring a permanent sapwood dressing subject of preservation. The dimensional change at this stage can be calculated by:

\[ d_b = \text{peeled diameter} \]
\[ s = \text{thickness of sapwood (\% of } d_b) \]
\[ d_s = \text{sawn/peeled diameter} \]
\[ d_s = [d_b \ (100/100-s/100)] + [d_b \ (s/100)20/100 \ to \ 80/100] \]

C) Preservation operations are likely to be performed immediately after sawing and will influence only the sapwood on a very small proportion.

D) The seasoning of peeled/sawn/preserved poles will imply radial contractions as the wood reaches hydroscopic balance with the environment; such contraction is usually expressed as percentage of its diameter at saturation level.

Improved seasoning methods should prevent tangential contractions from being more dramatic than radial contractions avoiding radial cracks. The dimensional change at this stage can be calculated by:

\[ d_m = \text{seasoned/preserved/sawn/peeled diameter} \]
\[ \text{(commercial diameter)} \]
\[ r = \text{seasoning radial contraction (\% of } d_s) \]
\[ d_m = d_s - d_s(r/100) \]

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As a matter of example:

\[
\begin{align*}
  b &= 4\% \text{ of the trunk} \\
  s &= 15\% \text{ of xilema} \\
  r &= 6.8\% \text{ of xilema}
\end{align*}
\]

For maximum harvesting triggering diameter:

\[
d_m = 0.7873x
\]

For minimum harvesting triggering diameter:

\[
d_m = 0.8678x
\]

<table>
<thead>
<tr>
<th>Marketing diameter</th>
<th>Harvesting Diameter</th>
<th>Triggering Diameter</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100 mts</td>
<td>0.127</td>
<td>0.115</td>
<td>0.012</td>
</tr>
<tr>
<td>0.125 mts</td>
<td>0.158</td>
<td>0.144</td>
<td>0.014</td>
</tr>
<tr>
<td>0.150 mts</td>
<td>0.190</td>
<td>0.172</td>
<td>0.018</td>
</tr>
<tr>
<td>0.175 mts</td>
<td>0.222</td>
<td>0.201</td>
<td>0.021</td>
</tr>
<tr>
<td>0.200 mts</td>
<td>0.254</td>
<td>0.230</td>
<td>0.024</td>
</tr>
</tbody>
</table>

Growers should maintain careful records of growth rates within their plantations, not only during the first rotation but throughout the whole operation in order to establish the most efficient harvest timing. It is important to understand that a wide range of factors can affect growth rates and that even within a single plantation with identical plantation methods, climate, and soil, it is still possible a certain degree of uneven growth.

It is predictable that growth rates previous to a first rotation will be smaller that those previous to the second and third rotation; in similar way, growers must be prepared for the fact that as they continue performing rotations it is very likely that growth rates will tend to drop.

It is also important for growers to maintain a constant sampling programme supplying hard data for their calculations on harvest triggering dimensions; we can predict that harvesting margins may be small (from 1 cm to 1 inch), and the use of national or even local averages for dimensional transformations may happen to be misleading.

The best time for performing rotations is at the end of the dry season; such timing will imply advantages on the logging operation considering that the water content of the green wood will be lower, and therefore trunks will be easier to move and dry; in addition, talon shutings will

---

38 Example using present average value of calculation variables.
almost immediately react with the incoming rainy season. Growers must try to achieve harvesting dimensions at optimum harvesting season, for such purpose margins on the harvest triggering diameter may prove to be sufficient.

If by any chance, not necessarily implying careless control of the plantation, a grower is unable to achieve relation between harvesting dimensions and harvesting season, further considerations may be applied; on one hand he can wait until the end of the dry season and perform a rotations aimed for a different market, he can also spare a rotation and wait for the achievement of larger marketing diameters on a future harvesting season; or he can perform an out-of-season rotation that will imply certain operational disadvantages but can be compensated by the prices an out-of-season supply may achieve.

The logging operation itself can be performed by sorting or by open-forest exploitation; in economical terms, an open-forest operation may prove to be more efficient and in new forests applying improved plantation methods there is no specific reason for discouraging such practice. On the other hand, sorting operations may be more demanding but can insure a better control on the dimensional evenness of the output and benefit the forest environment in an almost self-sustained basis; on the balance, both logging approaches appear to be evenly suitable for our new E. Globulus plantations. Extensive practical applications may in the future pin-point advantages and disadvantages that may not be foreseen at present time.

LOGGING TECHNICS.

Improvements on present logging technics can mean a substantial difference on the productivity of a E. Globulus forest; each step of the logging operation should be carefully performed in order to achieve an output free of damage, insure the welfare of remaining trees, and generate strong new forests after every rotation.

A first step may be to clear the standing tree from branches and summits, such operation can be performed by means of a small axe and climbing up the tree, or by more sophisticated methods such as a telescopic trolley and chain saw that do not imply high costs and can be also used for forest maintenance works. This operation is specially recommended in forests that are exploited by sorting in order to avoid the damage that falling trees may cause among their neighbours; in operational terms, the approach of clearing the main stream of a tree while it is still standing may prove to be faster and less hazardous to perform than after its logging.
Another operation that might be easier to perform on a standing tree is its peeling, for such purpose it is advisable to perform a superficial incision around the tree at about 20 cm over ground level and tear-off the bark by pulling it upwards. This operation should not be performed if there are intentions of preserving the trunks by means of the boucherie system, the same criteria will apply if there is an intention of retarding the seasoning process of the wood.

The actual logging of a E. Globulus tree must always be performed by the use of a chain saw or a double handle saw; the common use of axe can frequently damage the talons resulting on quality deterioration of the next harvest.

In order to insure a healthy new harvest, the cutting of trees must be carefully performed; the cut itself should be as sharp as possible through-out the whole cross section of the trunk avoiding the also common practice of pushing-down the tree after sawing little more than half of its section. The cut should be at about 12 cm over ground level, and well within the area still holding bark if the tree was peeled before logging.

It is also advisable to consider a mild slope on the cut in order to drain rain water from the top of the remaining talons, as the rainy season approaches any accumulation of water on the top of talons can result on the development of fungus.

Healthy talons can generate several new shutings that the grower must evaluate carefully; by the end of the rainy season, not more than two shutting per talons should remain, the sorting of shutings is done by natural means (weak shutings will tend to fall down) or by the decision of the grower. As the new rainy season approach a second sorting should be performed leaving only the most promising stem for future rotation.

After logging, the trunks should be moved out of the forest patches and into service corridors; trunks may be extremely heavy at this time due to their high water content and therefore a good distribution of service corridors during plantation operations will start to pay of. It is also advisable to clear out the forest from all waste material resulting from the logging operation, part of such material can be sold or stored for firewood, the useless waste can be put on safe areas where it can rot; the practice of burning waste material with no additional benefit should be discouraged unless extreme precaution are taken. A forest free of waste prevents development of fungus and insects that can damage future harvests.
EXTRACTION.

The green wood of E. Globulus trees can hold 100% of water content, therefore we can hardly recommend immediate extraction from the forest environment towards areas of treatment infrastructure, that can eventually stand far from the logging area.

Hereby we would recommend to dry the wood down to a level near to its saturation point before any major transportation operation is undertaken, on average, transport weight can be reduced at least 30% if such guide-line is applied.

On areas subject to strong rainy seasons or in the nearness of rivers, the end of logging operations will coincide with abundant availability of running water; this is likely to be the case in most plantations applying improved plantation methods; such resource can be used at its best if recollected from forest patches (in case of rain) or derived from the river stream into a lineal network of channels along the service corridors of the forest.

A network of canals can imply several advantages for extraction operations and can eventually assist growers during plantation operations if selective watering of the fields happens to be necessary.

As we previously recommended, immediately after logging operations the trunks should be pulled out of the forest patches into the service corridors, there the trunks can be dropped into the flowing water canals and anchored at a stand-still position by means of ropes or a sequence of gates that will retain the trunks as the flowing water is left free to run along; as a result, the green trunks will start bleeding out a considerable amount of vascular free water and substances. There is extensive evidence pointing towards the fact that the now old fashion practice of guiding logs down the stream towards the mills had very positive side effects on preventing deterioration of unpreserved wood, as well as on realising tensions within the trunk that will surely make easier their later seasoning and sawing; the suggested bleeding technique can duplicate such very desirable side effects.

After 24 hours of bleeding the trunks can be released from their anchorages, or gates can be removed, leaving the trunks free to flow down the channels towards recollection areas that can be arranged on the outskirts of the plantation and near to main treatment infrastructure areas.

39 In-field survey by the author.
If by any chance, site conditions or investment limitations unable growers to develop a network of channels; an alternative for bleeding the wood may be found on the creation of a single flowing water pool at the side of a stream or within the stream itself. The transport of green logs from service corridors can be performed with the aid of dry sliding frameworks (i.e. rails), crane-truck equipment, or animal traction on a down-hill motion.

If a grower is forced to perform an out-of-season logging operation and their is no flowing water source for proper bleeding of the wood, we can only recommend a superficial but careful washing of the trunks as a prophylactic procedure previous to its seasoning.

II.3. DRYING METHODS.

The seasoning of E. Globulus trunks starts in theory immediately after logging, but in practical terms, we can assume that the seasoning process starts after bleeding in accordance with the previously explained technique.

The seasoning process can be divided in two clearly separated stages; the first stage takes the wood from its green or wet condition down to its saturation point, and the second stage implies the achievement of hydroscopic balance with the environment.

The first seasoning stage can still be performed far from main treatment infrastructure areas in order to minimise the transport costs of heavy wet timber. It is advisable to perform this operation on a transit location out of forest patches; service corridors or recollection areas at the end of water channel networks can be well suited for such purpose.

Wood will not experience any dimensional change at this first seasoning stage, in which the basic objective is to eliminate the free water content of the wood; nevertheless, there are certain dangers involved in the process.

Wet wood is a very suitable environment for the development of fungus; good ventilation and periodical movement of the timber can help avoiding the generation of fungus colonies.

Sapwood (albura) holds a higher water content that heartwood (duramen), and usually such natural uneven distribution of water help to maintain a balance between the higher speed at which sapwood will dry. Nevertheless, the sapwood of E. Globulus trunks holds a very
dilatated vascular system generating extremely fast drying rates that can eventually overwhelm the heartwood drying rate with the risk of causing a case hardening situation, in which, wet heartwood is trap inside dry sapwood; it may be advisable to consider certain measures like, for instance, superficial spraying of the trunks in order to delay sapwood drying.

Wood near to the ends of trunks will dry faster than wood near to the longitudinal centre and eventually fast drying wood can exceed saturation levels before the rest of the wood; it may be advisable to prevent the wood at the ends of trunks from exceeding saturation levels, and control the appearance of radial cracks in case drying speed can not be delayed any further. For such purpose we will not recommend the common practice of painting the end cross section of trunks because it will not only delay the drying of the ends but the drying of the whole trunk, since such cross sections are the main areas for water elimination; instead, a more generous selective straying programme may be appropriated.

Regarding crack control, the common practice of wire lacing around the ends of trunks should be also discharged; on one hand, steel wire of the quality that may be required can be hardly available or extremely expensive, and furthermore, as soon as contractions occur the lacing will go loose and become useless. In practical terms, we must recommend lacing with goat skin strips that can be always available at low price since parallel markets for such skins only admit large pieces discharging the small ones; skin lacing can be strongly applied and will tend to go loose when the wood swallows and contract together with the wood as it gets dry.

In operative terms, after bleeding, the trunks should be piled for a preliminary drying process that will reduce moisture content to an average of 32%, trunks will loose considerable weight, but problems deriving from dimensional changes are still far from affecting the timber, lacing is not necessary at this stage.

The arrangement of the pile should insure a clean environment, good ventilation, and protection from rain and direct sun rays. There is abundant information on piling methods for sawn timber that can guide the arrangement of trunk piles; nevertheless, we must hereby suggest a particular arrangement that can offer an advantageous alternative. (See Illustration 2.3.1)

Spraying programmes will strongly depend on local climate; in warm dry locations or seasons, it may be advisable to spray the whole pile every day, while in cold and humid environments a weakly operation
may be sufficient; special control should always be performed on the ends of trunks that might demand for additional spraying.

Drying time should be considered as a variable, personnel in charge of the operation should consider an average drying time of 6 month depending on climate, original water content of the green wood, and particular behaviour of the wood; constant control of moisture content by sampling each pile is compulsory, and as long as the wood does not show evidence of case hardening or dimensional changes, there is no reason for special concern.

PILING ALTERNATIVE
ILLUSTRATION 2.3.1

When the wood reaches a moisture content of not less than 32% (in theory it could be of 30%, but in the practice certain margin before reaching saturation level is desirable), the pile can be dismantled and trunks transported to the main treatment infrastructure area.

Treatment infrastructure can be owned and operated by a single plantation, by a cooperative of several small plantations, or as an independent enterprise that can rent its facilities or buy trunks at 32% moisture level for treatment and later trading.

After a preliminary sawing operation and preservation of the trunks, as we will explain in detail on the following sections, the second seasoning stage can be undertaken.
The processed trunks will be again arranged in drying piles that can be similar to the kind of pile used on the first seasoning stage, but considering the extreme control that should be applied on this stage, we would tend to suggest the erection of a drying shed in which more efficient regulations could be performed. Hereby we suggest a design for a drying shed that can imply a large number of advantages.

**Diagram**: Drying Shed Illustration 2.3.2
It is obvious that a drying shed will provide optimum protection from rain and direct sun rays, but as a bonus, it can also help controlling the speed, moisture content, and temperature of air flows that are key aspects at this seasoning stage. The orientation and dimension of openings on the walls and doors of the shed permits tailoring the speed of air flows, at the same time that openings on the roof allow the elimination of moisture; the use of external parasols and dark floor help to regulate the temperature of the air flow on different areas of the shed; in addition, moisture content can be easily increased by watering a dark floor under direct action of the sun.

More sophisticated sheds can consider the possibility of installing removable tin sheets instead of a dark floor with the advantage of being able to achieve faster changes in the temperature and humidity of air flows.

The piles of trunks can be arranged by a conventional parallel assembly separated by strips of treated hardwood; longitudinal slopes of about 2% can be achieved, not by the arrangement of the poles, but tailored on any of both directions by the suspension of the rail trolleys on top of which the pile stands during the whole process.

As soon as the drying pile is arranged, it is advisable to perform the previously mentioned lacing with goat skin strips, the lacing should be placed at approximately one inch of both ends of the trunk; the lacing itself can be done by a sliding knot and nail, or by the use of belt-like accessories; it is important to remember that such skin strip or belt should be fast to install and take away, the investment of specially made belts may prove to be feasible if we consider time savings and the possibility of using them several times before having to replace them.

As a second step, the loaded trolleys can be taken into the drying shed and the suspension set to a 2% slope. At first, the drying process can be relatively fast until reaching 26% moisture content in the wood; considerable amount of warm humid air can be induced into the shed in order to moisture the loads followed by an increase of speed and drop in temperature, this cycle can be maintained on a day-night basis until dimensional changes become notorious, moment on which loads should be moved further into the shed for a slower drying process.

Dimensional changes will start to show as the wood moves from its saturation stage towards hydroscopic balance with the environment, the risk of case hardening will be increased since sapwood and heartwood will have similar amounts of cellular water and yet sapwood will tend to loose it faster; at the same time, even though
bleeding techniques are likely to reduce wood tensions, it is still possible that tangential contractions in the wood may exceed on small proportion radial contractions, with the well known tendency of cracking the trunks.

Conventional drying programmes at this stage tend to fix an air flow with environmental moisture content, that is about 18% for the whole process, which means a dramatic moisture drop that is hardly controlled by spraying the timber.

Improved drying programmes at this stage, should consider a sequence of stations at hydroscopic balance giving the timber enough time for stabilization before a new moisture drop is induced, avoiding a moisture flowing drop that can hardly be hold fast enough and can inflict permanent damage.

It is advisable to fix moisture drops on an average of 4% for each station at hydroscopic balance which means 3 stations (26%, 22%, 18%) in the process of reaching 18% moisture content from 30% at saturation level.

It is of vital importance to maintain proper control on moisture and temperature values during this drying stage, a set of sensors can eventually trigger alarm systems connected to automatic spraying mechanisms that can increase moisture and reduce temperature during the day. Drops on moisture together with drops on temperature should not be matter of significant concern, actually it is very likely this may occur during night time; main concern should be always on preventing drops of moisture together with temperature increases that can accelerate the drying process beyond control.

It is again difficult to predict the drying time required for the achievement of each station at hydroscopic balance, but on average, we can expect one or two months for each moisture drop and one week for stabilisation before undertaking a new station; on the balance, the whole process can take from 4 to 7 month before the wood can be pulled out of the shed.

It is possible that the moisture content of the environment at the treatment site may be lower than the one in which the wood will be put into service; in particular, this is the case if the wood is dried somewhere in the Andes region (15% +- 1%) and is intended for service in Lima (18% +- 1%); in such case, it has no sense to dry the wood down to 15% stressing a shrinkage and later swelling as the wood moves towards the coast. It is advisable to retreat the wood from the drying shed as soon as it reaches 18% moisture level, and paint both.
ends of the trunks with moisture repellent additives as a coating. Finally, the trunks can be stripped from the goat skin belts, sawn to final marketing dimensions, and loaded in well protected trucks for their transport.

II.4. PRESERVATION METHODS.

As it was previously mentioned, the preservation process should be performed after a preliminary sawing stage in order to reduce the amount of material to be preserved. In addition to such obvious benefit on the saving of preserving substances, we must also point out that such preliminary sawing stage will open a large amount of vascular canals through which the preserving substances can penetrate the wood faster and more evenly.

From the many preserving methods and substances that can be used achieving different levels of penetration and retention, we must discourage the use of oil soluble compounds due to their high cost in a country that is not self-sufficient on its oil supply.

As we already know, the task at this stage is to preserve the sapwood of the E. Globulus trunks, since its heartwood is highly resistant to organic degradators and hardly preservable, no matter the method or compound that is used.

As an improved preservation method, we would like to suggest the following procedure that blends preservation and fire retarding by the use of water soluble compounds and a non-pressure process.

In terms of fire retarding, we must basically retard the ignition of the wood and slow down its eventual combustion.

As a wood warms up over 275 °C inner gasses are rapidly developed, the amount of CO2 goes down and rather large amounts of readily combustible carbon hydrates are produced, the ignited gasses form a sustained flame that warms up more wood on a chain reaction that must be retarded if not prevented.

An efficient fire retarding compound should have a twofold function: first, it should coat the wood so its warming-up process is retarded (as phosphates, borates and acetates will do); and second, develop inert gasses like carbon dioxide and ammonia that can slow down eventual combustion. In practical terms, the use of ammonium sulphate can be recommended even though it is likely to trigger a certain level of corrosion on metals in contact with treated wood.
otherwise the compound is cheap and easily soluble in water. Biammonium phosphate is recommended at most, since it does not cause corrosion on metals but can be more expensive than the ammonium sulphate.

Regarding preservation compounds, CCA (copper-chromo-arsenic) and CCB (copper-chromo-boro) salts are highly recommended in terms of performance, availability, and cost; actually both products are commercially available in powder and are easily soluble in water. Nevertheless whenever possible, it is advisable to avoid arsenic compounds since they are highly poisonous before chemical fixation within the wood. Compounds holding copper can again cause corrosion on metals; this negative feature should be evaluated on regard to the low price of copper compounds in a copper producing country like Peru; eventually, compounds holding fluor instead of copper can bridge this disadvantage with a moderated increase on price.

From our viewpoint, we must recommend the use of fire retarding compounds and preservation compounds that do not increase the risk of corrosion on metals, considering that such risk is already high in a humid environment like the one of Lima, where it is not unlikely to register atmospheric humidity levels over 95%.

As we have already mentioned at the time of describing improvements on drying methods, E. Globulus trunks will be transported towards the treatment areas before they reach saturation level at 30% moisture content; in practical terms, we can assume that transport operations can be undertaken when the wood is at about 32% moisture content and consider a margin of about 4% of moisture drop as the wood is transported and sawn before treatment.

Treatment will be, in any case, undertaken as soon as the wood reaches 28% of moisture content and not before such condition is met; it must be certain that the wood has lost all its free water and a small amount of cellular water for optimum behaviour during the preservation procedure.

Within the treatment procedure itself, an infrastructure of two neighbouring pools should be arranged for the performance of a hot-and-cold bath process.

As a first step, one of the pools holding a fresh water solution of fire retarding slats at 30% must be warmed up to a temperature between

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40 In - field survey by the author in cooperation with N. Rosen, chemical consultant / Toronto - Canada.
80°C and 90°C; this process can be achieved by the use of solar collectors in close circuit with the pool, a helical pump can suck fluid from the bottom of the pool into the network of collectors and back to the surface of the pool; we can propose the following design for such a purpose:

![Diagram of solar collectors and helical pump](image)

**HOT BATH TREATMENT POOL**
**ILLUSTRATION 2.4.1**

The trunks should be dipped in the hot pool and maintained within the fluid for a minimum period of 6 hours; the operation should achieve two objectives, by intravascular capillarity the fluid will penetrate the vascular system, and intracellular air will tend to expand.

After this first dipping, trunks should be placed in a warm area out of the pool, in such a way that intracellular air can remain on a expanded state but free water can drain out of the vascular system reinforcing the fixation of fire retarding salts. It is advisable to place the trunks with at least 50% slope under a cover of tin sheets similar to those used for the solar collectors; under such arrangement 60 to 90 minutes of drainage should be sufficient.

The second dipping should be performed immediately after the drainage of free water, this time the trunks will be dipped in a pool holding a cold solution of preservation salts at 30%; as previously, intravascular capillarity will allow the impregnation of the vascular network, but in addition, the warm air in the wood cells contracts.
upon cooling and creates a partial vacuum aiding the penetration of preservatives into the wood. There is evidence pointing towards the fact that most of the expected penetration will take place during the first 30 minutes of cold dipping; nevertheless, we must suggest a dipping of at least 2 hours in order to achieve proper fixation of preserving salts and reduce wood temperature before it is taken out of the pool and set to undertake its second drying stage as previously described.

The whole preservation procedure can and should be performed in one day; the best time to start may be one or two hours before noon, as solar collector accumulate sufficient heat for the warming of the hot pool, in such case, the hot bath procedure can be performed well within sunny conditions and the whole procedure can be resumed before summer sunset.

II.5. SAWING METHODS.

Non-conventional sawing of *E. Globulus*, as foreseen in several sections of this research, aims to the achievement of certain levels of quadrature on the circular cross section of the trunk, which do not necessarily imply its total quadrature.

In specific terms, the sawing process must be performed along the longitudinal axis of the trunk describing parallel flat planes in simultaneous basis avoiding the loss of balance in internal stresses, and the unavoidable deformation that such loss of balance can imply.

Sawing should always be performed within sapwood material; it is of fundamental importance to maintain a sapwood dressing that can be properly preserved and protects the inner heartwood; furthermore, sawing heartwood can be a very demanding task due to its hardness and should be avoided whenever possible.

Under such parameters, our suggestion is to divide the sawing process in two stages as follows:

A) preliminary sawing
B) final sawing

Preliminary sawing will take place as the trunks reach the main treatment infrastructure area, and before preservation procedures are undertaken; actually, in theoretical terms, this sawing stage should be performed as early as possible taking advantage of the relative softness of green wood in comparison with its future dry hardness,
but, in practical terms, it is advisable to do it at the main treatment infrastructure area where sawing equipment can be properly installed and working conditions are more suitable.

The aim of this first sawing stage is to reduce the amount of material to be preserved and perform the heaviest sawing task as the wood still holds about 30% moisture content with sensible advantage regarding its future dry hardness.

Personnel responsible for sawing operations must first sort the trunks looking for specimens not suitable for the process; in basic terms, trunks must have circular or nearly circular cross sections with an even sapwood ring and centre medulla, trunks not meeting such requirements should be set apart for other purposes. If E. Globulus growers follow our previous suggestions regarding improved plantation methods, it is very likely that most of the material will fulfil sawing requirements.

The sawing operation itself should be performed by the use of two circular sawing blades mounted on a single power axis with adjustable bridge between them; such equipment is available in machinery markets, but eventually the development of man powered tools for such purpose should be explored. (See Illustration 2.5.1)

Sawing should be performed taking into account the dimensional changes that the trunks will experience during the second seasoning stage, maintaining at least 10% margin for final sawing and achievement of marketing dimensions.

Undertaking previous calculations made for the definition of harvest triggering dimensions, the distance between saw blades can be calculated by the following formula:

\[
HT_{\text{max}} = \text{maximum harvest triggering diameter} \\
B = \text{bark thickness} \left(\% \text{ of } HT_{\text{max}}\right) \\
S = \text{thickness of sapwood} \left[\% \text{ of } HT_{\text{max}} - HT_{\text{max}}(B/100)\right] \\
BD = \text{distance between saw blades}
\]

\[
BD = HT - \left\{HT(B/100) + \left\lfloor HT-HT(B/100)\left\lfloor S/100\right\rfloor 70/100\right\rfloor\right\}
\]

As a matter of example, if we consider present value of variables, we can calculate the distance between saw blades for each marketing diameter as follows:
<table>
<thead>
<tr>
<th>Marketing diameter</th>
<th>Distance between blades</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>0.1090</td>
</tr>
<tr>
<td>0.125</td>
<td>0.1357</td>
</tr>
<tr>
<td>0.150</td>
<td>0.1632</td>
</tr>
<tr>
<td>0.175</td>
<td>0.1907</td>
</tr>
<tr>
<td>0.200</td>
<td>0.2182</td>
</tr>
</tbody>
</table>

Resaws arranged as Double Band Saws

The Unimaster Resaws can be easily arranged as double resaws. With this arrangement the Unimaster Resaws can also be used within a mechanized and automatic band saw line. If requested, documents for the technical operational sequence of the mechanization and automation can be supplied, as well as, the documents for the corresponding control system.

ILLUSTRATION 2.5.1
Again, it is of fundamental importance that growers and personnel responsible of timber treatment must gather and evaluate hard data on the wood characteristics and behaviour of their plantations in order to establish precise values for calculation variables; we must always remember that E. Globulus material can present different conditions from one plantation to another and that national and even regional averages do not necessarily imply the reality of individual plantations.

Preliminary sawing operations will produce a considerable amount of waste material, actually, the wood strips that are cut-off will react to the lose of balance on inner stresses and twist, nevertheless, such material has an industrial market in the production of wood wool & cement slabs that insures its profitable allocation.

After preliminary sawing, the resulting trunk will be subject of preservation and final seasoning as it has been previously explained. Final sawing will take place as the trunks come out of the drying sheds holding a moisture content equivalent to hydroscopic balance with the involvement on which they are intended to serve.

The final sawing procedure is similar to the one performed at the preliminary sawing stage, but now, the the bridge between saw blades will be set to a span directly related to the marketing diameter achieving the final product ready for its immediate transport towards its final marketing place.

II.6. COMMERCIALISATION METHODS.

Commercialisation under present conditions can be regarded as highly informal in administrative terms, and precarious regarding its physical implementation.

In physical terms, eucalyptus poles are stored mostly on vertical position without protection from rain an sun-rays; as a result, poles usually present cracks near to the cross sections due to extended exposure to sun-rays and water.

Storage methods should be improved, actually, the new characteristics of the marketing product do imply conditions for such improvements. First, poles should be stored on horizontal position; the virtual quadrature of eucalyptus poles can now offer the possibility of storing them the same way as saw timber is conventionally stored.

Storage sheds should be implemented in order to protect the poles from rain and direct exposure to sun-rays; poles should never be stored on
direct contact with the ground, and sanitary conditions should be always observed in order to avoid the proliferation of wood degrading agents.

Handling should also be improved, mechanical devices for storage and retrieval of products may be economically feasible only in very large deposits and, as a matter of fact, they can imply considerable advantages in terms of commercial efficiency, but small deposits may have to rely on labour for such procedures. Essentially, handling should be performed by a team of two men avoiding careless dumping of products; if necessary, dumping can be performed over a bed of used truck-tires in such a way that the dumping impact is reduced to a minimum.

In administrative terms, we must be very realistic and avoid suggesting a rigid formal practice in relation to an overwhelming informal market; experience has shown that traders tend to perform in accordance with their client, and as long as such clients remain uninterested on the formality of transactions, the whole commercial operation will continue to be informal.

At present, the members of our target group, have no concern on the formality of the transactions they perform, actually, informal transactions represent an obvious saving as they avoid taxation upon purchasing.

Nevertheless, as our research states, a building technology based on the use of eucalyptus timber should be first introduced to high and middle class segments of the Peruvian society, avoiding its eventual tipification as a technology for the poor; such fact will imply the intervention of formal building contractors demanding formal transactions from their suppliers, as a result, the performance of traders will have to move towards a formal structure in order to cope with the demand.

In global terms, the commercial structure for eucalyptus trading can be very diversified, depending mostly on the national and regional investment climate. Basically we can foresee 4 different but not necessary independent structures:

A) Holdings: large plantations and powerful building contractors controlling key activities of the general commercial structure, are likely to extend their activities towards each other trying to control intermediate activities such as treatment, transport, and open trading. Bilateral commercial agreements between growers and large scale builders can be frequent.

B) Associations: medium and small plantations will establish
national and regional associations in order to gain strength on their relations with suppliers (seeds, soil, fertilisers, equipment, etc.); such approach may also be extended towards the commercialisation of their output, establishing cooperative infrastructure for treatment, transport, and trading.

C) Private firms: independent intermediaries may find convenient to operate in any of the particular activities without a fix agreement.

D) Public and semi-public organisations: public organisations such as the "Banco de Materiales" (Bank of Building Materials) are likely to link their activities to any commercial structure, addressing market segments that may need subsidies on their access to a supply of building materials. Foundations, non-profit organisations and welfare institutions operating within the housing field are also considered among such kind of structures.

In terms of price, eucalyptus poles are not, and will hardly be, priced as a volumetric product; their production, treatment and handling costs are more related with those of building components and therefore a unitary price structure will always be the most fair approach.

Under present conditions, an average eucalyptus component is 4.69 times less expensive than an homologous timber component with a cost structure substantially different on regard to plantation and treatment costs; there is also a substantial gap between profit margins currently applied.

<table>
<thead>
<tr>
<th>Woods</th>
<th>Eucalyptus</th>
<th>Other woods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6&quot; on quadrature</td>
<td>6&quot; x 6&quot; x 3 mts</td>
</tr>
<tr>
<td>x 3 mts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantation cost</td>
<td>1x</td>
<td>3.5y</td>
</tr>
<tr>
<td>Plantation profit</td>
<td>25%</td>
<td>40%</td>
</tr>
<tr>
<td>Treatment cost</td>
<td>0.33x</td>
<td>0.33</td>
</tr>
<tr>
<td>Treatment profit</td>
<td>5%</td>
<td>0.0165</td>
</tr>
<tr>
<td>Transport cost</td>
<td>0.60x</td>
<td>0.60</td>
</tr>
<tr>
<td>Transport profit</td>
<td>10%</td>
<td>0.06</td>
</tr>
<tr>
<td>Commercial cost</td>
<td>0.15x</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>2.2565</td>
<td>7.995</td>
</tr>
<tr>
<td>Commercial profit</td>
<td>25%</td>
<td>70%</td>
</tr>
</tbody>
</table>

\[ \text{3.00x} \quad 42 \quad 14.10y \quad 43 \]

\[ ^{41} \text{In-field survey by the author among timber commercial outlets in Lima.} \]

\[ ^{42} \text{"x": variable implying unitary price structure} \]

\[ ^{43} \text{"y": variable implying volumetric price structure} \]
The improvements on plantation, exploitation, treatment, and commercialisation methods described in this Chapter, will have a direct impact on the present price structure of eucalyptus components.

Costs are likely to increase substantially in some activities at the same time that demand triggers an increase in profit margins; nevertheless, productivity based on the methods hereby suggested will yet determine advantageous costs, and the availability of the material can achieve balance with the demand giving little chance for commercial speculation.

Plantations costs will increase due to the financial costs of improvements, but on the other hand, exploitation costs will be reduced substantially as a result of those same improvements. On the balance, plantation costs can be increased on 30% to 45% reaching a maximum cost of 1.45x. Profit margins will also increase, but the availability of production sources will prevent it from reaching the profit margin of homologous plantations, we can foresee profit margins on the range of 30% to 45%.

Treatment costs will be dramatically increased, the costs of drying can be comparable with those of other woods, preservation can be yet cheaper due to the small volumes of timber that is actually preserved (only the albura) and the low operational cost of the preservation method itself. Sawing most of the wood as it still holds a substantial amount of water can reduce sawing costs with the bonus of a substantial amount of waste material that can be allocated in the production of wood wool and cement boards. On the balance, our calculations imply a treatment cost on the range of 1.20x.

Treatment profit margins can be the same as for other woods considering that treatment infrastructure may serve eucalyptus plantations amount others for which a 30% profit margin is already customary.

Transport costs depend largely on the location of forests and treatment facilities; if we consider present sources, costs will tend to drop as a result of transporting dry timber instead of green wood as it is currently done; trucks will be able to transport about 12% more material over the same load with better loading and unloading productivity due to the geometrical improvements performed on the eucalyptus components. On the balance, a cost reduction of about 12% can be foreseen.

In commercial terms, improvements on storage conditions can imply 100% increase over present costs reaching those of conventional sawn
timber.

The very important commercial profit margin will increase due to an expanding demand but the availability of the product will prevent the levels of speculation that are so common with other woods, for such evaluation, we can assume 45% as the minimum profit margin that is currently applied to other woods when by any circumstances the offer is abundant.

As a result, we can predict the following price determination structure for the future supply of eucalyptus components:

<table>
<thead>
<tr>
<th>Eucalyptus</th>
<th>6&quot; x 3 mts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantation cost</td>
<td>1.45x</td>
</tr>
<tr>
<td>Plantation profit</td>
<td>35%</td>
</tr>
<tr>
<td>Treatment cost</td>
<td>1.20x</td>
</tr>
<tr>
<td>Treatment profit</td>
<td>30%</td>
</tr>
<tr>
<td>Transport cost</td>
<td>0.528x</td>
</tr>
<tr>
<td>Transport profit</td>
<td>10%</td>
</tr>
<tr>
<td>Commercial cost</td>
<td>0.30x+</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{Total cost} &= 4.39 \\
\text{Commercial profit} &= 1.97 \\
\text{Total cost} &= 6.36x
\end{align*}
\]

In the future, an average eucalyptus component will still be 2.21 times less expensive than an homologous timber component.

This yet substantial price advantage of eucalyptus components over homologous timber components must be subject of further analysis out of an average condition; conventional woods are mostly treated on a volumetric basis since components are sawn out of standard trunks, the value of "y" is therefore almost constant, "y" will change only for very large or small components that happen to be out of the dimensional spectrum of eucalyptus components.

In the case of eucalyptus, components are sawn out of individual trunks, implying a trading on unitary basis; "x" is a variable that grows as the diameter of components is reduce; the following chart shows the factors that should be applied to "x" as diameters change over and under the average:
<table>
<thead>
<tr>
<th>Diameter (on quadrature)</th>
<th>&quot;x&quot; value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>1.28x</td>
</tr>
<tr>
<td>0.125</td>
<td>1.12x</td>
</tr>
<tr>
<td>0.150</td>
<td>1.00x</td>
</tr>
<tr>
<td>0.175</td>
<td>0.89x</td>
</tr>
<tr>
<td>0.200</td>
<td>0.80x</td>
</tr>
</tbody>
</table>

As a result, small components will come to a marketing price that is 1.73 times lower than homologous components and large components will gain further advantage, reaching a price of 2.77 times lower.

As we end this chapter, we can resume on the fact that eucalyptus poles, as we know and use them today, can be substantially improved into highly competitive building components, not only in technological terms but in marketing terms as well.

OVER: Conventional E. Globulus products of 4" and 8" by 3 meters long
CHAPTER III

PROPERTIES OF E. GLOBULUS BUILDING COMPONENTS

Building materials, as their name textually implies, are aimed towards the erection of buildings and within such context it is of vital importance to study and learn how to work with them, making the best out of their virtues and limitations.

This research has already established the feasibility of producing building components out of eucalyptus wood, we can even say that a building material has been developed in terms of product; now it is imperative we define its attributes as we move towards its technological application.

III.1 PHYSICAL CHARACTERISTICS.

III.1.1. APPEARANCE.

E. Globulus building components will present a uniform light-cream colour (preservation may give a low copper or yellow colour tendency) with hardly any shaded pattern offering a smooth texture. The material
will offer an optimum surface for simple polishing or the application of transparent lacquers. Eventually, it can be easily painted with light colours with no need for undercoating.

III.1.2. **WEIGHT.**

The traditional heavy weight of eucalyptus poles will be substantially reduced as we achieve building components at hydroscopic balance with environmental moisture levels; nevertheless, it will still be among the heaviest woods used for building purposes. With an average density of 0.657 gr/cm³ (air dry to 18%) component of 6" inches diameter and 3 mts lengths will weight about 45 kg.

III.1.3. **DIMENSIONAL STABILITY.**

The dimensional stability of E. Globulus building components can be affected by variations on temperature and moisture. Longitudinal dilatation and swelling are likely to be so small in the marketing components we have defined, that it can be neglected; but on radial and tangential directions, dimensional changes can be substantial and should be prevented.

Components set on service in environments that may change from warm and humid to cold and dry conditions are the most susceptible ones, actually, such conditions are frequently met at settlements in the Andes region near to fresh water deposits. During the day temperatures can raise even over 30 °C and atmospheric moisture reach 98% while at night temperature may drop to 5 °C and moisture decrease to about 65%.

In Lima City, the main target market for our product, conditions are far less dramatic, warm weather coincides with drops on atmospheric moisture and it is during winter time that environmental humidity reaches its peak; this means that temperature and moisture effects tend to compensate each other. In addition, environmental conditions change little from day time to night and from summer to winter seasons; nevertheless, summer day time temperatures may exceed 35°C and winter atmospheric humidity can reach 99%, reasons why dimensional stability should be regarded as a concern.

Regarding the possibility of shrinkage and swelling, components will reach Lima's market on hydroscopic balance and with both cross sections protected by a coating of tar or coating paint, fact that will reduce the eventual exchange of moisture between timber and environment; during storage time, slow and small dimensional
changes can be foreseen, but can be considered as negligible since they will not imply any decrease in the quality of the product.

As the components are set on service, dimensional changes of about 0.5% can occur representing at most 1 mm change on the cross section of our largest component; such small dimensional variation can still imply substantial concern regarding timber joints where such dimensional changes may work on an accumulative basis resulting on severe deformations.

Designers and builders must prevent any risk deriving from the shrinkage or swelling of E.Globulus components, as with most timber components, and establish building margins so joints may cope with such dimensional changes; eventually, complete coating of the components with water proof substances can still reduce further any tendency towards dimensional change and make it negligible all together.

Regarding the conventional expansion and contraction of most building materials, as result of temperature fluctuations; wood in general, can have from one-tenth to one-third of the thermal expansion coefficient of other common structural materials and glass. For this reason, consideration must be given to the differential thermal expansion of various materials used in conjunction with eucalyptus timber components. Eventually, any regard towards dimensional changes due to moisture variations in E. Globulus components will exceed those that may be regarded due to thermal expansion or contraction.

III.1.4. THERMAL INSULATION.

With the exception of mineral wool and other building materials specially manufactured for thermal insulation purposes, wood is by far the most efficient alternative.

Thermal conductivity on woods is directly proportional to its moisture content and density, therefore, E. Globulus components treated as foreseen, will achieve a relatively low insulation performance if compared with other woods, specially softwoods.

A E. Globulus component is likely to offer a thermal conductivity of about 0.15 kcal/hour-mt-°C on longitudinal basis and 0.062 kcal/hour-mt-°C on radial or tangential basis, which is yet substantially lower that the conductivity of clay brick (0.75 kcal/hour-mt-°C) or concrete (1.27 kcal/hour-mt-°C).
III.1.5. ACOUSTICAL PROPERTIES.

Wood is in general terms regarded as a satisfactory sound-insulating material, its anatomical nature, elasticity and low density, if compared with other materials, are substantial attributes.

E. Globulus building components do share such positive attribute, but their high density among other woods, implies a performance that must be improved through an acoustic-minded use of them in the building environment.

For designers and builders, an analyses of sound conductivity and absorption on E. Globulus components can be considered irrelevant; like most common construction materials, wood alone may not provide the desirable sound insulation, but, when combined with other materials specially conceived for such purposes, the resulting product can achieve outstanding performance.

In particular, E. Globulus components can be quite efficient, as most woods, on the absorption of low-frequency sounds.

III.1.6. ELECTRICAL CONDUCTIVITY.

The electrical resistance of wood varies with its moisture content and density on an inverse progression.

Metallic salts that may be used during preservation treatment may lower electrical resistance considerably.

As previously mentioned, E. Globulus timber is not a low-density wood, actually it can be regarded as a dense one with an average of 0.657 kg/cm³, and if in addition we consider it may reach hydroscopic balance at 18% moisture content, we can predict an electrical resistance under 3 megohms; such medium-low electrical resistance can be reduced even further by the use of copper salts during the preservation treatment.

Therefore, E. Globulus components should not be considered as electric insulation, and direct contact between electrical sources and timber should be avoided.

III.2. MECHANICAL PROPERTIES.

We have already established the mechanical advantages that E. Globulus timber can offer as part of our Chapter I, the information contained
under this title may differ slightly from the one previously given as a result of the material technological improvements described in Chapter II.

III.2.1. AXIAL COMPRESSION.

Columns are the most typical building components working under this kind of stress; actually, a wooden column, on such regard, works very much like a set of paper cylinders bounded together into a larger cylinder, and as such, density plays a fundamental role.

E. Globulus timber has a considerable density that makes it quite resistant towards compression, but from previous information we can see that its elastic module on compression remains to be far lower than its E. module on static flexion which is not the typical behaviour among tropical woods.

E. Globulus timber can present twisted fibbers as a result of its conventional growing environment; the action of winds upon a top mass of branches and leaves implies a powerful torsion stress along the stem of the tree, generating such twisting in the wood fibbers; therefore, compression stresses applied along the longitudinal axis of a component do not necessarily act on parallel direction to the wood fibbers that tend to collapse, not due to compression stresses but due to bending forces.

As plantation and growing methods are improved according to our recommendations in Chapter II, E. Globulus timber fibbers will be less twisted implying substantial increase in its capability to cope with compression forces along its axis.

According to tests made on specimens presenting minor twisting in their fibbers, we can predict that the previous value for E. module towards axial compression ranging at about 96 tons/cm², will be increased to about 119 or 120 tons/cm².

On similar way it has been possible to establish the following data:
- collapse limit 511 kg/cm²
- proportional limit 403 kg/cm²
- allowable stress 254 kg/cm²

III.2.2. STATIC FLEXION.

The technological improvements on the material described in Chapter II, have also affected the behaviour of E. Globulus timber towards
static flexion.

Beams are the most common building components working under this kind of stress, actually a wooden beam, on such regard, works very much like a book when it is bounded at both sides and forced into a flexioned condition; the pages on top will be compressed and perhaps crashed as those at the bottom are subject to traction.

In a E. Globulus beam, top fibbers will be subject to compression at the same time that bottom fibbers act under traction; conventionally, the twisted fibbers on the top of the beam will offer a smaller resistance to compression generating a deformation, and the twisted fibbers at the bottom will act under tension with a reduced capability due to the same reason.

The straightening of E. Globulus fibbers will mean further resistance to compression, as we have previously stated, and therefore, top fibbers on a beam will more hardly give up to the stress, at the same time that bottom fibbers will work on tension with upgraded capability.

According to tests made on specimens presenting minor twisting in their fibbers, we can predict that the previous value for E. module towards static flexion ranging at about 147 tons/cm² will be increased to about 154 tons/cm².

On similar way it has been possible to establish the following data:

- collapse limit 1276 kg/cm²
- proportional limit 956 kg/cm²
- allowable stress 554 kg/cm²

III.2.3. CUT STRESSES

In terms of cut stresses applied on an axial direction, the content of lignine as bounding component between fibbers is fundamental; on such regard, chemical tests made by the paper industry have shown that E. Globulus timber has a relatively small amount of lignine that makes it good for paper production, but do limit its performance under this kind of stress.

Laboratory test made on this regard have shown a maximum allowable stress of 20.74 kg/cm² which is low if compared with other woods.

On a perpendicular plane, allowable stresses can be substantially larger than its theoretical ration of 4 to 1 with axial loads; tests
made on specimens free of defects have registered allowable stresses up to 133 kg/cm².

III.2.4. HARDNESS.

E. Globulus timber is traditionally considered as a hard wood, nevertheless, recent tests on specimens aging between 4 and 12 years old, grown in areas of minor slopes, have shown substantial drops on side hardness.

Cross section hardness remains substantial, rating between 760 kg/cm² and 731 kg/cm², but side hardness has dropped from a conventional rate of 638 kg/cm² to about 440 kg/cm² offering better working conditions.

On the balance, the predictable mechanical performance of new generations of E. Globulus woods can be very promising; but as previously mentioned in Chapter I 1.3, until behaviour standards for this kind of wood are officially fixed, builders are strongly encouraged to test their wood sources before establishing structural dimensioning.

III.3. BEHAVIOUR TOWARDS BUILDING IMPLEMENTATION.

Eucalyptus building components will be subjects of diverse implementation actions in order to modify their marketing characteristics towards their introduction within a specific design; components may have to be cut and joint together, as well as with other materials; this title deals with the behaviour of E. Globulus timber regarding the most common building implementation needs that housing design and construction may imply.

III.3.1. CUTTING (sawing)

One of the most frequent implementation operations to which E. Globulus components may be subject, is the one of cutting their standard length down to design requirements; cross section sawing can be very demanding on eucalyptus timber due to its hardness and therefore it should be performed in the most efficient way possible.

If the operation is performed by hand, it is advisable to fasten the component with hand clamps to a rigid bench before starting to saw, strokes may need to be quite strong and on such regard hand-holding of the component may prove to be insufficient. If clamps are not available, it is advisable to use a handsaw with small teeth applying not much pressure on the blade and saw at a rate of 1.5 to 2 strokes per
second in order to minimise the power of stock-backs; tests have shown that a single man can hold a component with one hand over a rigid surface and perform a cross section cut only by means of a hacksaw aimed for cutting metals.

If a E. Globulus component can be fastened rigidly to a working bench, the worker can use almost any crosscut saw without major difficulties; nevertheless, it is advisable to use blades of about 8 points per inch in order to achieve a good balance between power applied and sawing speed.

For extensive cross section sawing, we must encourage the use of motor powered tools; a circular crosscut saw mounted on a radial sawing machine can be very efficient in terms of rendiment. It may be a good idea for traders to offer the use of a radial sawing machine to their customers at a small additional cost with the bonus of the waste material that can be sold again as eucalyptus firewood.

In any case, we must recommend not to saw through timber knots avoiding their extreme hardness, and through timber coming from natural forests since it may contain bullets that can be dangerous not only for the tools, but for the worker himself.

III.3.2. SHAVING.

Shaving E. Globulus components can also be a frequent need, specially if the component is to be exposed as a decorative item. For such purpose the use of standard plane with adjusting nut can be recommended with the only regard of avoiding an excessive knife penetration that may prove to be difficult to control; otherwise shaving E. Globulus timber can be a very rewarding experience.

If design requirements demand for massive shaving of timber it is again advisable to use motor-powered tools as a bench planing machine, most timber workshops will have one and its use on eucalyptus timber demands no special concern.

For minor details, a lightweight tang chisel can be the most efficient shaving tool, but as in the case of the standard plane, the carpenter must avoid dramatic penetrations that may crack the wood along its fibber; we must always remember the natural tendency of eucalyptus timber towards cracking.

Sources: In-field survey by the author
III.3.3. NAILING.

Nails are the most common mechanical fasteners used in the timber construction environment. They can come in many different sizes, head and point types, shak types, kinds of metals, and finishes. However, within the context of our research we must restrict ourselves to the use of the common steel wire - nail since other types are not available in the market or are extremely expensive.

Splitting is the main concern as we consider the nailing of E. Globulus timber; tests have shown that the most common preventive measures like clamping or applying pressure where the nail is driven, blunting the point of the nail, and even soaping or oiling nail shanks, have been of little help avoiding the splitting of the wood.

On such regard, the best nailing technique we can recommend may seem quite elaborated; first, a small amount of glue must be applied in the contact surfaces that are then clamped together into a fixed arrangement, second, pilot holes of about 2/3 of the diameter of the nail must be drilled, third, a soaped nail is driven through the pilot hole and clamps are retrieved.

As a general rule, the thickness of any eucalyptus component must be at least 6 times the diameter of the nail used, same should apply for the minimum distance between nails if due to mechanical reasons more than one nail is necessary.

Whenever possible the use of gang nails should be advisable on replacement of large nails, eventually, the cost of gang nails can be covered substantially by the higher productivity that they can imply in comparison with the elaborated nailing technique just described.

III.3.4. SCREWING.

The most important use of screws in the timber building environment is in fastening other materials to wood, eventually they are also used for wood joints due to their superior holding power if compared to nails.

The behaviour of E. Globulus wood towards screwing is similar to the one towards nailing, splitting remains to be a limitation, but tests have shown that on average such risk is reduced on about 40%; nevertheless, the performance of pilot holes must be recommended as well as the soaping of shanks and roots before they are driven into position.
Screws can be several times more expensive than nails, therefore, our recommendation will be to use them only where the use of nails is clearly unsuitable; for instance, joints that may be subject of swelling can be unsuitable for nailing since such swelling will tend to drive nails out, screws can be much more efficient in such case and eventually they can always be driven back into position with a small reduction in their holding capability; this is a practice we can hardly recommend in the case of nails.

Screws can be used efficiently on plated joints, instead of bolts if mechanical stresses are not high, this may be the case within a housing structural environment where nailed joints may be considered as weak and bolted joints may be excessive.

III.3.5. BOLTING.

The use of bolts within the timber building environment is quite frequent, specially on heavy timber construction due to the outstanding structural soundness they imply.

In practical terms, bolting procedures change very little regarding the characteristics of the wood that is used, we can even say that bolting will always imply the introduction of a bolt through a hole drilled across timber components arranging a joint without any further practical specifications on how to perform the task.

In the case of bolting, wood behaviour is more related with the design of joints, distribution of bolts, and metal platings, that with the way in which the actual bolting is performed.

E. Globulus timber is very suitable for the arrangement of bolted joints, as a matter of fact, metal plating in eucalyptus woodwork is frequently considered excessive; since eucalyptus timber can take substantial loads on compression perpendicular to the fibber, the use of washers under the head of bolts may prove to be sufficient.

In design terms, the general rule is to avoid bolting timber components with a thickness under 2D (D = diameter of the bolt), if more than one bolt is necessary the distance between bolts, measured from axis to axis, should be as a minimum 4 D. Regarding the design of joints, bolts together with metal plates can imply great design flexibility, it is frequent to find that designers tend to dramatise joints far beyond real structural demands due to aesthetical reasons that are quite in fashion within the so-called hi-tech style.
OVER: Radial crack produced by driving a nail without the aid of a pilot hole; a screw behaves better under similar procedure.

UNDER: Nail driven with the aid of pilot hole.
III.3.6. LACING.

Lacing timber joints is a practice that can be traced down to ancient times, the use of leather and vegetal fibbers has been frequent in old civilisations, but as metals were developed and metal hardware produced, the use of lacing methods was substantially reduced.

During the last years, there has been certain interest on rescuing lacing technics using steel wire instead of organic materials to do so; on such regard, the main problem has been on the development of tools able to lace wire with the tightness required by building structural stresses.

The Faculty of Civil Engineering at Delft University of Technology (Holland), has developed a wire lacing tool able to perform structural wire lacing on round timber; the feasibility of using such fastening technology in the production of housing structures is very promising.

OVER: Conventional wire lacing of doubtful tightness
CHAPTER IV

TECHNOLOGICAL APPLICATION OF E. GLOBULUS BUILDING COMPONENTS

We can hardly conceive a building material or component in isolation from its application technology. A brick is of very little practical use if we do not count with the basic know-how for building a wall with it; in similar way, it is of little use to develop a building material like our E. Globulus building components if we neglect the development of a related building technology for its actual use.

This chapter is therefore concerned with the development of the basic know-how needed for building with E. Globulus building components.

As we undertake this task, we must remember our fundamental criteria of developing a building technology for low income housing, that will be first introduced to higher social sectors as a mechanism for insuring good levels of acceptability among our low-income target group.

Therefore, the basic E. Globulus building technology we are about to
describe must be understood as a "know-how platform" from which simplifications as well as sophistications could be derived.

IV.1. BASIC TECHNOLOGY

The basic technology hereby detailed will be described within the context of a diversified building system, in order to illustrate at the same time its compatibility with other basic technologies.

Due to methodological reasons, the basic technology will be described in accordance with the following structure:

- structural system
- covertures
- doors, windows and staircases
- networks

IV.1.1. STRUCTURAL SYSTEM

Most structural technologies used for housing design and construction offer the possibility of arranging the transfer of loads by means of load bearing porticos (columns and beams) or load bearing walls. It is a common engineering practice to use load bearing walls whenever it is possible, but sometimes designs may require large openings between functional spaces or between the interior and exterior of the building; in such cases load bearing porticos are used.

Our E.Globulus basic technology will also address such two structural approaches on benefit of design flexibility.

IV.1.1.1. LOAD BEARING WALLS SYSTEM.

This is perhaps the most common structural system used for conventional housing designs; it is very frequent in relation with brick and wood technologies and is considered by many as the most economical approach towards solving the structural needs of a house.

The system is based on the criteria of transferring the loads of the building from floors and roofs towards walls that stand as load bearing elements supported by some sort of foundation.

Within wood technologies, this structural system has been called: modular frame system, skeleton wall system, structural partition system, etc; we prefer to remain using its general denomination -load bearing walls system- due to its self-explanatory nature.
FOUNDATION AND FIRST LEVEL FLOORS.

Foundations are the base over which the load bearing walls are to be erected aiming towards the transfer of loads from the wall to the ground or soil, spreading them by means of an enlarged contact area with the soil.

On conventional cases, a load bearing walls system is related with foundations in the form of longitudinal footings or foundation slabs. Foundation slabs are recommended in the case of soils with good mechanical performance, well drained sites and relatively small structural demands from the dwelling. This kind of foundation relays completely on concrete or re-enforced concrete technology.

The concrete slab is thickened along its perimeter and under the future location of load bearing walls as the following illustration shows.

ILLUSTRATION 4.01

On the case of soils with lower mechanical resistance or considerable structural demands, the use of longitudinal footings should be recommended. This alternative offers at the same time the possibility of establishing a floor level separated from the soil, in such case, E. Globulus technology can be efficiently introduced.
The following illustrations show the same foundation alternative based on concrete or re-enforced concrete technology, but the first one considers a concrete slab as first level floor in contact with the ground, while the second one makes use of E. Globulus technology for the construction of a floor separated from the ground level.

It must be mentioned that direct contact between E. Globulus building components and soil should be avoided whenever possible, as any other wood component, E. Globulus components may required special additional protection towards degradation agents such as underground termites or constant contact with a humid environment.

**ILLUSTRATION 4.02**

Foundation walls may be centred or marginal to longitudinal footings and have different heights, in accordance with design specifications; it is important to mention though, that the thickness of foundation walls must be larger in relation with wooden floors above ground level not only in order to accommodate the heads of floor beams, but to improve its behaviour regarding eventual flexion stresses.
SECOND LEVEL FLOORS.

Second level floors can be built using mostly a E. Globulus technology; in conventional cases we must consider the use of 3 different kinds of components: first, sleeper beam running on top of the load bearing wall, second, a sequence of floor beams giving support to a conventional male-female wooden floor slab, and finally, short separators set on top of the sleeper beam and between floor beams. The illustration 4.04 shows an arrangement that can be regarded as standard.

It may be also frequent to have second level floors that extend themselves over load bearing walls and continue covering additional spans. The illustration 4.05 shows an alternative arrangement under such cases.

ILLUSTRATION 4.03
On second level floors, it is often needed to establish perforations for the arrangement of staircases; it is always convenient to locate stairs in the same direction that floor beams and try to reach a sleeper beam with the summit of the staircases. But, if such arrangement is not possible, we can consider the use of double roof beams making a frame that defines the needed perforation as the following illustration 4.06 may show.

ILLUSTRATION 4.06

E. Globulus roof-floor beams have square-like cross sections that require no intermediate separators as they cross a span; even if due to
unconventional spans or loads there is a need for the arrangement of laminated-like beams, holding several components one on top of the other, the use of intermediate separators will be required only in the extraordinary case of 4 or more components assembled together.

WALLS AND PARTITIONS.

Within a load bearing wall system not all the walls have a load bearing function, actually we can consider that on average 50% of all the walls in a house can be considered as non-bearing partitions.

Designers must consider 2 important criteria at the time of developing a design based on this structural system:

1. Load bearing walls do permit perforations for doors and windows, but whenever possible, the widthness of such perforations must be restricted.

2. On areas that may be affected by earthquakes it is compulsory to establish load bearing walls with diversified orientations, trying to maintain a homogeneous density of structural sections.

There is a basic difference between the constitution of load bearing walls and partitions; the first ones have an internal structure based on poles at a distance that hardly exceeds 0.90 mts, the partitions have a similar structure of poles but they are separated by at least 1.20 mts. In conceptual terms, the structure of load bearing walls is aimed for a vertical transfer of loads while the structure of partitions is aimed for the support of enclosure elements.

Walls and partitions are structures made out of 2 basic E. Globulus components; frame beams, and frame poles, arranging a structural frame that can be built in-situ or prefabricated somewhere else and later installed on top of sleeper beams.

The illustration 4.07 shows an alternative for the arrangement of walls and partition frames.

The structure of wall frames is mainly directed towards coping with compression stresses once it has been installed between sleeper beams; nevertheless, the structure must be able to cope with some lateral stresses. If compatible with the intended technology for enclosure, it is advisable to cover both faces of the structure with plywood panels that will add stability to the frames and prevent diagonal deformations.
If the use of plywood panels is not compatible with the enclosure technology, or the quality of plywood panels makes them unable of confident structural performance, the wall frames must be re-enforced by diagonal components made of sawn timber as shown in the illustration 4.08.

ILLUSTRATION 4.08
Wall perforations for doors and windows should be arranged carefully; if possible, designers must coordinate the location and the dimensions of perforations with the free span between frame poles in the wall, if such arrangement is not convenient due to functional or aesthetical reasons, it is advisable to reinforce the structural section of perforations as it is shown in the following illustration.

**ILLUSTRATION 4.09**

Wall frames can be set together arranging "L" joints, "T" joints, and "X" joints according with design requirements; the designer must prevent the future requirements of the enclosure technology and supply at least half of a pole for the fixation of the intended enclosure material. The following illustrations show some alternatives for such arrangements.

**ILLUSTRATION 4.10**
ROOFS.

Roof structures are on principal very similar to floor structures, they are also based on free span beams supported by sleeper beams running on top of load bearing walls; the main difference though, is that roofs must hold a certain slope in order to drain rain water and for the same reasons must often extend themselves beyond the perimeter walls of the buildings.

Slopes on roofs within a load bearing wall system are achieved by differential heights of the structural walls under it. Single and double slope roofs can be considered as standard alternatives within this structural system; the following illustrations show an alternative solution for each case.

ILLUSTRATION 4.11
IV.1.1.2. COLUMNS AND BEAMS SYSTEM.

In the field of housing timber constructions, this system is less common than the one of load bearing walls; columns and beams systems are mostly used in relation with steel and re-enforced concrete technologies; nevertheless, sometimes design requirements may call for the use of this structural system on timber, and therefore it must be included within the basic E. Globulus building technology.

The system is based on the criteria of transferring the loads of a building from floors and roofs towards structural beams, and from them to columns that reach ground level with a concentrated load that is finally distributed on the ground by foundation unitary element.

FOUNDATION AND FIRST LEVEL FLOORS.

Foundations for concentrated loads can be of two basic types: piles or unitary footings.

Piles can be arranged by the use of re-enforced concrete technology or E. Globulus technology, and are strongly recommended on sites where the mechanical performance of superficial soil is extremely low. Re-enforced concrete piles should be used if consistent soil can only be
found at more than 6 meters under the surface; it implies the need of equipment and skilled laybour; for less dramatic piling requirements, the use of E. Globulus components must be recommended, specially if the pile can be buried in the ground instead of driven into it.

On the case of E. Globulus piles, it may be advisable to consider its superficial section as a column, such pile-column will be subject of considerable flexo-compression stresses that must be properly evaluated.

The following illustration shows an alternative for the most common case of a pile-column buried in the ground, and its relation with a first level floor. We must call the attention of our readers towards the use of a wooden reinforcement cylinder in the column, which offers a section of horizontal fibbers to the cut stress that bolts may introduce, otherwise the stress would act parallel to the wood fibbers with the eventual tendency of producing cracks along them.

ILLUSTRATION 4.13

On soils with normal mechanical performance, there is no need for piles, as a matter of fact, this may be the most common circumstance; in such cases the use of re-enforced concrete technology
for the production of unitary footings is by far the most convenient alternative.

Unitary footings will perform basically under comparison stresses, distributing the concentrated loads that are applied by columns over a larger contact area with the soil; in some cases though, unitary footings may need to be substantially large performing over soil of poor load bearing capacity, and therefore a grid of steel bars may be arranged at its bottom section in order to safeguard its integrity.

First level floors also rely on concrete technology, but since they only receive the loads of partition walls, we can conceive such floors as a simple concrete slab.

The following illustration shows a standard alternative for unitary footing foundations.

ILLUSTRATION 4.14

SECOND LEVEL FLOORS.

Second level floors within a column and beam system can be arranged by using a E. Globulus technology. In structural terms, the arrangement is based on main beams, secondary beams, and floor
surface. Main beams and secondary beams can be E. Globulus components, but the floor surface must yet rely on additional technologies as for instance conventional timber technology.

Joints between columns and beams can be easily solved if the designer can foresee the use of columns covering the height of two stories with a single E. Globulus component, and double components for beams approaching such columns; in such case the arrangement can be identical to the one suggested for first level floors in illustration 4.13.

If by any reason, the designer or builder finds necessary to perform a column-to-column joint between stories, it may be advisable to use double E. Globulus components in the beams reaching such joint, and to use them as shown in the following illustration.

ILLUSTRATION 4.15
On the other hand, under certain circumstances a designer may wish to use single beams instead of the double beams already described; in such case, it shall be advisable to avoid a column-to-column arrangement within the joint, and adopt a detail like the one suggested by the following illustration.

**ILLUSTRATION 4.16**

**WALLS AND PARTITIONS.**

Within a column and beam system, the structural frameworks of walls and partitions do not have a structural function other than that of giving support to the enclosure elements. In conventional terms, walls are placed along the perimeter of the house and partitions in the interior of the dwelling.

The structural framework of a wall or partition is basically made out of posts, fitted between columns with a spacing directly related to the dimension of enclosure elements; some times it is possible to find gaps as large as 1.80 or 2.40 meters between posts.

Within a pre-fabrication approach, the structural framework of walls
and partitions is very similar to the one of load bearing walls due to the stresses that may be foreseen during transportation; but nevertheless, the density of the structure will be notoriously lower.

The subject of walls and partitions will be discussed in further detail within the section related with covertures.

**ROOFS.**

The structure of roofs in relation with the column and beam system is also based on a framework of main beams and secondary beams.

This kind of structures are specially suitable for the development of aesthetical concepts; designer can find great flexibility on the fact that the roof is actually supported by columns and beams instead that by walls.

Within this basic version of the E. Globulus technology, we will describe only the most common arrangements for a double slope roof and look-out roof, giving our readers the change of innovating further upon it.

The following illustrations show the fact that main beams can be substantially apart one from the other, actually the span between main beams may be the same as between columns. Such span requires the introduction of secondary beams that will reduce the span down to a dimension suitable for the fixation of enclosure elements.

![Diagram of roof structure with labels: tin fixation plate, wooden re-enforcement cylinder, column, structural beam (E.G.), bolt.]

**ILLUSTRATION 4.17**
IV.1.2. COVERTURES.

For the design and construction of housing covertures such as walls and roofs, the E. Globulus basic building system must make use of
additional technologies in order to optimize the performance and cost of the dwellings where it is applied.

From a technical point of view, it is possible to produce laminated components out of eucalyptus timber, but the production costs involved in such processes would hardly permit their competition among other materials in the market.

Nevertheless, there is one alternative for covertures that is fully consistent with our global dynamic upon the use of E. Globulus timber; as described in previous sections of this research, it is possible to use E. Globulus waste material in the manufacturing of wood wool and cement slabs.

Therefore, the E. Globulus basic building system we are hereby describing, will make use of E. Globulus wood wool and cement slabs as coverture technology.

IV.1.2.1. WALLS.

The E. Globulus structural framework of walls and partitions must be covered by both sides with wood wool and cement slabs (wwc slabs). This is an operation that should take place "in situ", considering that wwc slabs are aimed as coverture elements and not as part of the structural framework of such walls or partitions.

A key factor on making the E. Globulus structural technology compatible with the wwc slabs technology, is to be found in the dimensional coordination that both technologies must account. The following chart shows the dimensions in which wwc slabs are currently produced; designers must take into account such information at the time of specifying the dimensions of the structural frameworks giving support to wwc slabs.

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>H X W</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWC SMALL SLABS</td>
<td>0.5&quot;,1&quot;,2&quot;,3&quot;,4&quot;</td>
</tr>
<tr>
<td>WWC LARGE SLABS</td>
<td>0.5&quot;,1&quot;,2&quot;,3&quot;,4&quot;</td>
</tr>
</tbody>
</table>

The following illustrations show the way in which wwc slabs can be display over a wall or partition framework.
We must call the attention of our readers upon several recommendations at the time of fixing wwc slabs over the E. Globulus frameworks:
1. WWC slabs can be display on vertical or horizontal position; nevertheless, it is advisable to place them horizontally since in such way most of the joints between slabs will be based on a mortar strip.

2. Horizontal joints between slabs must be covered by a metal net or a piece of rough fabric in order to avoid the appearance of cracks on the plaster finishing over such areas.

3. WWC slabs must be fixed to the E. Globulus framework by means of nails. It is advisable the use of some kind of wacher together with the nails, some times soda cups are used for such purpose.

4. Vertical joints between slabs must be nailed to a single structural unit of the framework; it is advisable to apply a wire zig-zag among the nails in order to avoid any outward twisting of such nails.

5. The thickness of the wwc slabs to be used will largely depend on:
   - the distance between framework elements.

<table>
<thead>
<tr>
<th>SPAN</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50-0.60 mts</td>
<td>0.5&quot;-1&quot;</td>
</tr>
<tr>
<td>1.00-1.20 mts</td>
<td>2&quot;</td>
</tr>
<tr>
<td>1.50-1.80 mts</td>
<td>3&quot;</td>
</tr>
<tr>
<td>2.00-2.40 mts</td>
<td>4&quot;</td>
</tr>
</tbody>
</table>

- the level of thermal and acoustic insulation required. (see manufacturer specifications)
- the visual requirements regarding the thickness of finished walls.

IV.1.2.2. ROOFS.

Most of the roof structures already suggested in this chapter show the use of a conventional roof coverture made out of male-female-joined planks; nevertheless, within this section we would like to suggest the use of E. Globulus wood wool and cement (wwc) slabs for such purpose.

For the fixation of wwc slabs to a E. Globulus roof framework it is advisable to consider the following recommendations:

- It is advisable to place the wwc slabs following the same direction of the supporting structure, in such way that most joints between slabs fall on top of the structural framework.
- The wwc slabs can be fixed to the timber framework by means of nails. It is advisable to use some kind of washer and a wire zig-zag among the nails as previously described for the case of wall enclosures.

- WWC slabs coming to a joint without a timber support element directly below them, should be joint together by "u" nails performing across a male-female section.

- The rough texture of wwc slabs permits the application of a mud-cement topping able to offer a convenient base for the display of shingles.

The following illustrations show an alternative arrangement for roof covertures by means of wood wool and cement slabs.

![Diagram showing wood wool & cement slabs, wire zig-zag, "u" nails, roof tiles, mud-cement mortar, secondary roof beams (E.Q.), and wood wool & cement slabs.]

**ILLUSTRATION 4.21**
Additional alternatives for roof covertures will be discussed within the sections of upgraded technology and simplified technology of this document.

IV.1.3. DOORS, WINDOWS AND STAIRCASES.

It would be unrealistic to suggest a E. Globulus technology for the production of doors, windows, and staircases; the production of all such housing components is based on the use of profile elements that are extremely difficult and expensive to achieve with a hard wood like the one of eucalyptus globulus. For such purpose, conventional carpentry technology can be integrated with the basic E. Globulus technology we have been describing in order to achieve a rational building system.

Within this document, we will not devote deep considerations upon conventional technics for the production of wooden doors, windows,
and staircases; our aim is to show a basic alternative for integrating such building components within the E. Globulus technology subject of this dissertation.
WINDOWS

wall frame (E.G.)

plaster

wood wool & cement slab

flashling

wood wool & cement slab

lintel (E.G.)

window frame profile

wall frame (E.G.)

flashling

plaster

alfeslar

wood wool & cement slab

ILLUSTRATION 4.25
IV.1.4. NETWORKS

Within conventional housing requirements, we must foresee the need of establishing sanitary and electrical networks. Each of such networks implies an specific technology that should be articulated with the E. Globulus technology.

According with prevailing standards, all networks should be hidden inside walls, floors, and roofs; this implies that the required articulation between network technologies and the E. Globulus
technology finds its key know-how on the feasibility of moving in and through the concrete and timber structure of the dwelling.

Network technologies are fundamentally based on the display of pipes, that transport fluids or electrical conductors from urban networks towards specific locations within the dwelling and vice versa. The following sections will show a basic know-how for the display of such tubular networks within a building system that makes extensive use of the E. Globulus technology we have been describing.

IV.1.4.1. SANITARY INSTALLATIONS

Within sanitary installations we must distinguish two different networks; the water supply network and the sewerage network.

WATER SUPPLY

Pipes for water supply networks are mainly made out of galvanised steel on diameters that hardly exceed one inch; therefore, it is possible to run such network using a concrete floor, a panel wall, or a ceiling.

As a general rule, we must suggest the use of a first level floor for most of the longitudinal network, moving the pipes on vertical direction directly towards service points. It is advisable to avoid extensive networking in a second level due to the potential damage that a eventual leak can cause on the level directly below.

The illustration 4.27 shows an alternative for the arrangement of a water supply network for diversified requirements on a first and second level basis.

SEWERAGE.

Within conventional housing requirements, pipes for sewerage networks are mostly made out of PVC on diameters ranging between "2" and "4" inches; it is possible to drive pipes of "2" inches on diameter through panel walls, but eventually those of "4" inches may need the arrangement of sanitary beams, columns, or walls.

In general terms, it may be advisable to restrict the distribution of sewerage discharge points to the first level of the house, in such way, that most of the network could run within a concrete floor.

As we can foresee that according with most common design arrangements, there may be a water-closet (w.c.) discharge on the
ILLUSTRATION 4.27
second level of the house, we must set an alternative of arrangements based on such requirement. The illustration 4.28 shows a sewerage network alternative, that runs through a sanitary wall in the first and second level of the house.

ILLUSTRATION 4.28
IV.1.4.2. ELECTRICAL INSTALLATIONS

The articulation of electrical networks within the E. Globulus building technology, is somehow similar to the one established already for water supply networks.

Electrical installation pipes are made out of PVC types "sap" and "sel" on diameters that hardly exceed 1"inch, and therefore it is possible to run the complete network through concrete floors, panel walls, and ceilings. The following illustration shows an alternative for the arrangement of several network requirements such as pipes, power outlets power switches, and distribution boxes.

[Diagram of electrical installation]
IV.2. UPGRADED TECHNOLOGY

The basic E. Globulus technology described in the preceding section of this dissertation, can be subject of a large number of upgrading features in order to cope with the requirements of residential design foreseen within section 1.4.2. of this document.

As we review the findings of our section on "high income housing design demands", we can see that most of the required attributes can be properly fulfilled by the basic technology; but nevertheless, there are few requirements that demand for certain technological upgrading in order to be fulfilled.

IV.2.1. ACOUSTIC PERFORMANCE

The internal acoustic performance implied by the basic technology can be substantially upgraded by the use of acoustic absorbents and double frameworking.

A) Acoustic absorbents and double frameworking within the structural framework of floors and ceilings.

One of the most perturbing acoustic problems of traditional timber construction, is the transmission of noise through the floor of a certain level to the ceiling of the level immediately below it; on such regard, the use of acoustic absorbents, double framework, and other compatible technologies can prove to be quite relevant. The illustration 4.30 show a set of upgrading features on such specific regard.

B) Acoustic absorbents and double frameworking within the structural frameworking of walls and partitions.

A very demanding market used to the acoustic performance of concrete walls at residential level, may find the need of upgrading the acoustic performance implied by the basic E. Globulus technology on walls and partitions; on such regard, the use of acoustic absorbents, double framework, and other compatible technologies can prove to be an upgrading solution. The illustration 4.31 show a set of alternatives of such regard.

Acoustic performance on walls and partitions can be of special concern in the relation between bathrooms and bedrooms, in such case, the additional measure of designing build-in-closets or walk-in-closets between both areas is most desirable on acoustic terms, as well as in functional terms.
LOW COST HOUSING BY MEANS OF EUCALYPTUS WOOD

Basic Technology
(frontal view)

Upgraded Technology
(frontal view)

ACOUSTIC UPGRADED TECHNOLOGY ON ROOF/FLOOR/CEILING
ILLUSTRATION 4.30
IV.2.2. THERMAL PERFORMANCE.

Regarding thermal performance, the basic technology takes into account the use of wood & wool and cement slabs, which act as outstanding acoustic and thermal insulation elements at low costs; nevertheless, a very demanding market may require an upgraded performance that can be achieved by the use of rock-wool, or other insulation materials within the framework of walls, partitions and roofs as it has been shown for the upgrading of acoustic performance.

In addition to such measures that act directly upon temperature transmission, moisture transmission should be controlled as well.

For moisture control, it is advisable the placement of moisture chills covering the whole foundation area, perimeter walls, and roofs as it is shown by the following illustrations (4.32, 4.33, 4.34)
MOISTURE SHIELD AT FUNDATION LEVEL
ILLUSTRATION 4.32

MOISTURE SHIELD AT WALL LEVEL
ILLUSTRATION 4.33

MOISTURE SHIELD AT ROOF
ILLUSTRATION 4.34
IV.2.3. ARCHITECTURAL PERFORMANCE.

Special architectural features may be the most demanding aspects upon a building technology that aims towards residential applications, and its gravitation may be stressed even further as design trends claim technological expression, as in the case of hi-tech architecture.

On such grounds, the present dissertation must feed on the work of other designers and researchers in order to show technological feasibility, understanding that the universe of needs and solutions can not be review within the research horizon of this dissertation.

In order to show technological feasibility on this regard, we can undertake a special architectural feature from our high income housing design exercise of section 1.4.2., and review an alternative solution for it.

One of the most dramatic features of the design in question, is the space frame structure that covers the living-room, studio and entrance foyer of the residence. (See section 1.4.2.)

On such regard, conceptual design can imply the use of a 3-dimensional framework of E. Globulus components, with articulation on steel plated joints that have been the target of other research adventures within Delft University of Technology.

On particular, for such kind of 3-dimensional frameworks, we must make reference to the work of Dr. ir. P.Huybers, who during recent years has accomplished technological feasibility for the articulation of such structures using round timber 45; a technology that can find residential applications in the context of an upgraded E. Globulus building system.

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45 Sources: "Bowen met Inlands Rondhout" made by Dr. ir. P.Huybers. (See bibliographical references.)
SIDE: Wire lacing tool

UNDER: Metal plated joint using round timber with wiring lacing fixation

BOTTOM: Space frame structure based on wire lacing technology

(Courtesy of Dr. ir. P. Huybers)
IV.3. SIMPLIFIED TECHNOLOGY.

If we compare the findings of our section 1.4.1. on "low income housing design demands" with the attributes of our E. Globulus basic technology, it shows clear that the main criteria of evolutionary capability can be implemented without obstacle. Nevertheless, there are certain aspects of the technology that may not be applicable on the most primary levels of evolutionary development, and deserve special attention within this section.

IV.3.1. EVOLUTIONARY STRUCTURE.

We know from section 1.4.1. that the evolutionary process in question starts by the erection of a housing unit based on a column and beam structural approach, that must be re-enforced as structural needs evolve.

On such regard, the E. Globulus basic technology is fully consistent with this task; considering that a column and beam structural framework can be subject of reinforcement by the addition of load bearing walls under the original free-span beams. The structural evolutionary process can be simply defined as the evolution of a column and beam framework towards a load bearing wall framework of added structural strength.

In similar way, foundations can evolve from a system of free standing footings, related to a column and beam framework, to a system of longitudinal foundations, related with the later load bearing wall structural framework as described on the basic technology.

Structural joints in general can be arranged following the recommendations given by the basic technology, since such arrangements are based on a criteria of replacing material costs by extensive laybour, which happens to be the main resource of the target group.

A global evaluation of the initial structural framework in terms of rescue index, has shown that on the eventual case of having to dismantle such structures due to a relocation programme, it will be possible to rescue more than 85% of the global material investment for re-assemble in a new location.

IV.3.2. EVOLUTIONARY COVERTURE.

The E. Globulus basic technology recommends the use of wood wool and
cement slabs as enclosure elements. WWC slabs can be produced locally using wood wool of eucalyptus globulus which implies a low cost; but nevertheless, it is an industrial product that may prove to be unaffordable for our target group during their most initial consolidation stages.

An alternative solution for enclosure technology, fully compatible with the E. Globulus basic technology is to be found in the context of the research of Prof. arch. C. Díaz at the "Universidad F. del Sagrado Corazón" in Lima-Peru; who during the last years, has been building temporary shelters by means of conventional timber using plastered straw mats as enclosure elements.

Such alternative technology can be implemented by our target group during initial consolidation stages avoiding a perhaps premature investment on wwc slabs. Enclosures based on plastered straw mats can offer a "temporary" solution to coverture needs.

OVER: Original drawing showing key aspects of an enclosure technology base on the use of straw mats (estera) / The Marks Wasi project by arch. C. Díaz

Sources: "El Proyecto Markawasi" by arch. C. Díaz. (See bibliographical references.)
IV.3.3. FINAL CONSOLIDATION.

In the context of the E. Globulus basic technology, final consolidation is a product of evolutionary development, in which activities are not encapsulated on a recepy-like routine. The sequence of construction tasks must be tailored in accordance with a structure of priorities and actual capabilities.

Construction tasks such as the casting of concrete floors, plasterings of walls, and tiling of roofs are costly in material terms and reduce the rescue index of the dwellings; we know that our target group is reluctant to undertake such activities until having total certainty of permanency in the chosen location. On such regard, the E. Globulus basic technology offers the possibility of delaying such activities as long as necessary.

The use of the E. Globulus basic technology is not restricted to new building adventures, conventional brick, and re-enforced concrete houses can be complemented by additions following a E. Globulus technology.
SUMMARY

The present document explains a research process and its resulting achievements as an integral dissertation on the subject of appropriate technology and the feasibility of producing low cost housing by means of eucalyptus timber.

The aim of this document is not restricted to the transmission of new knowledge and know-how but to make an account of the process that has lead to such new knowledge as well. On such regard it can be used by builders willing to apply new know-how, scholars interested on a new understanding of the subject, and researchers motivated to undertake further research on this very promising and gratifying field.

From a highly fundamental start-up stage, the dissertation explains a context in which a global housing problem sets a spectrum of needs and responses at professional and non-professional level that is systematically narrowed to the housing problem of informal builders in Lima-Peru and their empirical use of eucalyptus timber as a response.

Informal builders are not an unusual target group for research in Latin America where most capital cities are witnessing the proliferation of informal urban settlements as a result of massive housing shortages, nevertheless, the case of informal builders in Lima-Peru is quite unique as former squatters and self-help builders have evolved toward
informal housing promoters that use eucalyptus poles for the construction of transitory shelters.

Within such narrow but yet complex human and technological environment, the research makes a break-down of needs and present technological feasibility on a quest towards undertaking a universe of criteria to be fulfilled and variables upon which an intervention may prove to be fruitful.

Fellow researchers may find specially interesting the methodology used to identify "Low Income Housing Design Demands" which implies a new fundamental approach in terms of "Future Reality Simulation" that has been applied at experimental level within this research.

After achieving full understanding of the research subjects, the dissertation moves towards a "Development Mode" in which constant feedback with the conceptual framework is performed and new knowledge starts shaping a correlated new know-how that covers a multi-disciplinary spectrum.

On forestry terms, the study and analysis of present plantation and exploitation methods derives on a set of recommendations for improving not only such methods but the integral quality of the output product within a feasibility framework that insure environmental welfare.

In terms of wood processing technology, the well-known limitations implied by the wood of eucalyptus globulus are subject of deep understanding, and a unitary process for drying, preserving, and sawing such peculiar kind of wood is developed.

In terms of building technology, the analysis of architectural demands toward an intended building technology is complemented by an understanding of the reasons why a large number of building technologies considered to be appropriate for use on low-cost housing schemes tend to fail on achieving social acceptability and are hardly used by the target group. In such sense, technological flexibility in terms of potential application, evolutionary development, and investment rise as key considerations.

On marketing terms, fundamental variables such as availability, and price are subject of evaluation insuring that the impact resulting from intended levels of intervention will remain to be an affordable one.

On the balance, a raw material commonly known as "Eucalyptus Poles" is transformed into "Eucalyptus Globulus Building Components" and an
empirical building technic is upgraded to the context of Building Technology.

Finally the Eucalyptus Globulus Building Technology is described as a basic technology able to cope with a wide range of sophistications and simplifications in accordance with a potentially diversified housing market.

SUMARIO

El presente documento explica un proceso de investigación y sus resultados a modo de disertación integral en el campo de tecnología apropiada y la factibilidad de producir viviendas económicas mediante el uso de la madera de eucalipto.

El objetivo de este documento no se restringe a la transmisión de nuevos conocimientos y procedimientos, adicionalmente hace un recuento sobre el proceso del cual dicho nuevo conocimiento se deriva. De tal forma, puede ser usado por constructores que deseen aplicar nuevos procedimientos, estudiosos interesados en un nuevo entendimiento del campo, e investigadores motivados a retomar estudios en esta prometedora y gratificante temática.

A partir de un inicio altamente fundamental, la disertación presenta un contexto en el que una problemática de vivienda global plantea un universo de necesidades y respuestas a nivel profesional y no-profesional que es sistemáticamente restringido a la problemática de vivienda de constructores informales en Lima - Perú y el uso empírico que le dan a la madera de eucalipto.

Los constructores informales no son sujetos inusuales en el contexto de investigaciones referidas a América Latina donde la mayor parte de las ciudades capital atestiguan la proliferación de asentamientos urbanos informales como resultado de grandes déficits de vivienda; sin embargo, el caso de constructores informales en Lima - Perú es un tanto único en el sentido que invasores y auto-constructores están evolucionando para convertirse en promotores de viviendas informales que hacen uso de postes de eucalipto para la construcción de viviendas.
transitorias.

Al interior de este restringido pero aún complejo contexto de factores humanos y tecnológicos, la investigación realiza una fragmentación de necesidades y factibilidades tecnológicas actuales con la intención de capturar el universo de criterios ha ser satisfechos y variables en las que se pueda intervenir de manera provechosa.

La metodología utilizada para la identificación de "Requerimientos de Diseño para Vivienda Económica" ("Low Income Housing Design Demands") puede ser de especial interés para investigadores en el campo de la informática y viviendismo pues implica métodos para la simulación de realidades futuras que han sido aplicados a nivel experimental en la temática que nos ocupa.

Con un completo conocimiento del sujeto de estudio, la investigación se traslada a un "contexto de desarrollo" en el que se realiza constante retro-alimentación con la estructura conceptual del estudio y nuevos conocimientos empiezan a dar forma a nuevos procedimientos que cubren un ámbito multidisciplinario.

En el campo forestal, el estudio y análisis de métodos actuales de plantación y explotación deriva en un conjunto de recomendaciones que buscan no sólo mejorar los métodos actualmente aplicados pero así mismo la calidad integral del producto resultante al interior de una estructura de factibilidad que salvaguarda el bienestar del medio ambiente.

En el campo de tecnología constructiva, el análisis de los requerimientos arquitectónicos que la tecnología constructiva deberá satisfacer, es complementado por el entendimiento de las razones por las que un gran número de tecnologías constructivas consideradas como apropiadas tienden a fracasar en conseguir aceptabilidad y son poco usadas por la población en cuestión. En tal sentido, flexibilidad tecnológica en cuanto a su aplicación potencial, capacidad de desarrollo evolutivo y fragmentación de inversión, resulta ser factor fundamental.

En cuanto a los aspectos de comercialización, variables de gran importancia, tales como, disponibilidad y precio son sujeto de evaluación, ratificando que el impacto de la pretendida intervención es costeable.

En resumen, un material conocido como "palo de eucalipto" ha sido transformado en "componente constructivo de eucalipto globulus" y una técnica constructiva empírica ha sido elevada al contexto de tecnología
constructiva.

Finalmente, la tecnología constructiva es descrita en términos de tecnología base a partir de la cual es posible derivar sofisticaciones y simplificaciones de acuerdo con un mercado viviendista potencialmente diversificado.

SAMENVATTING

Dit document omschrijft een onderzoeksproces en de daaruit voortvloeiende resultaten als een integrale dissertatie omtrent het onderwerp van de uitvoerbaarheid van "low cost housing" door gebruikmaking van eucalyptus hout.

Het doel van dit document blijft niet beperkt tot de overdracht van nieuwe kennis en technische vaardigheden, maar beoogt tevens om verslag uit te brengen van het proces van kennisverwerving. In dit opzicht kan het document gebruikt worden door bouwers die bereid zijn om nieuwe technische kennis toe te passen, door academici met belangstelling voor nieuwe kennis over het onderwerp, en door onderzoekers die gemotiveerd zijn om verder onderzoek in dit bijzonder veelbelovende en bevredigende terrein te verrichten.

Vanaf een zeer fundamentele beginfase verklaart de dissertatie de context van een wereldwijd huisvestingsprobleem met een spectrum van behoeften en antwoorden op professioneel en niet-professioneel niveau. Deze context wordt systematisch teruggebracht tot het huisvestingsprobleem van zelf bouwers in Lima (Peru) en hun empirisch gebruik van eucalyptus hout.

Zelf bouwers zijn geen ongebruikelijke doelgroep voor onderzoek in Latijns-Amerika waar de meeste hoofdsteden getuige zijn van de sterke toename van zelf gebouwde stedelijke kolonies als gevolg van massaal gebrek aan huisvesting. Zelf bouw in Lima (Peru) is evenwel nogal uniek, aangezien voormalige illegale landbezitters en zelf bouwers zich hebben ontwikkeld tot huisvestings-promotors die eucalyptus hout gebruiken voor de constructie van tijdelijk onderdak.
Binnen een dergelijke nauwe doch complex menselijke en technologische omgeving voert het onderzoek een analyse uit van behoeften en hedendaagse technologische uitvoerbaarheid tijdens een speurtocht naar een universum van te vervullen criteria en variabelen, waarop een professionele aanpak nuttig kan blijken.

Voor collega onderzoekers is vooral de methodologie interessant, die gebruikt werd om "Low Cost Housing Design Demands" te identificeren. Dit betekent een nieuwe fundamentele benadering in termen van "Toekomstige Realiteits Simulatie" dat op experimenteel niveau binnen dit onderzoek is toegepast.

Na het bereiken van volledig begrip van de onderzoeksonderwerpen, richt de dissertatie zich naar een "Ontwikkelings Wijze" waarin constante terugkoppeling met het conceptuele kader wordt uitgevoerd. Nieuwe kennis levert een gecorreleerde nieuwe technische wetenschap op die een multidisciplinair spectrum omvat.

In bosbouw-terms leidt het onderzoek en analyse van huidige aanplantings- en exploitatiemethoden tot een serie aanbevelingen om niet alleen dergelijke methoden te verbeteren maar ook om tot integrale kwaliteiten verbetering van het produkt te komen binnen een haalbaarheidskader dat tevens milieu-welzijn waarborgt.

In termen van houtverwerkingstechnologie zijn de welbekende beperkingen die het hout van eucalyptus globulus bij zich draagt, onderwerp van diepgaande studie. Een uniform proces voor het drogen, conserveren en zagen van dergelijk bijzonder hout wordt ontwikkeld.

Op het gebied van de bouwtechnologie wordt de analyse van architectonische eisen die aan de bedoelde bouwtechnologie gesteld worden, aangevuld door een uiteenzetting van de redenen waarom een aantal bouwtechnologieën er gewoonlijk niet in slagen om tot sociale aanvaarding te komen. Deze technologieën die als toepasbaar worden beschouwd voor gebruik in lage-kosten huisvestingsprogramma's, worden door de doelgroep nauwelijks gebruikt. In dit opzicht komen technologische flexibiliteit in de betekenis van mogelijke toepassing, evolutionaire ontwikkeling en investering naar voren als hoofdoverwegingen.

In marketingterminologie worden fundamentele variabelen zoals beschikbaarheid en prijs bij de evaluatie betrokken. Zodoende wordt gegarandeerd dat het effect dat voortkomt uit bedoelde niveaus van aanpak steeds een betaalbare blijft.

Per saldo; een ruw materiaal dat algemeen bekend is als "Eucalyptus
Hout" wordt omgevormd tot "Eucalyptus Globulus Componenten" en een empirische bouwtechniek wordt bevorderd in de context van Bouw-Technologie.

Ten slotte wordt de Eucalyptus Globulus Technologie beschreven als een basis-technologie die in staat is om een wijd scala van verfijningen en versimpelingen te hanteren in overeenstemming met een potentieel veranderende huisvestingsmarkt.
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