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STUDY ON THE RECYCLING OF WOOD FROM FORMWORK IN THE LATIN AMERICAN CONSTRUCTION INDUSTRY *

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* The views expressed in this document are those of the author and do not necessarily reflect those of the Secretariat of the United Nations Industrial Development Organization (UNIDO). This document is a translation of an unedited original.

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SUMMARY

The present report is the result of a study on the recycling of wood from formwork in the Latin American construction industry carried out in six countries of the region. The purpose of the study is to formulate recommendations for improving efficiency in the use of wood and derived products in formwork, reducing pressure on the exploitation of forests and improving productivity in the construction sector.

The construction sector is one of the most important final consumers of wood products, if not the most important, and represents approximately 5 per cent of the regional GDP. In Latin America there is a housing deficit of approximately 24 million dwellings, more than 30 per cent of the population being affected. The most commonly used construction methods are based on the use of reinforced concrete, which requires the use of formwork to give the elements their final form.

Wood is now, was previously and will in the future continue to be the predominant construction material for formwork, especially in building one-family houses of one or two storeys, which on the average represent more than 85 per cent of the Latin American housing stock. Formwork wood and other timber used temporarily in construction work account for between 50 per cent and 70 per cent of the total consumption of wood per housing unit.

The new building materials used in formwork, especially of metal, are mainly used in the construction of multifamily housing, large buildings or major engineering works; even in those cases, they do not completely replace wood. Wood formwork represents between 5 and 10 per cent of the direct costs of projects and is on the average responsible for the consumption of 17 per cent of sawn wood and plywood produced in the region.

It is necessary to act immediately in optimizing the use of wood in formwork, and any effort made will be supported and welcomed both by the forestry industry and the construction industry, particularly on the part of the producers and/or consumers of cement and concrete. There is a favourable scenario for the implementation of a plan of action that would act as a catalyst for the concurrent interest of various sectors of the economy in the Latin American countries.

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INTRODUCTION

The fact that formwork is used temporarily as an aid in the construction of a reinforced concrete structure and is used "only" during the placement of the reinforcements, the pouring and the later setting of the concrete and that afterwards is not part of the structure seems to indicate that it is of little or no importance in contributing to the overall stability of the structure. In practice it is shown in actual fact that the importance of formwork cannot be dissociated from the other components of the structure, since the formwork and the quality of workmanship are responsible for various important factors with regard to the stability of a structure, such as, among others:

* Actual adherence to dimensions in a project
* The verticality and alignment of the structure, to avoid the occurrence of unforeseen stresses
* Support for appropriate compacting in order to guarantee the projected strength
* Watertightness to guarantee homogeneous density and avoid dangerous porosity that would permit oxidation of the reinforcements.

From the economic point of view and speaking both of conventional systems and industrial construction methods, the importance of formwork is of ever-increasing importance, since owing to the possibility of utilization several times, formwork is the only component of variable costs, which is not the case with the reinforcement rods or the mass of concrete, which are part of the finished structure and cannot be reutilized.

Civilian construction in Latin America is basically the application of constructional systems based on reinforced concrete, there being a close relationship between the volumes and areas of structures and the consumption of cement. The use of that material as a basic component of structures is more important than its utilization in other parts of the building, such as floors, plaster, coatings, etc. At the same time, references to reinforced concrete structures indirectly mean reference to concrete formwork, because structures cannot be made without them.

From the early days of the utilization of formwork, the use of wood became widespread and it is still the principal raw material in the manufacture of formwork, although alternative materials have recently begun to be used, especially steel in metal formwork. It can be stated that, generally speaking, at the Latin American level the more reinforced concrete is used in construction, the greater is the consumption of wood and wood-based products which are used in formwork.

There are differences from country to country in the techniques for utilizing and reutilizing wood and wood-based products in formwork. Moreover, different terms are used. In Mexico they are called *cimbras*, in Ecuador, Peru and Argentina *encofrados*, but in Brazil they are *formas* and in Chile *moldes* or *moldajes*. In all cases they perform the same function and are mostly made of wood or wood-based products.

Accordingly, the United Nations Industrial Development Organization - UNIDO – thought it desirable to carry out a study in six Latin American countries on the use and recycling of wood in the construction industry, emphasizing the analysis of formwork made of wood or wood-based products. The purpose of the study is to formulate recommendations to improve efficiency in the use of wood and derived products in formwork, reducing waste, improving reutilization and improving existing technology, thus contributing toward reducing pressure on the exploitation of forests and improving the productivity of the construction industry.

The study was intended to analyse the volumes of concrete and the comparative costs of the various types of formwork and was to propose action on various aspects such as the production of raw material, standardization, training, technology, marketing, institutional support, etc. As a consequence of the study a medium and long-term programme was to be worked out involving a series of activities of a national or, if necessary, of a regional character.

The research was carried out in Mexico, Ecuador, Argentina, Chile, Brazil and Peru, covering a period of four months, six weeks of which was devoted to fieldwork and the compilation of information. This was carried out by means of interviews with housing and construction authorities in the public and private sectors, construction enterprises, forestry industries, manufacturers of formwork, research and standardization agencies, centres for vocational training and the training of foremen, associations of producers, organizations of professionals, etc. The study was concluded in February 1994.

In the analysis of each country, a brief diagnosis was first made of the housing sector, the construction industry sector and the forestry industry sector. These sectors were considered as being directly involved in the use of wood as a building material. Later, the use of various formwork systems using wood and alternative materials and the volumes of consumption of wood were analysed in the light of existing construction systems. Also, the impact of the costs of formwork on the direct cost of the structure was investigated and the comparative costs of formwork made of wood and alternative materials were calculated. Finally, conclusions and recommendations were drafted at the level of each country and also conclusions and recommendations at the Latin American level.

1.0 DIAGNOSIS OF MEXICO

1.1 THE HOUSING SECTOR

During the 1980s, Mexico, like the other Latin American countries, encountered a difficult economic situation which reduced the capacity of the population to meet their housing requirements. In that period investments were hampered and national financial markets were exposed to pressure. This situation led to a limitation of credit, reduced amortization periods and favoured high rates of interest, which affected access to credit. Also, the high costs of capital and the weak purchasing power of the population hampered the solution of the housing problem.

In recent years, there has been an improvement of the Mexican economy as the result of control of inflation, reorganization of public finances, renegotiation of the external debt, opening of the market and economic deregulation. As a result, more resources are available for mortgage loans, both in the public and private sectors, interest rates are lower and amortization periods longer, up to 30 years in some cases.

The problem of housing is affected by the inadequate, though growing, supply of housing in view of demographic growth, the needs for improvement and crowding conditions in the housing stock.

According to the 1980 census, Mexico had a population of 66.8 million, occupying 12.1 million dwelling units. Ten years later, the population had risen to 81.2 million, while the housing stock comprised 16.2 million units. This effort to scale up building activity represented a growth of 33.9 per cent in the supply of housing, rather higher than the population growth of 21.5 per cent.

It is estimated that, on the basis of the Xth General Population Housing Census that the country will have 85.2 million inhabitants and a housing stock of 17.7 million units in 1993. The occupational density in 1990 was 5.0 persons per dwelling unit and the crowding index was 1.5 persons per room whereas 65.5 per cent of the total stock of houses had three or more dwellings. This situation is quite encouraging in comparison with that of 1980 when there was a housing density of 5.5 persons per dwelling and a crowding index of 2.2 persons per room, while only 38 per cent of the housing stock had three or more dwellings.

Also, by comparison with the 1970 census, positive changes can be noted in the availability of services in dwellings, for example, the proportion of dwellings with piped water increased from 61 per cent to 79 per cent of the total stock; those with drainage from 42 per cent to 64 per cent and those with electricity from 59 per cent to 88 per cent.

Similarly, the census showed that 1.7 million dwelling units (10.5 per cent of the total) had problems of crowding, that is to say they were occupied by more than one household or needed to be extended to house a family appropriately. Similarly, in that year, 1.4 million residential houses needed improvements or repairs owing to their dilapidated condition.

The latter aspects determine what is called the qualitative deficit which, added to the quantitative deficit resulting from demographic growth, is the basis for calculating the total housing deficit at the national level of approximately 6,400,000 units or dwellings.

Table 1.01 shows the housing deficit for each of the 32 federal states, according to the 1990 census. With a population of 81.2 million, there were 16.2 million dwelling units, representing a deficit of 6.35 million in terms of the housing stock and a deficit of 74,000 in terms of the population, giving a total housing deficit of 6,423,263 units.

The federal States with the largest absolute deficits are, in descending order: Mexico, Veracruz, the Federal District, Chiapas and Querétaro. In proportional terms, however, it was noted that 60.4 per cent of the population in Chiapas suffered in some respect from a housing deficit, the national average for Mexico being 39.5 per cent.

Table 1.02 presents the development of the total housing deficit with a projection for 1980-2000. This estimate, made in 1987 by the Secretariat for Urban Development and Ecology (SEDUE), which has since 1992 been the Secretariat for Social Development (SEDESOL), agrees in general with figures contained in the previous table. In this second table, a deficit of 6,406,731 houses is estimated for 1990, a figure which is fairly similar to the previous one, it being specified that the cumulative deficit was 6,288,504 units, the housing needs to cope with the population increase totalled 274,590 while needs resulting from deterioration numbered 308,435. The housing needs totalled 6,871,529 and the estimated supply was 464,798, giving the figure of 6,406,731.

TABLE 1.01

HOUSING DEFICIT BY FEDERAL STATE, 1990*

FEDERAL PROVINCE	HOUSING STOCK	SHORT-AGE %	SHORTAGE, ABSOLUTE	POPU-LATION	HOUSING NEEDS	SHORT-AGE REL. TO POPULA-TION	TOTAL HOUSING SHORTAGE
TOTAL	16,197,802	38.77	6,349,265	81,249,645	16,271,800	73,998	6,423,263
AGUAS CALIENTES	130,709	30.29	39,592	719,659	130,847	138	39,730
BAJA CALIFORNIA	373,898	22.56	84,351	1,660,855	377,467	3,569	87,920
BAJA CALIFORNIA SUR	68,694	39.10	26,859	317,764	69,079	385	27,244
CAMPECHE	110,366	51.07	56,364	535,185	110,575	209	56,573
COAHUILA	408,495	32.28	131,862	1,972,340	410,904	2,409	134,271
COLIMA	90,263	46.08	41,593	428,510	91,172	909	42,503
CHIAPAS	597,724	59.82	357,558	3,210,496	605,754	8,030	365,588
CHIHUAHUA	540,922	30.04	162,493	2,441,873	542,638	1,716	164,209
DISTRITO FEDERAL	1,799,410	23.87	429,519	8,235,744	1,830,165	30,755	460,275
DURANGO	263,191	35.73	94,038	1,349,378	263,550	359	94,398
GUANAJUATO	701,247	37.00	259,461	3,982,593	711,177	9,930	269,392
GUERRERO	512,445	61.50	315,154	2,620,637	512,845	400	315,553
HIDALGO	367,400	46.01	169,041	1,888,366	368,103	703	169,743
JALISCO	1,044,105	29.34	306,364	5,302,689	1,045,895	1,710	308,074
MEXICO	1,003,098	34.31	646,091	9,815,795	1,884,030	932	647,023
MICHOACAN	677,141	43.52	294,692	3,548,199	682,346	5,205	299,897
MORELOS	246,373	40.56	99,929	1,195,059	248,971	2,598	102,527
NAYRIT	171,855	44.49	76,458	824,643	171,801	(54)	76,404
NUEVA LEON	647,367	31.50	203,921	3,098,736	645,570	(1,794)	202,124
OAXACA	589,295	54.11	318,868	3,019,560	589,758	463	319,330
PUEBLA	775,525	45.39	352,011	4,126,101	775,583	58	352,069
QUERETARO	195,569	42.66	83,430	1,051,235	195,761	192	83,621
QUINTANA ROO	106,094	52.74	55,954	493,277	106,310	216	56,170
SAN LUIS POTOSI	382,025	44.89	171,496	2,003,187	382,288	253	171,748
SINALOA	426,257	44.41	189,301	2,204,054	426,316	59	189,360
SONORA	383,290	34.94	133,922	1,823,606	383,917	627	134,549
TABASCO	286,693	56.95	163,272	1,501,744	287,140	447	163,719
TAMAULIPAS	494,454	39.46	195,112	2,249,581	495,502	1,048	196,160
TLAXCALA)	137,412	43.28	59,472	761,277	137,415	3	59,475
VERAACRUZ	1,271,457	48.05	610,935	6,228,239	1,273,669	2,212	613,147
YUCATAN	275,231	46.85	128,946	1,362,940	275,341	110	129,056
ZACATECAS	239,707	38.05	91,209	1,276,323	239,910	203	91,412

* Source: SEDUE and INE, 1991 CENSUS

TABLE 1.02

DEVELOPMENT OF TOTAL NATIONAL HOUSING DEFICIT
1980 - 2000 (PROJECTION) *

Year	Deficit	Population growth	Deterioration	Housing needs	Housing supply	Deficit
1980	4.438.070	298.711	308.435	5.045.216	366.867	4.678.349
1981	4.678.349	300.121	308.435	5.286.905	385.882	4.901.023
1982	4.901.023	302.556	308.435	5.512.014	400.100	5.111.914
1983	5.111.914	303.074	308.435	5.723.423	410.117	5.313.306
1984	5.313.306	301.921	308.435	5.923.662	417.593	5.506.069
1985	5.506.069	299.367	308.435	6.113.871	420.224	5.693.647
1986	5.693.647	295.670	308.435	6.297.752	426.024	5.871.728
1987	5.871.728	291.081	308.435	6.471.244	445.363	6.025.881
1988	6.025.881	285.865	308.435	6.620.181	459.144	6.161.037
1989	6.161.037	280.284	308.435	6.749.756	461.252	6.288.504
1990	6.288.504	274.590	308.435	6.871.529	464.798	6.406.731
1991	6.406.731	268.591	308.435	6.983.757	478.548	6.505.209
1992	6.505.209	262.100	308.435	7.075.744	498.479	6.577.265
1993	6.577.265	257.628	308.435	7.143.328	513.181	6.630.147
1994	6.630.147	256.337	308.435	7.194.919	532.576	6.662.343
1995	6.662.343	257.129	308.435	7.227.907	543.620	6.684.287
1996	6.684.287	257.566	308.435	7.250.288	569.406	6.680.882
1997	6.680.882	257.895	308.435	7.247.212	599.850	6.647.362
1998	6.647.362	258.385	308.435	7.214.182	636.240	6.577.942
1999	6.577.942	258.831	308.435	7.145.208	667.242	6.477.966
2000	6.477.966	259.053	308.435	7.045.454	700.000	6.345.454

* Source: SEDUE. Housing Information System (1987).

1.2 THE CONSTRUCTION SECTOR

1.2.1 The economic context

The construction industry plays an important part in the economy of Mexico, contributing more than 5 per cent of the GDP, creating approximately 10 per cent of national employment and generating 3 per cent of wages and salaries. In the housing sector, 95 per cent of the inputs are of local origin, being supplied by about 40 industrial branches. Similarly, 61 per cent of the gross capital formation is due to the construction industry, in which housing has a 34.8 per cent share.

It is interesting to note that, according to National Institute of Statistics, Geography and Information Sciences (INEGI) for 1980, sawn wood and three-ply represented 3.1 per cent of the total of national inputs consumed in construction, basically used in formwork for concrete). For reference purposes, it is pointed out that this figure is equivalent to that for cement, which represents 3.3 per cent of the consumption of inputs, and that in the case of cement 87.6 per cent of national production is allocated to the construction sector whereas this sector represents only 46.9 per cent of the consumption market for sawn wood and plywood panels.

In 1991, the number of persons employed by the formal sector of the construction industry was 448,134, consisting of wage earners (70 per cent) and salary earners (22 per cent). The breakdown of construction activities was as follows:

Housing	9.39%
Non-residential construction	14.61%
Installations	7.07%
Industrial buildings	12.83%
Urban development	9.58%
Maritime and river	3.7%
Hydraulic works	7.51%
Land communications	19.21%
Professional services	4.17%
Other	11.93%

The 1991 figure for nominal growth in the total value of production by enterprises affiliated to the National Chamber for the Construction Industry, which represents 40 per cent of the construction enterprises in Mexico, was 57.02 per cent and real growth 37.11 per cent from the year 1990. [1]

1.2.2 Annual production of housing

As was mentioned before, in 1991, housing construction represented 9.39 per cent of the total value of production by enterprises affiliated to the National Chamber for the Construction Industry (CNIC). However, the actual figure must be much greater, since CNIC incorporates only 40 per cent of construction enterprises in Mexico and the percentage quoted does not include housing built by the informal sector, that is to say, the incomplete dwellings produced by the social sector through self-help construction.

TABLE 1.03

MEXICO. ANNUAL HOUSING PRODUCTION, 1975-1991
('000)

Year	Total apparent production	Acceptable	Public sector	Private sector			Social sector
			Social housing, completed	Low-cost, without financing	Inter-mediate type	Resi-dential	With defici-encies
1975	369.6	-----	62.4	-----	-----	-----	-----
1980	446.1	-----	113.0	-----	-----	-----	-----
1985	538.1	-----	171.2	-----	-----	-----	-----
1986	558.7	-----	142.3	-----	-----	-----	-----
1987	580.0	349.3	173.5	66.4	82.3	27.1	230.7
1988	602.0	302.2	165.6	50.9	65.2	20.6	299.8
1989	625.1	350.5	144.4	95.9	86.1	24.2	274.6
1990	647.8	352.1	158.8	70.8	95.7	26.7	295.8
1991	674.0	381.2	202.2	62.7	90.0	26.7	292.8

Source: CIHAC 1991 Construction Catalogue, based on the INEGI 1960, 1970 and 1980 censuses. The 1989 and 1990 figures for the public sector are taken from the 1989 and 1990 SEDUE housing statistics, respectively.

Table 1.03 gives detail of the annual production of housing in Mexico over the period 1975-1991. Estimates according to the CIHAC catalogue, based on information from INEGI and SEDUE, indicate a production of 674,000 dwelling units for 1991, only 56.6 per cent of which were constructed by the public and private formal

[1] *Revista Mexicana de la Construcción*, No 455 – December 1992

sector and were of the social housing scheme, low-cost without financing, intermediate and residential types. The remaining 43.4 per cent, that is to say 292,800 dwelling units, were constructed by the self-help method in the informal sector.

These figures are larger than those projected in 1987 and presented in table 1.02, because of the much more active presence of the public sector which in 1993 alone granted 320,000 loans for new dwelling units, including financing in respect of completed units, progressive units, co-financing and building on occupier's own land. This more aggressive participation of the public sector in Mexico was a response to the 1990-1994 National Housing Programme, which envisages the implementation of various lines of priority action intended to reverse the present cumulative trend towards a housing deficit by the year 2000.

Table 1.04 shows the materials predominantly used for walls and roofs for the total of 16,035,233 private dwellings occupied on the day of the census.

The materials predominantly used for walls are thin and thick brick partitions and concrete blocks, which are used in 70 per cent of the total dwelling units, that is to say in 11,148,978 units. Adobe is the second commonest material, representing almost 15 per cent of the total and wood accounts for 8 per cent of the national total.

The predominant materials in roofs are concrete slabs, brickwork barrel vaults and flat brickwork laid on beams, which together represent 49 per cent of the total. The other predominant roofing materials are: asbestos or metal sheet (18 per cent), ceramic tiles (10 per cent), laminated cardboard (10 per cent) and palm leaves, shingles or wood (8.5 per cent). Cement is the predominant material for floors with 53.5 per cent, followed by mosaic or other floor covering with 26.7 per cent and beaten earth with 19.5 per cent.

In general it can be deduced that a typical Mexican dwelling is made of the following predominant materials:

- Floors	Cement	(53.3%)
- Walls	Thin or thick concrete wall blocks	(69.5%)
- Roofing	Concrete slabs, brickwork barrel vaults and flat brickwork roofs laid on beams	(49.0%)

As can be noted, cement or concrete are the predominant materials in the large majority of dwellings in Mexico. Wood is used for structural purposes in 50-60 per cent of roofs, in combination with various types of roofing materials.

1.2.3 Housing density

The last census did not indicate the quantity of dwellings in the housing stock of 1990 represented by one- or two-storey one-family dwellings, nor multifamily buildings of more than three storeys.

However, this percentage can be obtained by analysing the real value of production of one-family dwellings and multifamily buildings in the formal construction sector. According to the National Institute for Statistics, Geography and Information Sciences (INEGI), multifamily houses represented on the average 28.5 per cent of total production in the period January 1992 - February 1993, while one-family dwellings represented the remaining 71.5 per cent.

It was shown in table 1.03 that the formal sector constructed 55.5% of dwellings in Mexico and that the informal sector constructed the remaining 44.5%, basically incomplete dwellings of one or at most two storeys. Accordingly, it can be deduced that the density of buildings in this country was broken down as follows:

	ONE-FAMILY (1-2 storeys)	MULTIFAMILY (3 or more storeys)
- Formal sector	39.7%	15.8%
- Informal sector	44.5%	------
TOTAL	84.2%	15.8%

As is to be expected, the highest percentage of multifamily houses is found in large cities in the urban zones of the country which, for the purposes of the present study are those with the highest consumption of wood for formwork.

TABLE 1.04

HOUSING STOCK IN 1990
PRIVATE DWELLING UNITS IN THE REPUBLIC, PREDOMINANT MATERIAL
IN FLOORS AND WALLS BY PREDOMINANT MATERIAL IN ROOFS

			ROOFS						
		Total private dwelling units	Laminated cardboard	Palm leaves, *tejamanil* or wood	Asbestos or metal sheet	Tiles	Concrete or other slabs [1]	Other materials	Not specified
UNITED STATES OF MEXICO		16,035,233	1,550,833	1,366,792	2,871,586	1,532,706	8,244,841	375,475	92,999
	Laminated cardboard	199,788	157,652	13,709	17,913	3,728	3,748	1,857	1,181
	Reeds, bamboo or palm	320,163	88,140	146,636	48,423	25,203	1,159	9,255	1,347
W	Mud	376,844	102,225	121,045	76,518	59,761	5,014	11,449	832
A	Wood	1,303,481	442,596	358,879	373,618	98,421	5,134	23,105	1,728
L	Asbestos or metal sheet	119,542	16,779	7,275	75,277	4,965	12,864	1,296	1,086
L	Adobe	2,342,987	184,409	357,202	497,279	804,660	324,365	171,795	3,277
S	Flat brick, brick, blocks	11,148,978	530,558	343,067	1,755,825	521,899	7,864,596	119,951	13,082
	Other materials	139,594	26,464	16,967	24,334	12,131	23,091	36,313	294
	Material not specified	83,856	2,010	2,012	2,399	1,938	4,870	455	70,172

[1] Also includes barrel vault roofs and flat brickwork roofs laid on beams.

Source: SEDUE and INE, 1991 Census

1.3 THE FORESTRY SECTOR

1.3.1 Forest resources

According to the 1991-1992 economic memorandum of the National Chamber for the Forestry Industry, Mexico has 38,889,075 hectares of forest, covered by trees of which 27,482,917 ha (70.7 per cent) represent woods in the temperate-cool climatic zone where basically 67.9 per cent are coniferous species and the remaining 32.1 per cent broad-leaved species. The resources in the area of the tropical and sub-tropical climatic zone amount to 11,406,158 hectares (29.3 per cent), of which 81.4 per cent are located in medium-altitude forests and the remaining 18.6 per cent in high-altitude forests.

The volume of standing timber is estimated at 3,125.6 million m^3 of logs, i.e. 1,989.4 million m^3 (63.7 per cent) in forests of the temperate-cool climatic zone and 1,135.8 million m^3 (36.3 per cent) in forests of the tropical and sub-tropical climatic zones.

It is important to point out that the increase in the volume available owing to the growth of plantations of coniferous species is 27.3 million m^3 per year, while it is estimated that the increase in broad-leaved species is equivalent to 1 per cent of the existing volume, i.e. 13.0 million m^3 in woods and forests.

1.3.2 The forestry industry

The most recent statistics available in the National Chamber of the Forestry Industry indicate that the decline in growth of the sector was 15.1 per cent in 1991, although the manufacturing sector as a whole grew by some 4.2 per cent over 1990. This declining trend has been observed since 1986, and became more acute last year. The annual share of wood and wood-based products fell and represented 2.5 per cent of the real gross product of the manufacturing sector in 1991, whereas the average in the previous five years had been 3.8 per cent.

With regard to the forestry industry linked to the use of wood in formwork, the installed capacity of the sawmill industry is as follows:

Number of sawmills	1,543
Installed capacity ('000 m^3 of logs)	12,344
Capacity utilization (%)	44.62
Production ('000 m^3 of logs)	5,509
Number of persons employed	18,516
Investment (US$ '000)	367,229

The wood-based boards industry is a large supplier of inputs for construction formwork. Its characteristics in 1991 were as follows:

	Plywood	Particle board	Fibre	Total
Number of plants	35	14	2	49
Installed capacity ('000 m^3)	556	685	125	1,366
Capacity utilization (%)	33.1	60.4	36.0	47.1
Production ('000 m^3)	184	414	45	643
Investment (US$ '000)	---	----	----	720,232
Persons employed	---	----	----	11,433

1.3.3 Forestry production

The figures for timber fellings in 1991 indicate production of 7.6 million m^3 of logs, there being a 5.5 per cent decrease from the previous year. Of that total, 7.2 million m^3 represented industrial timber, the rest of the timber felled being used for fuel, firewood, charcoal and brushwood.

Industrial timber was used for products of rectangular cross-section, mainly sawn, which accounted for 70.1 per cent of the industrial total, and 21.2 per cent was used to make pulp products, 2.6 per cent for panels and board and 1.2 per cent for log products such as posts, piles and firedogs.

With regard to the species extracted, they have traditionally been conifers, especially pines, which represent more than 83 per cent of logging in Mexico, the remainder being various types of broad-leaved species, chief among which is the oak.
If forestry production is analysed from the point of view of origin, 46.9 per cent comes from the Sierra Madre Occidental (the States of Durango and Chihuahua), 31.7 per cent from the Sierra Neovolcanica (States of Jalisco, Michoacán, Veracruz, México and Puebla), while the third most important area is the Sierra Madre del Sur (States of Guerrero and Oaxaca), where 9.6 per cent of forestry production was logged.

1.3.4 Foreign trade

The preliminary figures available in the CNIF indicate a negative balance of trade for 1991 of US$ 523.3 million, resulting from exports to a value of US$ 299.3 million and imports of US$ 822.9 million.
The largest deficit is constituted by pulp products, representing 65.5 per cent of imports, followed by products with little value added, particularly sawn wood, with 20.2 per cent, and in third place wood-based panels and boards, which represent 8.4 per cent of imports.
The information available shows that imports grew in 1991 by between 50 and 90 per cent in relation to 1990, especially in sawn wood and wood-based board. This increase in imports will probably be greater in future, considering the aspect of costs and expediency in the supply of forestry products from North America in the framework of the new North American Free Trade Agreement (NAFTA) recently ratified between the United States, Canada and Mexico.
In the opinion of the National Association of Manufacturers of Board (ANAFATA), NAFTA may possibly intensify the crisis in the forestry industry, which makes it necessary to analyse the possibility of injecting greater value added into the national product or to attempt joint ventures, making use of the advantages of tropical timber.
In 1992, the production of plywood in the 14 factories operating out of the existing 35 was 99,000 metric tons, whereas imports were almost 100,000 metric tons from the United States and 60,000 metric tons from Indonesia, a country which has been exporting plywood from Mera... for reasons of cost and type of finish (decorative).
In general, 38 per cent of the trade in plywood is provided by Mexico and the remaining 62 per cent by the United States and Indonesia.

1.4 THE USE OF WOOD IN FORMWORK

1.4.1 Background

Mexico has, without any doubt, world-wide prestige in architecture. In pre-Hispanic times, when the building of cathedrals began in Europe, pyramids and structures were being erected in Mexico that still exist. Various cultures have bequeathed to us structures scattered throughout Tajín, Chichén-Itza, Uxmal, Tula, Monte Albán, Mitla, Teotihuacán, Palenque, Bonampak, etc.
These cultures doubtless had abundant manpower in the form of artists and artisans who were able to work stone and fit it together following a special geometry, the result of which was the structures that we can still admire today.
The use of wood, in the form of tree-trunks, greatly helped in building these structures, since neither the wheel nor steel were known. That can be considered as the original of structural frameworks in the country.
In the colonial epoch there emerged structures of great value built with European technology but with the valuable collaboration of native manpower, giving a richer finish and resulting in of a blend of two cultures, whose examples in the form of churches, convents, buildings, etc. have their equal only in those in Lima, Peru.
With the passage of time, the use of cement and concrete became widespread in Mexico, so that it was necessary to position moulds to receive, shape and support them. At that time, wood was used for formwork. The forms introduced initially were boxes constructed of boards and strengthened by nails to keep the components in place; later, three-ply panels of "formwork grade", whose dimensions were normally 1.22 x 2.44 m and whose thickness was normally 5/8" (15.9 mm) were used.
In whatever type of construction work, either urban development, buildings, heavy or industrial construction, the use of wooden formwork and cross-ties or stanchions was more than widespread, since both obtaining the raw material (wood) and manpower for manufacture and assembly were extremely cheap, apart from being abundant owing to the artisanal skill of the construction workers.
However, at present there has been a radical change from past conditions. The development of new techniques in formwork and structural frameworks has resulted from the high cost of purchasing wood, the rise in the price of manpower, the difficulty of finding it, the need to enhance productivity and to use more modern and much more rapid systems for construction, as well as the fact that construction takes place in so changeable an

economic environment, apart from the enormous waste of wood, a natural resource that is not abundant in Mexico.
The need to alter the traditional system was the preponderant consideration and forced Mexican engineers and architects to develop technology with the use of new materials and new approaches, in which optimization of the number of uses, speed in positioning and striking formwork and its removal, the avoidance of waste, the facilitation of operations, are obligatory parameters which must inevitably lead to a substantial reduction in construction costs.

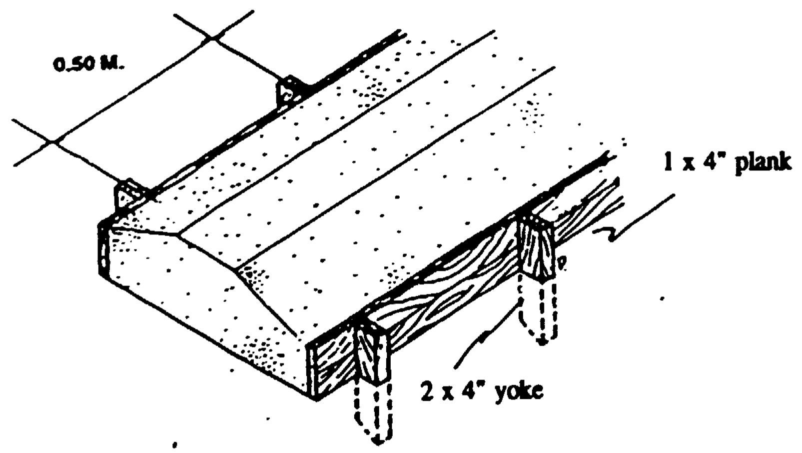
1.4.2 Types of wooden formwork

Wood has been the most commonly used material for the fabrication of formwork, and most types are constructed on the basis of experience, which is an appropriate system for ordinary structures. However, this is not true beyond that point, with another type of design in which it is not possible to work empirically but it is necessary to design and make static calculations of the structures of all its constituent elements, taking into account ordinary working and safe stresses, factors that are reflected in savings if the problem has been correctly solved.
The formwork or moulds are normally made of wood because it is a material that can with relative facility take on different shapes and whose cost was relatively low, though it no longer is so. Wooden formwork in direct contact with concrete can be used four to six times, given good manpower. If the elements are not in direct contact with the concrete, as is the case with stanchions, posts, flooring reinforcements, walings, stringers, wind-bracing, etc., their useful life is normally calculated as ten to twelve uses.
Many systems are used in formwork for the various concrete elements and we shall try to analyse some examples with the purpose of establishing a relevant criterion.

1.4.2.1 Formwork for foundations

a) For foundation footings or mats: For the formwork in reinforced concrete foundations footings or mats, the lateral mould consists of boards of 10-20 cm width, according to the depth of the footing, and is fixed to the ground by means of yokes set approximately 50 cm apart and nailed to the board. Board 2.5 cm (1") thick is employed if it is intended to use the formwork one to three times, and 3.81 cm (1½") or 5.08 cm (2") board if it is intended to use it more than that number of times.

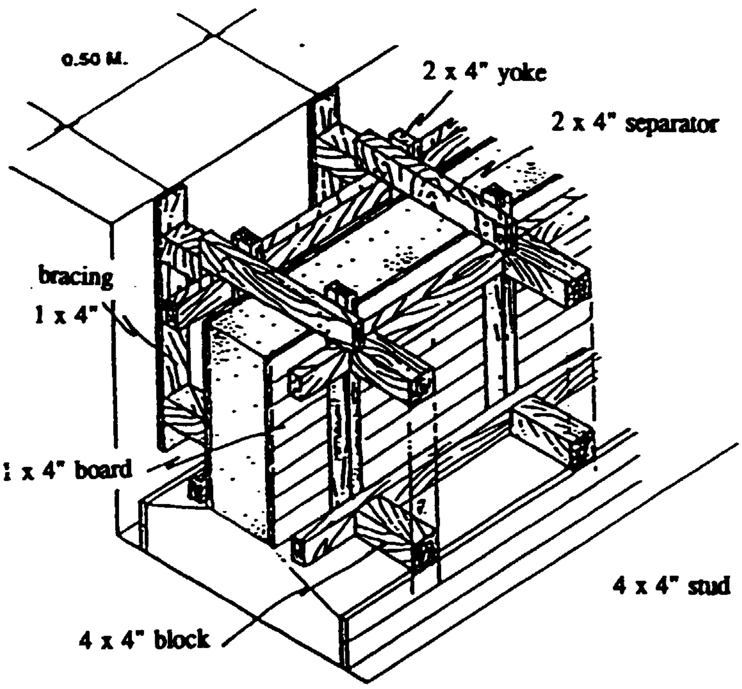
FIGURE 1.01 Normal formwork for a footing of 15-25 cm depth



b) For foundation beams or walls: Probably the most correct and cheapest system with regard both to manpower and wastage of material in the manufacture of formwork for foundation walls, and in general for other elements such as floor slabs, is the use of prefabricated formwork made from 2.5 cm (1") board with lateral bracing of 3.81 cm (1½") board, in sizes of about 1 m according the module chosen and believed to be most

suitable for the execution of the work. Using such parts avoids the wastage of wood, since it need not be cut up continuously to obtain various sizes, and because special parts need be made only in order to adjust for differences between modules and the openings in the foundations or distances between centres.
It is very important to point out that the wood most used in Mexico City for the manufacture of formwork is 10 cm (4") board so that it is very advisable to use it in designing sections of concrete and distances between centres. This 10 cm module is used for reasons of expediency by lumber dealers and builders, so as to make the smallest number of cuts within the normal 30.4 cm (12") boards that come from the sawmill.

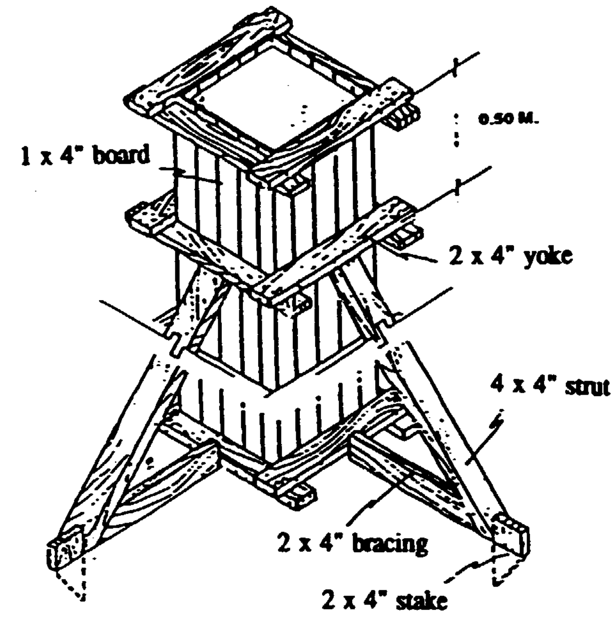
FIGURE 1.02 Normal formwork for 20 x 80 cm foundation walls



1.4.2.2 Columns

For the formwork of a column of square or rectangular cross-section, four side elements are made, equal in dimensions to the lateral dimensions of the element to be poured, in which the contact surface is permanently nailed to cross pieces or yokes located 40 or 50 cm apart. These cross-pieces are located edge on so that when the case for the column is made those on two opposing faces are mounted exactly on those of the lateral faces. This creates a series of right angles on the corners formed by the projecting portions of the cross-pieces on which nailing strips can be positioned, by means of which the complete formwork element can be fixed by means of metal or wood clamps.
The box thus formed is held upright by means of four inclined struts resting on wedges set on the floor slab or the ground. In this way it is possible to build an element which can be struck simply and rapidly and above all without destroying the wood in contact with the concrete. To prevent the wood from sticking to the concrete and also to increase the useful life of formwork, it is desirable to grease it, using any normal product, such as crank-case oil, yellow grease, linseed oil or any other type of special grease based on petroleum or paraffin. In order to make maximum use of 10 cm wide boards, the dimensions of the poured element must be multiples of 10 less 2.5 cm or less 5 cm, depending on the form in which the stands are placed.

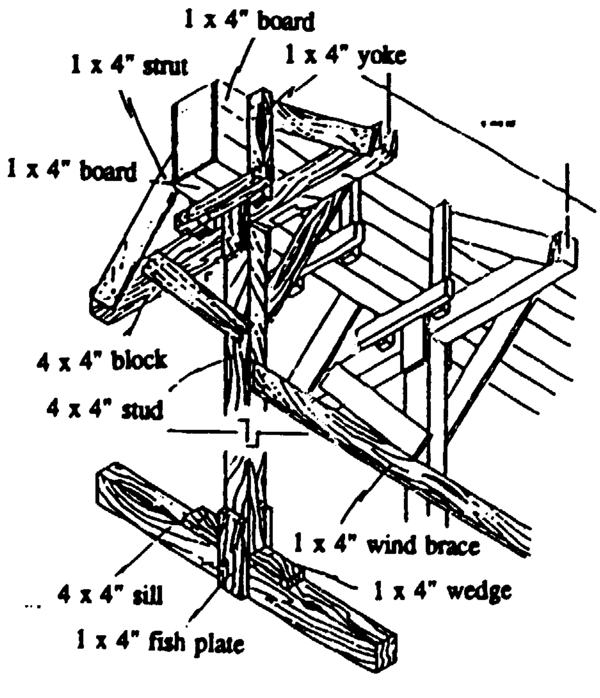
FIGURE 1.03 Normal formwork for a 50 x 50 cm column



1.4.2.3 Beams

If the beam structure is designed from the top, the formwork for such elements is similar to that for the foundation beams. If the beams are underneath the slab, the base and the sides are constructed separately.
It is desirable to use thicker wood (2") for the construction of the base than for the sides (1") and the contact wood that constitutes the base is supported on a number of 4 x 4" stringers set at 1 m distance from one another. The sides are nailed to 2 x 4" tie elements which are connected with the braces by 1 x 4" struts to stiffen the case. Finally, the bases are braced with diagonal elements and are supported by 4 x 4" uprights resting on the floor and on floor blocks, also 4 x 4".

FIGURE 1.04 Normal formwork for 15 x 30 cm beam

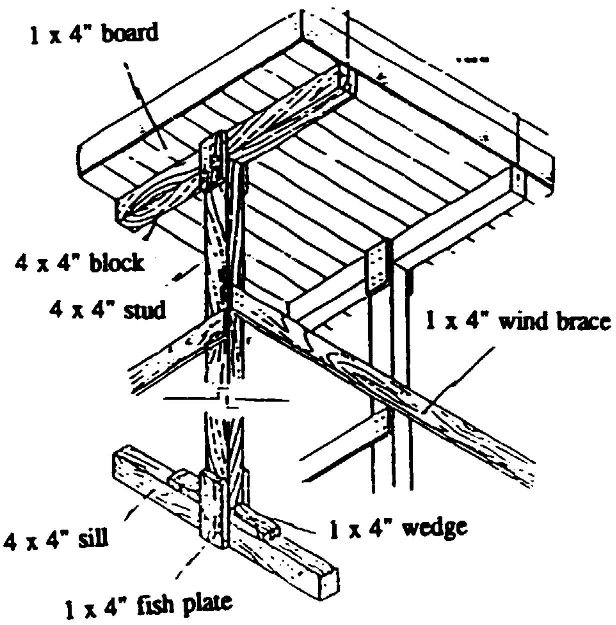


1.4.2.4. Slabs

For the slabs formwork, a series of trays or boxes of appropriate dimensions should be constructed, according to the span to be covered, consisting of a contact formwork lining nailed to a rigid framework of thicker wood. These boxes should be made with great care, squaring them and planing their surface, so as to obtain a better finish in pouring concrete.

They are located side by side on a structure consisting of supporting beams and bracing elements, spaced at a maximum of 1 m from one another and resting on appropriately spaced 4 x 4" uprights to which they are joined by means of fish plates. Finally, the uprights rest on the floor blocks and are connected to them by means of wedges and fish plates.

FIGURE 1.05 Normal formwork for floor slabs of 5 to 19 cm depth



1.4.3 Mixed formwork

This system of United States origin (the STEEL-PLY SYSTEM of SYMONS CORPORATION) has spread throughout the world and is based principally on modular panels with a metal framework and wooden contact face, which are joined together by means of elements specially designed to facilitate and optimize the operations of setting up and striking formwork for walls, beams, columns, slabs, etc.

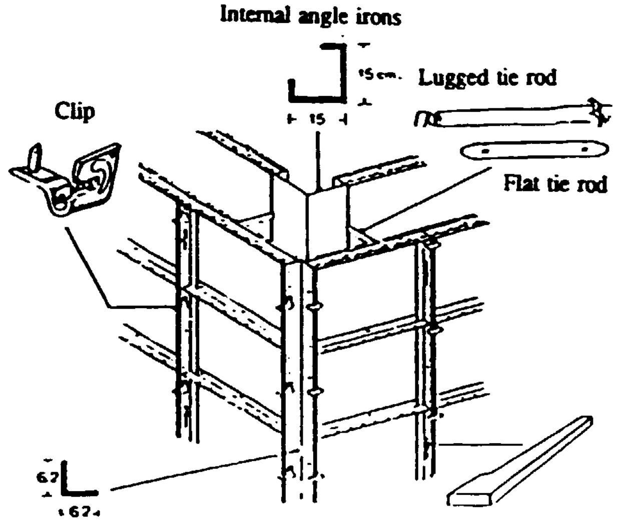
This system has been used in Mexico for more than twenty years and is offered on the market for sale and hire by the two best known enterprises, namely, CIMBRA-MEX. S.A. and INGENIERIA DE CIMBRAS S.A. Apart from the metal frames which support the plywood, reusable tie bolts and clips are used to join the panels and wedges that serve to fix the tie-rods to the panels. The modules are supplied in standard dimensions of 30 cm and multiples up to 60 cm broad and 2.4 m high.

CIMBRA-MEX uses marine three-ply board of heavy pine, 12 mm thick with one face covered with kraft paper impregnated with resin, which can thus be used between 60 and 70 times with the use of release agents. INGENIERIA DE CIMBRAS S.A. uses national Parral Duraply of 12 mm thickness (40-60 uses) or Eastwood plywood from Canada (100 uses).

Since 1970, CIMBRA-MEX on its own has supplied formwork for the construction of about 150,000 dwellings, principally in social housing projects, in addition to other civil engineering and industrial works. The system is appropriate for the construction of concrete walls of 8 to 15 cm thickness and concrete slabs for floors and roofing. The second alternative for roofs is beams and arches, which is a prefabricated system that is very popular in Mexico and requires hardly any forms.

The advantage of this type of composite formwork compared to 100 per cent metal types is the lower initial investment, the lower weight (a composite panel of 0.60 by 2.40 m weighs 40 kg and a metal form 45-50 kg), the greater versatility in respect of modules and the greater degree of reuse of the frames. The principal advantage of metal panels is the large number of possible uses (200), but much more equipment is needed for handling.

FIGURE 1.06 Mixed formwork system



1.4.4 Other types of formwork

There are many alternatives in the building market in Mexico, among which are the following:

1.4.5 Climbing formwork system

This technology originated in the United States and was modernized in Europe after the Second World War. It was again utilized in North America and has been used in Mexico for about 25 years. It is used basically for the construction of silos, chimneys, high tanks, elevator shafts, etc.

The term is used for formwork equipped with an independent system that permits the continuous raising of the forms, without the need for tie bolts or spacers, as the pouring of the concrete progresses. The concrete is continuous and thus monolithic.

The system consists of form sides 1.20 m wide whose length varies from 1.2 to 6 m. They are constructed of wood or metal and are connected by means of metal spacers which can be regulated according to the thickness of the concrete wall. The whole system slides continuously by the use of high capacity hydraulic jacks which climb on special steel bars resting on the previously constructed concrete.

The concrete and reinforcement rods are positioned from a wooden platform resting on the metal bracing elements of the internal portion of the forms. The metal brackets fastened to the metal spacers receive the external wooden platform for the storage of reinforcement rods. In Mexico there are about 8 plants for sliding forms, half of which use wood an the four others metal formwork surfaces. One of the enterprises visited, OBRAS Y DESLIZADOS S.A. also uses tongue and groove pine boards from Michoacan of 4" and 6" width and 30 mm thickness. Pine from Chihuahua and Durango is also used. The wood is not kiln dried and can be used up to 20 times although the optimum figure is 12.

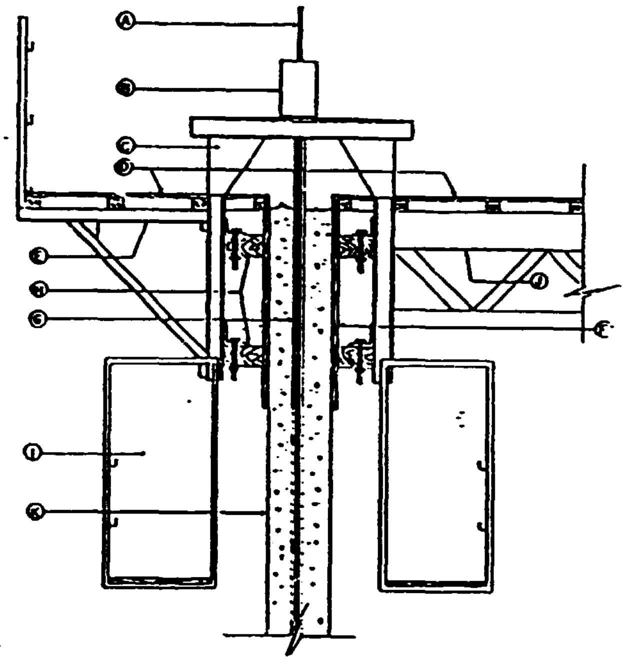
1.4.6 Metal formwork

This type of formwork is still relatively little used in Mexico owing to its high initial cost, although its use is justified in all mass production in which the high number of uses makes it possible to spread the initial investment.

In this type of system, the use of wood is almost completely avoided since the uprights, posts and struts are replaced by telescopic metal elements, which can be reused very many times and are very simple to position and assemble.

The finish of the structural elements is perfect in appearance, the surfaces being free from all irregularities so that it is possible - and this is the trend in the use of this method - to leave the concrete as it is without applying any later coating.

FIGURE 1.07 Climbing formwork



1.4.7 Formwork of other materials

We can mention cardboard or fibre tube (Sonotubo) formwork, which is made from kraft paper in the form of tubes which are used only once; however, the system offers great advantages with regard to cost and the excellent finish that is achieved.
Formwork made with FIBRACEL sheet, which is intermediate between wooden and metal formwork, reduces costs and gives a finish similar to that achieved with metal forms.
Asbestos cement formwork is also used and is suitable for circular columns, in which tubes of that material are used, leaving the asbestos tube as the finished surface.

1.5 CONSUMPTION OF WOOD IN FORMWORK

The volume of consumption of wood in formwork varies basically according to the construction system used and the number of uses that is made of the material. In the case of Mexico, wooden formwork for traditional concrete slabs is being replaced by prefabricated slabs laid on joists and arches that use less concrete and above all much less wood than the construction of traditional slabs.
According to the most recent census of 1990, 51.4 per cent of the roofs of dwellings in Mexico use concrete slabs or a joist and arch system. Though the statistics do not show the percentage corresponding to the joist and arch system, it can be stated that in the construction of large-scale housing programmes, this type of solution is being used more frequently day by day.
Various consultation sources have been analysed to establish the volume of consumption of wood in formwork. Table 1.05 describes the consumption characteristics of a completed dwelling of 52.87 m², using four alternative construction systems of the National Workers' Housing Fund Institute (INFONAVIT) type, together with information provided by SEDESOL on the basis of a study on the macro-economic impact of housing on the construction industry. As an illustration, the construction of 110,000 such dwellings was programmed in 1993 and 307,832 units of this type were built in the period 1989-1992.
The fifth alternative represents a one-family social programme dwelling of 46.08 m² considered in the monthly publication of BIMSA-COSTOS of May 1993, which serves as a reference for preparing preliminary budgets and as a guide for the cost of construction projects. The dwelling unit is designed for a site measuring 7 x 15 m (105 m²), taking into account the minimum INFONAVIT areas.
That table describes the characteristics of each construction system which differ with regard to the foundation (masonry or concrete block) and in the type of wall (ceramic brick and concrete slab) and in the type of roofing (concrete slabs and joist and arch system).

The consumption of wood varies from 344 to 655 bd ft per dwelling unit (average, 506 bd ft), the average consumption per m^2 being 9.9 bd ft The cost of formwork represents on the average 6.0 per cent of the direct costs of the structure over a range of 4.1 per cent to 7.3 per cent. Finally, the average consumption of wood per volume of concrete is 0.069 m^3 of wood/m^3 of concrete or, in other terms, 29.1 bd ft/m^3 of concrete and, by reference to the area of the dwelling unit, 0.0234 m^3 of wood per m^2 of the dwelling unit.

The programme for the support of self-help construction of SEDESOL assumes a consumption of 311 bd ft of wood for progressive housing (self-help construction) and 93 bd ft for improved housing, the wood being used principally for formwork. If we assume the consumption of 529 bd ft per completed dwelling units obtained from table 1.05 it would be possible to deduce the annual consumption of wood by relation to the rate of construction envisaged in the country.

Table 1.06 shows the potential demand for basic building materials for a housing programme according to the study *México. Escenarios de la Industria de la Construcción y la Vivienda 1991-2000* (Mexico. Scenarios of the construction industry and housing 1991-2000), prepared by the architect Angel Mercado. The number of dwelling units envisaged for construction in 10 years is 7,430 million units (taking into account completed, progressive and improved dwelling units constructed both by the public and the private sector). Taking the unit consumption of wood for formwork considered above, 671,400 m^3 will be required per year, that is to say 6,714 million m^3 in the period 1991-2000.

This figure should be slightly higher if we consider that the consumption of wood is greater in large buildings compared to that required in one-family and multifamily units, which represent approximately 15 per cent of the housing stock.

That volume of wood would represent about 20-25 per cent of the total annual consumption of sawn wood and plywood, according to the statistics in the Yearbook of Forest Products 1980-1991 of FAO and of the National Chamber for the Forestry Industry (on the basis of 0.5 m^3 of industrial wood per m^3 of logs). In the case of plywood intended for formwork alone, annual consumption of 150,000 m^3 is estimated (30 per cent of total consumption), half being accounted for by national production and the other half by three-ply wood imported from the United States.

1.6 COST OF FORMWORK

According to information obtained during field visits to industrialists and builders, metal formwork costs between 20 and 30 per cent more than industrially produced formwork using plywood.

Nevertheless, metal forms are used for some type of work, because the unit costs can be lower, depending on the number of uses (200 uses on a conservative estimate), and finish is better. Normally they are used in casting slabs for roadways, kerbstones and pavements as well as for columns, slabs and beams in traditional structures. Their use is to be recommended in all mass production work in which the enormous initial investment is justified.

Wood or plywood still are (and will continue to be) the most versatile and comparatively cheapest materials for use in formwork, although their use can be made more competitive and efficient by the reduction of waste and the introduction of new formwork systems.

A summary table is presented below that was prepared especially for the present study and that compares the costs of concrete walls, using two systems of formwork, with the costs of traditional walls of clay brick and concrete blocks.

Table 1.07 presents the costs of a concrete wall built with the CIMBRAMEX system (metal frames and plywood) and the costs of the same concrete wall constructed with the "traditional" system of formwork (wooden framework and plywood).

The two alternatives are compared with walls of red baked brick and of 10 x 20 x 40 cm concrete blocks. The analysis was prepared in a simulated study on the construction of 100 dwelling units and was based on the reutilization of coated three-ply wood 60-70 times, normal three-ply wood 8 times and of the wood required in brickwork walls for the beams (*cadenas*) and the columns (*castillos*) 15 times. This study, which was prepared in October 1993, made an analysis of unit prices for formwork, concrete, steel and walls of the two types.

The results indicate that the most economical system is that of metal frames and plywood (CIMBRAMEX) followed by concrete block walls (39.7 per cent more expensive) concrete and traditional formwork walls (41.2 per cent dearer) and clay brick walls, the cost of which is 64.5 per cent higher.

TABLE 1.05

CONSUMPTION OF WOOD FOR FORMWORK BY CONSTRUCTION SYSTEM

Types of dwelling units	Construction area m^2	Area of formwork m^2	Volume of concrete m^3	Volume of wood m^3	Consumption of wood			Direct cost	
					m^3 wood / m^3 conc	m^3 wood / m^2 constr	bd ft* / m^2 constr	US$ / m^2 constr	% of d. c.
SEDESOL [1]	52.87	n.a	18	1.47	0.082	0.029	12	11.27	7.3
SEDESOL [2]	52.87	n.a.	15	0.81	0.055	0.015	06	6.36	4.1
SEDESOL [1]	52.87	n.a.	20	1.55	0.078	0.029	12	12.14	7.3
SEDESOL [2]	52.87	n.a.	17	0.89	0.052	0.017	07	6.98	4.2
BIMSA [2]	46.08	n.a.	16	1.25	0.077	0.027	12	23.44	7.0
A V E R A G E					0.080	0.023	10	12.08	6.0

Source: SEDESOL. "The macroeconomic impact of housing on the construction industry".
FRAPOR 1991. BIMSA.

(*) : 1 m^3 wood = 424 board feet (bd ft)
[1] : Masonry wall and flat concrete floor
[2] : Masonry wall and joist and arch roof.
n.a. : Information not available

TABLE 1.06

MEXICO: DEMAND FOR HOUSING CONSTRUCTION MATERIALS BY PRODUCTION BODY AND TYPE OF PROGRAMME 1991 - 2000 ('000)

TYPE OF MATERIAL	UNITS	PUBLIC SECTOR			NON-PUBLIC SECTOR		TOTAL MATERIALS 1991-2000	ANNUAL AVERAGE
		Dwelling units completed	Dwelling units completed	Dwelling units completed	Private Dwelling units completed	Social Dwelling units completed		
Total housing 1991-2000	Dwelling units	2,043.0	206.4	1,036.0	1,450.6	2,694.1	7,430.1	743.0
BASIC MATERIALS								
• CEMENT	TONNE	9,847.4	1,054.7	1,968.4	13,838.7	13,766.9	40,476.1	4,047.6
• STEEL	TONNE	1,552.7	70.2	124.3	913.9	916.0	3,577.1	357.7
• FLAT BRICK	'000	13,034.5	586.2	953.1	6,716.3	7,651.2	28,941.3	2,894.1
• SAND	m^3	4,739.8	2,710.0	5,066.0	35,525.2	35,373.5	83,414.6	8,341.5
• GRAVEL	m^3	7,089.3	1,248.7	2,331.0	16,377.3	16,299.3	43,345.6	4,334.6
• STONE	m^3	27,458.3	1,539.7	2,880.1	20,192.4	20,098.0	72,168.4	7,216.8
• WOOD	m^3	2,548.9	151.4	227.8	1,809.8	1,976.1	6,714.0	671.4

Source: Mercado M, "México. Escenarios de la Industria de la Construcción y la Vivienda 1991-2000"

TABLE 1.07

ANALYSIS OF COSTS FOR WALLS OF CONCRETE AND MASONRY
(Walls of social dwelling units) Length: 57.0 linear metres
Height: 2.10 m
Thickness: 0.10 m

	CIMBRAMEX	TRADITIONAL	FLAT BRICK	BLOCKS
- FORM				
Material	1,117.92	2,654.38	-------	-------
Labour	675.91	1,483.69	-------	-------
- CONCRETE				
Material	3,400.22	3,675.22	-------	-------
Labour	37.91	37.91	-------	-------
- STEEL				
Material	767.55	767.55	-------	-------
Labour	103.53	103.53	-------	-------
- WALL				
Material	-------	-------	7,786.93	6,753.26
Labour	-------	-------	2,236.99	1,775.55
TOTAL COST (pesos)	6,103.03	8,612.27	10,023.92	8,528.81
COST (US$)	1,994.5	2,184.5	3,275.8	2,787.2
COST (US$/m²)	8.33	11.76	13.7	11.64
	(100%)	(141.2%)	(164.5%)	(139.7%)

Source: CIMBRA-MEX S.A.

The analysis undoubtedly reveals the lower costs of an industrially based system such as that of CIMBRAMEX in the mass construction of 100 units, even though proportionally lower costs (not less than 15 per cent) were obtained by using the traditional system of formwork with appropriate plywood, which can be used more than 60 times and not 8 times like normal three-ply.

1.7 CONCLUSIONS AND RECOMMENDATIONS

In general it is observed that in Mexico the use of wood and other building materials in formwork for concrete keeps pace with the sustained development and technological level of the construction industry, which is stimulated both by the public and the private sectors.

In the Federal District alone, there are no less than 30 companies specializing in formwork that offer different types of alternative services: hiring formwork (19 companies), steel formwork for the casting of concrete (2 companies), climbing formwork (2 companies) and formwork made of other materials for the casting of concrete (7 companies). However, wood is still the predominant material, accounting for between 80 and 90 per cent of the total consumption of formwork.

Mexico has buildings constructed with the most modern formwork technology such as: prefabricated concrete elements, formwork for projecting structures, inflatable formwork, tunnel formwork and cantilever formwork. Formwork is also used for the construction of high concrete tanks, of hyperbolic paraboloid shape, whose diameters vary continuously so that the possibility of overlap must be taken into account in the system, apart from its having either hydraulic or pneumatic self propulsion mechanisms. Various technologies have been imported into Mexico, especially from the United States, Germany, France, United Kingdom, Spain and Italy, although it should be admitted that they have not always been successful.

With regard to the production of raw material, the wood used in formwork has some problems with regard to durability, wear and warping, which have an effect on the possibility of reusing the material, optimizing its use and reducing building costs. In the case of plywood, there is agreement that national producers offer products of good quality but low competitiveness in cost in relation with imported plywood. National three-ply supplies 38 per cent of the consumption market and plants are operating at 30 per cent of installed capacity. According to ANAFATA, the Mexican quality standard is stricter than the American.

From the point of view of standardization of the use of wood in formwork, there are no adequate technical specifications or standards and it is merely the recommendations of the American Concrete Institute (ACI) which are used – these are based on North American products. In some cases, even when specifications exist, they are voluntary and non-mandatory. There is work to be done in this area.

From the point of view of the training of labour, no information could be obtained concerning regular training courses for blue-collar workers and carpenters in the techniques of fabrication, positioning and striking of formwork. However, the National Chamber for the Construction Industry (CNIC) is doing intensive work, through the Training Institute for the Construction Industry (ICIC), on the training of carpenters for "rough work", on request by construction enterprises at the national level which are members of CNIC.

ICIC, in agreement with the Inter-American Research and Documentation Centre on Vocational Training (CINTERFOR), a specialized agency of the International Labour Organization (ILO), has produced a rough-work carpentry manual which contains basic information on knowledge related to the trade of carpenters for rough work with regard to the techniques for processing wood and its utilization in construction work, especially for temporary use, for instance in fences, scaffolding and especially formwork. This manual is an example that could be adopted in other Latin American countries.

As a better illustration of the work of ICIC in the training of construction carpenters, suffice it to mention that 127 courses, attended by 1,532 participants and comprising 30,452 man-hours of training for 23 delegations from the various States of the country were organized in the period January-October 1993. Despite the effort made, this type of training must still be stressed, especially for mastering new technology, which always arouses resistance on the part of building workers.

In addition, it has been found that there is a lack of training for engineers and constructors, not so much with regard to structural calculations but rather in the practical aspects of fabrication and the use of wood for formwork. According to the Mexican Cement and Concrete Institute (IMCYC), not less than 10 per cent of the disputes in which the intervention of the institution is requested are related to the inappropriate use of formwork made of wood or plywood. There are many problems with regard to waterproofing formwork which affect the strength and finish of the concrete. There is more concern regarding the strength of the formwork than with the concrete finish. According to IMCYC, 80 per cent of concrete surfaces were poorly finished.

With regard to technology and the materials available for formwork, an increase in the presence of metal formwork has been observed in recent years, including aluminium formwork, although there are also some difficulties in its large-scale utilization. Without any doubt, wood and plywood continue to be the predominant materials for concrete formwork and it is difficult to imagine large-scale substitution at national level, unless construction systems such as joists and arches totally replace the traditional construction system of concrete slabs.

Finally, in relation with market aspects, in view of the recent signature of the Free Trade Agreement between the United States, Canada and Mexico, it is envisaged that exports of sawn wood and plywood to Mexico will increase in the immediate future owing to the competitiveness of North American products in terms of price. At the moment, annual imports already amount to 75,000 m³, representing half of the consumption of plywood at national level.

This study suggests some recommendations aimed at optimizing and rationalizing the use of formwork made of wood and wood-based products, taking into account the enormous volume of consumption in this market for the forestry industry. The proposals will be grouped according to the following aspects:

(a) Production of raw material:

- To identify new forest species suitable for formwork that would replace or reduce pressure on the consumption of traditional species.
- To improve productivity in the manufacture of sawn wood and plywood, increasing value-added and improving quality control at competitive prices.
- To improve the physical and mechanical properties of plywood, increasing the elastic limit and load-bearing capacity of board intended to be used in formwork.

(b) Standardization:

- To standardize wood or wood-based products intended for formwork, standardizing dimensions and regulating quality control where necessary.

- To promote types of regulation at the level of mandatory specifications or standards, not necessarily of national scope but perhaps taking into account regional or local building regulations.

(c) Training:

- To disseminate and promote knowledge of the importance of formwork in construction, not only as a structural element but also owing to its importance with regard to the safety of the structure, the need for supervision, and care with regard to finish.
- To organize practical extension or specialization courses in the fabrication, assembly and striking of formwork, intended for professionals in architecture, engineering and construction.
- To evaluate the content and scope of courses or basic training imparted at universities with regard to the use of wooden formwork, not only with the purpose of optimizing use of the resource but also with the aim of reducing construction costs.
- To prepare teaching material, guides, manuals, elementary textbooks and audio-visual aids, compiling recommendations on good practice in the use of formwork and taking into account the characteristics of manpower and raw material available in the country.
- To expand the training of workers and carpenters in teaching centres not necessarily connected with building enterprises.

(d) Technology:

- To optimize the present use of traditional wooden formwork, developing improved methods of design, reducing waste and increasing the number of times that wood can be reused.
- To promote greater industrial manufacture of formwork and also better use of modules for architectural work, suited to the available systems of prefabricated formwork.
- To ensure better finish of the concrete surface, optimizing the use of release agents, coating resins or techniques for the vibrating and casting of concrete.

(e) Institutional support:

- To develop joint work linking the timber sector with traditional construction, taking into account the fact that various sectors and institutions traditionally have divergent interests and seldom devote their joint attention to each other's concerns and to a subject like wooden formwork.
- Accordingly, it is suggested that institutions such as the National Council for Wood for Construction (COMACO), should work closely with the National Chamber for the Construction Industry (CNIC) and the Mexican Cement and Concrete Institute (IMCYC).

Finally, it is desirable to analyse the impact on the forestry and construction industries of the implementation of the Free Trade Agreement between Canada, the United States and Mexico from 1994. Since the two first-mentioned countries have enormous resources and forestry industries, it is possible that, in order to increase trade, action will be developed to promote greater and better use of both imported and national wood products, not only in Mexico but also in the other Latin American countries.

2.0 DIAGNOSIS OF ECUADOR

2.1 THE HOUSING SECTOR

According to the Vth Population Census and the IVth Housing Census of 1990, Ecuador had a population of 10,782,000 and a housing stock of 2,339,281 dwelling units, 54 per cent of which were located in urban and 46 per cent in rural areas. By comparison with the 1974 census, there was an increase of 965,347 dwelling units over a period of 16 years, that is to say annual building of 60,334 units, both in the formal and informal sectors. Population growth in the period 1985-1990 was 2.6 per cent and for 1992 the Ministry of Urban Development and Housing estimated a housing deficit of 630,000, the quantitative deficit being 355,000 units (56.4 per cent) and the qualitative deficit 275,000 (43.6 per cent). The projection of the deficit for 1996 is 822,573 dwelling units (a quantitative deficit of 547,591 and a qualitative deficit of 274,982).

In the period 1989-1992 the supply of housing in the formal sector was 157,500 units, that is to say 25 per cent of the total demand required to make good the housing deficit. That means that the public, mutual and private construction sectors should supply ± 40,000 dwelling units/year, various types of facilities(new units, improvement, loans, etc.). The 20,000 additional dwelling units constructed annually would correspond to the informal or self-help construction sector. The composition of the housing stock by type of housing was as follows:

-	Houses or villas	1,520,465	(65.0%)
-	Apartments	182,393	(7.8%)
-	Rented rooms	159,637	(6.8%)
-	*Mediagua* huts	267,818	(11.5%)
-	Substandard	157,235	(6.7%)
-	Farm	9,194	(0.9%)
-	Cottage	37,117	(1.6%)
-	Others	5,422	(0.2%)
-	TOTAL	2,339,281	(100 %)

If we assume that only apartments are constructed in multifamily buildings, the other types would represent 92.2 per cent, corresponding to houses one or two storeys high. Similarly, the last five types of buildings are considered as semi-permanent, with an average life of 5-10 years and represent 20.4 per cent of the national total.

2.2 THE CONSTRUCTION SECTOR

One of the principal indicators of the country's economic situation is the growth rate of the gross domestic product (GDP). According to that indicator, the Ecuadorian economy has shrunk since the period of the oil boom. In 1973, it achieved a growth of 25.3 per cent, but has since declined, reaching a negative growth rate of -2.8 per cent in 1983 at 1975 prices.
Since then, the rate of growth recovered but this was halted in 1987 owing to the paralysis in oil exports caused by the earthquake in March of that year, the growth rate being negative, at -6.0 per cent. In 1992, the growth rate of GDP was 2.5 per cent. Table 2.01 shows the share of the construction sector in GDP.
From 1987, there was a sharp decrease in the rate of growth in the construction area, amounting to a 14.1 per cent decrease in 1987, finally becoming an 0.7 per cent decrease in 1992, though there was a slight recovery of activity of the order of 3.3 per cent in 1989.
Construction activity in Ecuador is undertaken by the State, which promotes 70 per cent of the national total, while the private sector accounts for the remaining 30 per cent. Accordingly, there are great hopes that the new Development Plan 1993-1996 will aggressively reactivate the construction sector since, as has been envisaged, it advocates the undertaking of construction projects for at least 60,000 dwelling units per year on the average.

TABLE 2.01

GROWTH RATE OF GDP AND CONSTRUCTION [1]

YEAR	ANNUAL GDP IN US$ MILLION	ANNUAL GROWTH OF GDP	SHARE OF CONSTRUCTION IN GDP %	INDEX OF GROWTH OR DECREASE IN ANNUAL CONSTRUCTION
1986	10,515	3.1	---	1.5
1987	9,450	-6.0	4.4	2.5
1988	9,129	10.5	3.4	-14.1
1989	9,972	0.3	3.5	3.3
1990	10,741	2.3	3.3	-4.9
1991	11,693	4.4	1.6	-3.2
1992	12,600	2.5	2.0	0.6

[1] Annual report 1992/1993. Chamber of Construction, Quito

With regard to materials used in house-building, concrete, brick or concrete blocks predominate in walls (57.7 per cent) and tiles for roofs (20.1 per cent). Concrete slabs are the second predominant material with 18.9 per cent. Floors are predominantly of boarding (42.6 per cent) and brick and cement with 26.3 per cent. It can be deduced from table 2.02 that 9.2 per cent of the dwelling units have walls of wood, although wooden structures are used in 81 per cent of roofs with different types of surfacing material (asbestos, zinc, tiles, straw, etc.).

2.3 THE FORESTRY SECTOR

2.3.1 Introduction

Ecuador is a country in which the use of and trade in wood and its derivatives have always been present in its economy. Ecuador has always been self-sufficient in wood products, but imports about two-thirds of its domestic demand for paper, leading to a significant balance of payments deficit in the forestry sector (US$ 48 million in 1990). Its principal exports are sawn balsa wood (US$ 9.0 million in 1992) and plywood (US$ 8.05 million in 1992).

In 1968, the country had a population of 5.8 million and consumed about 5.2 million m^3 of wood per year. Consumption for energy generation represented 77 per cent of the total. In 1992, the country had approximately 10.7 million inhabitants and consumed 9.7 million m^3 of wood per year, 66 per cent of which was intended for the generation of energy. Historically, the proportion of the consumption of wood for industrial use has increased (23 per cent in 1968 and 34 per cent of the total in 1992), while consumption for energy generation has decreased.

The product whose domestic consumption increased most in the period 1968-1992 was sawn wood (418 per cent), followed by plywood (404 per cent).

2.3.2 Forestry resources

Almost 42.4 per cent of the total area of Ecuador, or 11.5 million ha, is covered with natural forests, while forest plantations do not represent more than 0.3 per cent of the national area. About 29 per cent of the total area of the natural forests in the country, or 12 per cent of the national territory, has been declared as a protection zone (protective forests or special or experimental forests and areas).

The native forests provide about 88 per cent of the total wood consumed in Ecuador, that is to say, about 8.5 million m^3 per year, which, added to the 1.2 million produced from plantations, meets the annual demand for approximately 9.7 million m^3 of wood. Of the total, almost 6 million m^3 is felled for the generation of energy, and 93 per cent of the wood used for that purpose is obtained from natural forests. Of the 3.7 million m^3 used annually for the country's timber industry, 75 per cent or approximately 2.8 million m^3 comes from native forests. The North-Western region provides about 1.7 million m^3 of wood per year for industrial use, and at the moment resources are over-utilized, since the sustained production potential does not exceed 900,000 m^3 per year. The Amazon region provides about 1.1 million m^3 per year, which does not exceed its capacity, being limited above all the defective infrastructure of the region.

The area of forest plantations is estimated at 78,000 ha, consisting of *Eucalyptus* spp. (43 per cent), *Pinus* spp. (30 per cent) and other native and exotic species (27 per cent). Some 90 per cent of the plantations are located in the inter-Andean region, 8 per cent in the coastal region and the remaining 2 per cent in the Eastern region. The species *Eucalyptus globulus* represents about 95 per cent of the eucalyptus plantations of Ecuador. As to pines, 84 per cent is accounted for by *Pinus radiata*, and the remaining 16 per cent by *Pinus patula*.

The principal areas of plantations of balsa wood, laurel, teak and *pachaco* are established in the coastal province. The plantations in the Amazon region are at the initial stage and cover not more than 1,500 ha, in which experiments with native species of the region are prominent.

With a weighted growth rate estimated at 11 per cent, the stock (11.3 million m^3) in forestry plantations makes possible sustained production of approximately 1.2 million m^3/year, corresponding to the present volume of supply, which shows that planted Ecuadorian forests are at the equilibrium limit for production.

2.3.3 The forestry industry and foreign trade

During recent years the forestry industry of Ecuador has devoted its output to supplying internal demand. External market operations cover only small quantities, chiefly exports of balsa wood and boards and imports of pulp and paper. Table 2.03 presents the data updated to 1992 for production, export and apparent consumption of the principal forestry products.

TABLE 2.02

PRIVATE DWELLING UNITS OCCUPIED, BY PREDOMINANT BUILDING MATERIALS IN WALLS AND ROOFS

PREDOMINANT MATERIALS IN EXTERNAL WALLS	TOTAL DWELLING UNITS	PREDOMINANT ROOFING MATERIAL					
		CONCRETE SLABS	ASBESTOS ETC.	ZINC	TILES	STRAW, ETC.	OTHER MATERIALS
REPUBLIC OF ECUADOR: TOTAL	2,008,655	380,119	208,317	917,044	404,296	94,806	4,073
CONCRETE, BRICK OR BLOCKS	1,159,447	361,186	188,237	463,974	146,040	1	9
ADOBE OR MUD (*TAPIA*)	279,488	9,090	11,564	42,246	196,722	19,788	78
WOOD	186,761	6,695	4,381	150,571	18,960	5,615	539
MUD-PLASTERED CANE (*BAHAREQUE*)	130,318	2,443	2,021	78,450	32,418	14,547	439
UNPLASTERED CANE	237,937	-------	1,553	176,992	6,681	50,653	2,058
OTHER MATERIALS	14,704	705	561	4,811	3,475	4,202	950

Source: National Institute for Statistics and Censuses. Vth Population Census and IVth Housing Census, 1990

TABLE 2.03

ECUADORIAN MARKET FOR FORESTRY PRODUCTS - 1990 (m^3)

PRODUCT	PRODUCTION	IMPORTS	EXPORTS	APPARENT CONSUMPTION
Industrial logs	3,770,000	-----	60,000	3,710,000
Sawn wood	1,450,000	5	45,748	1,404,252
Particle board	58,000	225	17,541	40,684
Plywood boards	78,000	-----	23,000	55,000
Pulp and paper (tons)	90,000	248,300	700	337,600

Source : Project PD 137/91 Strategies for a sustained timber industry in Ecuador.

2.3.3.1 Sawn wood

There are 566 sawmills, located principally in the mountainous region and to a smaller extent in the coastal region of the country. The market for the consumption of sawn wood in Ecuador consists of the civilian construction sector and the industry for the manufacture of products of higher value added and other less significant products. The civilian construction sector is a bulk consumer of sawn wood for formwork, structural timber, roofing, etc.

In the last 11 years the domestic market absorbed more than 90 per cent of production. The only product systematically intended for export is balsa wood. The principal consumption centres for sawn wood are located in the major cities, chiefly Guayaquil, Quito and Cuenca, which together account for more than 70 per cent of consumption of sawn wood in the country.

Table 2.04 shows the apparent consumption of sawn wood in the Ecuadorian domestic market in 1992, estimated at 1,404,252 m^3. The principal bulk consumption sector for sawn wood is civilian construction, which absorbs 60 per cent of the domestic market. The product is used in the form of boards for formwork, structural timber, beams, roofs, etc.

TABLE 2.04

CONSUMPTION OF SAWN WOOD IN ECUADOR

CONSUMPTION SECTOR	VOLUME (m^3)	%
Civilian construction	838,252	60.0
Products with higher value added	566,000	40.0
* Furniture	232,000	16.5
* Mouldings, etc.	84,000	6.0
* Parquet flooring, etc.	25,000	1.5
* Other finished products	225,000	16.5
TOTAL	1,404,252	100.0

Source : Project PD 137/91 Strategies for a sustained timber industry in Ecuador.

Products of higher value added, including furniture, parquet flooring, mouldings, doors, windows, floors, sheathing, boxes, pallets, etc. absorb about 40 per cent of the local market, equivalent to 566,00 m^3. The furniture industry absorbed 16.5 per cent of the local market for sawn wood, that is to say 232,000 m^3.

2.3.3.2 Plywood panels and board

The domestic market absorbed 72.5 per cent of Ecuadorian production of plywood in 1992, that is to say, 56,606 m^3. Analysing the domestic market, the furniture sector absorbed about 92 per cent, or approximately 52,077 m^3. The remaining 8 per cent, approximately 4,529 m^3, was consumed for various uses, chief among which were the construction of internal partitions and panels, shipbuilding and other minor activities.

The principal macro-regions that consume plywood are the mountainous region and the coastal province. The mountainous region accounts for about 69 per cent of the domestic market for plywood, i.e. approximately 39,058 m^3. The coastal province consumes 28 per cent of production intended for this market whereas the Amazon region absorbs only some 3 per cent. There are in all 6 plywood factories in the country.

2.3.3.3 Particle board

Some 34 per cent of the particle board produced in Ecuador in 1992, was intended for export and 66 per cent consumed in the domestic market. The principal use of this product in the domestic market is in the production of furniture, which absorbed practically the entire production in 1992 intended for the local market, namely 40,684 m^3. There are only two particle board factories in the country.

It is estimated that the furniture industry consumes 95 per cent of the particle board produced, that is to say, approximately 38,950 m^3, while the rest, about 1,734 m^3, was consumed for other uses such as internal divisions, manufacture of small objects, crafts, etc.

2.4 THE UTILIZATION OF WOOD IN FORMWORK

2.4.1 Introduction

Wooden formwork plays a prominent role in the construction process in Ecuador although it is not sufficiently recognized, owing to a number of economic situations that we shall try to outline in the course of the present report. The process of extraction and processing of the raw material, the cost of wood for formwork, the experience of manpower in woodworking, the techniques available, as well as the fact that the wood is not generally reusable, create an alarming situation, both for industrialists in the forestry sector and for the civilian construction sector, which represents the principal consumer market.

Non-governmental organizations of the ecological and conservationist type blame the industrialists in the timber sector of Ecuador for the destruction of the forests and the latter in turn maintain that the problem is not limited to the extraction and processing of forestry resources but also to the poor level of utilization of wood, particularly as formwork in construction. In fact, the problem is more complex than it seems and deserves to be rapidly tackled by all the sectors involved.

The wood used in formwork comes from the so-called third cycle of forest exploitation. The logs are extracted firstly for plywood, secondly comes commercial grade sawn wood and thirdly trunks for construction wood and other uses with a smaller value-added component, using motor saws. 55 per cent of the output of sawn wood comes from the use of motor saws and the products are of very low quality and in general have to be resawn before being marketed, with a consequent increase in total losses of raw material.

There are boards, planks and other types of sawn wood, generally not of accurate dimension, which is logical in view of the equipment used in processing the logs. Because of the use of motor saws and obsolete and worn equipment in the sawmills it is not possible to obtain more precise dimensions of boards. Oversized wood is always ordered in order to compensate for this inaccuracy. Sawn wood is normally marketed by intermediaries who are not on the established lists, in the green state and not in fixed dimensions.

On the other hand, many contractors in the construction sector do not take sufficient interest themselves in the use of wood for formwork and disregard its importance in the structure. In many cases not only do they not plan it but leave the initiative to the site foreman or overseer to fabricate and assemble the formwork. Neither is it common practice in Ecuador, as it is, however, in other countries, for the contractor to subcontract piecework to a manufacturer of formwork who provides his own wood and, once the concrete has set, recovers the wood and uses it on other sites, thus reducing waste and optimizing the use of this resource.

Another great problem of wood for formwork, or *madera de monte* ("mountain timber"), is its low selling price, since it originates from forests cleared for agriculture or cattle raising or is produced by the use of motor saws, which reduces production costs to the detriment of optimum utilization of forestry resources. The alternative, namely, plywood for formwork, has a price of almost US$ 400/m^3, whereas "mountain timber" costs US$ 40-60/m^3, so that a greater initial investment is justified only in the case of major works.

The level of the use and recycling of wood and wood-based products in formwork must be analysed in the light of these conditions. The task of optimizing the use of wood for formwork should also take into account existing practice on the part of the construction workers and operatives, who use the waste wood from the site as fuel for the preparation of meals.

2.4.2 The use of wood in formwork

There are three techniques for the use of wood in formwork: the traditional technique with sawn wood or boards from forest clearance, matchboard and plywood panels. The two last-mentioned techniques are used only in multifamily buildings and series production, whereas the bulk of construction activity is for one-family dwellings and self-help building. Bamboo, or Guayaquil cane, is very widely used in the coastal zones and, like *guadua* in Columbia, replaces sawn wood and logs for structural and non-structural uses.

2.4.3 Traditional formwork

Wood of low density is used (0.30-0.35 specific gravity) which under the designation of "mountain timber" for formwork includes an indefinite number of unclassified species chief among which are: the avocado tree, the white cedar, the *sajo*, the *tangama* and other white woods. The laurel and the *sande* are also used as harder and stronger woods to stiffen the formwork surface. The commonest dimensions are 2 x 25 x 240 cm for formwork boards and 4 x 25 x 240 cm for planks. Similarly, battens (7 x 7 x 240 cm), scantling (4 x 4 x 240), strips (2.5 x 2.5 x 240 cm) and rails of eucalyptus (1.5 x 2.5 x 240 cm) are used.

An element that is much used in the Sierra is eucalyptus battens, which are used 10-15 times as uprights in the form of logs 8-10 cm in diameter and 240 cm in length at a density of 4 or 5 poles per m^2 of roof. Finally, eucalyptus "*pingos*" are exported to Europe as wood for pulping plants, which has increased their price in the local market, and has stabilized prices at a new level which will stimulate new development in national forestry.

The advantages offered by traditional formwork are based on the low initial investment, the possibility of adapting to complex forms, the ease of transport and the tradition of use. The principal disadvantages are the limited reuse of wood (once or at most twice), waste of the order of 30 per cent (cutting up in making the formwork and destruction on striking the formwork), swelling and cracking of the wood and the longer time taken to execute the work.

2.4.4 Matchboard

This is used in formwork for walls, columns and concrete slabs, using eucalyptus tongue-and-groove boards of 1.5 cm thickness and 10 cm width. The commonest dimensions are 0.60 x 1.20 m and 0.80 x 1.20 m. Normally, two or three 4 x 4 cm walings of cinnamon wood or *Colorado* of varying lengths are used. The panels can be reused four or six times and are employed in the construction of blocks of flats and multifamily houses.

The advantages are: time-saving in the assembly of formwork, the relatively low initial investment, the ease of placement of the elements, with little nailing required, the ease of striking the formwork and the advantages of storage. The disadvantages are: possible cracking, the necessity of strengthening the end pieces to avoid warping and the weight and handling of the panels.

2.4.5 Plywood panels

These are prefabricated elements using 12 or 15 mm plywood board with water- resistant glue and in some cases protective coatings. The plywood can be stiffened by the use of wood or metal elements and can be used 8 or 10 times.

The boards are normally made in multiples or sub-multiples of 1.20 m to make use of the module for plywood board, namely 1.2 x 2.44 m (4 x 8 ft). They are used principally in formwork for columns, walls and solid slabs, replacing matchboard.

The commonest dimensions of panels are: module I of 0.30 x 1.20, module II of 0.40 x 1.20, module III of 0.60 x 1.20 and module IV of 1.20 x 1.20 m. As in the case of matchboard panels, they are used in the construction of apartment buildings and multifamily houses as well as in other works.

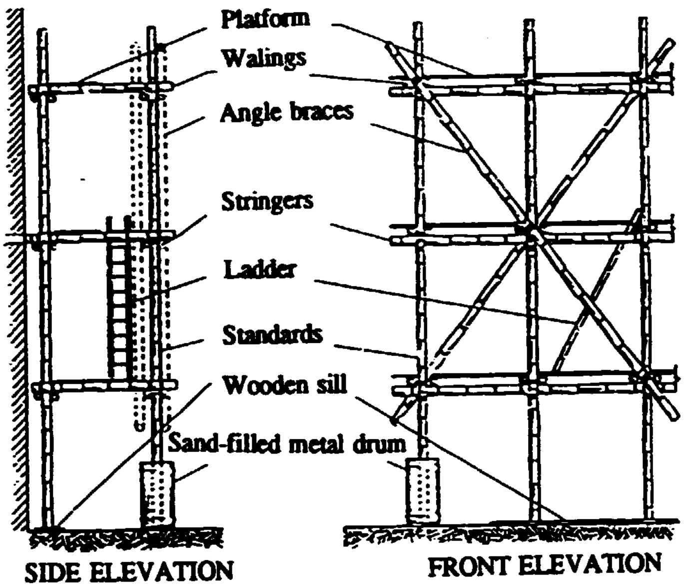
The principal advantages are smooth and better finished surfaces, the large number of reuses, great rigidity and resistance to bending, the possibility of covering large areas and flexibility for adapting curved shapes. The disadvantages may be the higher initial cost – so that their use is justified only if certain requirements have to be met – damage to edges when dropped and vulnerability to torsion during the striking of formwork.

2.4.6 The use of bamboo in formwork

Bamboo, or Guayaquil cane, is much used in the coastal cities of Ecuador, where the material is abundant, its use spreading chiefly to the coastal zones of Columbia and to cities in the departments of Valle del Cauca and Caldas.

One of the commonest uses is in the construction of scaffolding to be used by workers and for handling materials in the construction or repair of all types of buildings. At present, metal scaffolding has replaced bamboo for very high structures, but single or double bamboo scaffolding is still very popular and in some cases can even be regarded as a genuine engineering structure.

FIGURE 2.01 Double bamboo scaffolding



Bamboo is used for bracing and support elements in the construction of slabs. The stanchions are located at distances of between 0.60 and 1 m, depending on the diameter and slenderness of the poles. The bamboo stanchions are located vertically, fixed by means of horizontal and diagonal braces in both directions.
Not only split cane or bamboo matting can serve as a contact surface for concrete slabs, but coffering for lightweight slabs is also very widely used. The purpose of this coffering, which normally consists of lost formwork that is not reused, is to give the required form to the concrete beams and joists and to support flat ceilings. It replaces hollow roofing bricks which generally are very expensive and increase the weight of the slab, thus affecting the dimensioning of the foundation, especially in soils with little resistance.

2.5 CONSUMPTION OF WOOD IN FORMWORK

Owing to the low level of reutilization of wood for formwork in Ecuador, the consumption per unit of construction is greater than that found in other countries, included in the study.
Three buildings are presented, two being one-family social housing dwellings constructed by the National Housing Board and the third a multifamily building constructed by a private building firm.
The average consumption in one-family dwellings was 0.29 m^3 of wood/m^3 of concrete and 0.052 m^3 of wood/m^2 of construction area, or 22 bd ft per m^2 of roofed-over area. In the case of the seven-floor building, the consumption was 0.13 m^3 wood/m^3 concrete and 0.059 m^3 wood/m^2 construction area, or 25 board ft per m^2 of roofed-over area.
As can be observed, the consumption in multistorey buildings is generally more efficient than in one-family dwellings, owing to the greater use of plywood and the low proportion of "mountain timber", which rather tends to predominate in the construction of houses. It is necessary to bear in mind that formwork was not used in the roofs of the first National Housing Board dwelling, since the latter have a wooden structure.

TABLE 2.05

CONSUMPTION OF WOOD IN FORMWORK

TYPES OF DWELLINGS	CONSTRUCTION AREA m^2	AREA OF FORMWORK m^2	VOLUME OF CONCRETE m^3	VOLUME OF WOOD m^3	CONSUMPTION OF WOOD		
					$\frac{m^3 \text{ wood}}{m^3 \text{ conc}}$	$\frac{m^3 \text{ wood}}{m^2 \text{ constr}}$	$\frac{\text{bd ft}}{m^2 \text{ constr}}$
J.N.V. 1 floor [1]	36	n.a	3.79	1.36	0.36	0.038	16
J.N.V. 3 floors [2]	372	n.a	107.89	24.5	0.22	0.066	28
A. MORENO 7 floors [3]	3,710	n.a	1,660	52.87	0.13	0.059	25

n.a: Information not available

[1] Masonry wall; wood and Eternit roof

[2] Masonry wall; inaccessible concrete slabs

[3] Masonry wall; curtain walls and concrete slabs

2.6 COSTS OF FORMWORK

Owing to the low price of wood that follows from the system used in its processing and marketing, the unit cost of formwork is lower than in other countries, so that its impact on the direct cost of the work is also less. Table 2.06 presents the comparative costs in United States dollars of the two houses of the National Housing Board and the costs of a seven-floor building with an area of 3,710 m^2.

TABLE 2.06

CONSUMPTION OF WOOD IN FORMWORK
COMPARATIVE UNIT COSTS OF FORMWORK

CHARACTERISTICS	ONE-FAMILY HOUSE (1 storey)	THREE-FAMILY HOUSE (3 storeys)	APARTMENT BUILDING (7 storeys)
Construction area	36 m^2	371.6 m^2	3,710 m^2
Cost of formwork	US$ 76	US$ 1,214	US$ 48,718
Total direct cost	US$ 3,877	US$ 43,333	US$ 1,061,723
Impact	1.96%	2.8%	4.6%
Cost/m^2 constr.	US$ 2.11	US$ 3.27	US$ 13.1

Source: Ministry of Urban Development and Housing.

It can be observed that on the average the cost of formwork accounts for only 2.38 per cent of the direct cost of one-family dwellings and 4.6 per cent in the case of multifamily buildings. The costs of formwork were US$ 2.69/m^2 in one-family dwellings and US$ 13.10 in multifamily buildings.
Finally, table 2.07 presents the comparative costs of five tenders (October 1992) for formwork boards for slabs and walls quoted by the construction firm ELEPEVE for the World Trade Center building in Quito, which is 25 storeys high and has a construction area of 22,000 m^2.
It can be observed that the 1.20 x 0.80 eucalyptus matchboard fabricated on site represents the best offer with a cost of US$ 15,423 (US$ 38,790 including labour). The other bids for matchboard panels and plywood panels offered better prices than those of metal panels proposed by Bagant Ecuatoriana Cia. Ltda, one of the two enterprises that hire out metal formwork in the city of Quito.

2.7 CONCLUSIONS AND RECOMMENDATIONS

The situation in Ecuador regarding the consumption of wood and wood-based products for formwork is rather unusual and different from that of other Latin American countries. There are specific problems for which there are fortunately possibilities of solution although the work to be done is considerable and requires immediate action. We shall indicate below in summary form the present situation of the sector in the country:
With regard to the *production* of raw material, it can be noted that some aspects work in favour of better use of wood in formwork although 60 per cent of sawn wood is intended for the civilian construction market, a volume that is exceeded only by that of the consumption of wood as fuel.
It is observed that not much value is attached to wooden formwork because wood is cheap, being processed with motor saws (51 per cent of the total) and coming from forests cleared for agriculture and cattle raising. The price of wood is also related to the very poor quality of wood and the absence of any type of treatment, so that the level of reutilization is only once or at most twice.
No attempts can be observed to promote new forest species that would replace those used at present, which normally have a low average density of 0.30-0.35 gr/cm^3 specific gravity. Similarly, the wood used for formwork is sold without quality control, in non-standard thicknesses, has little resistance to humidity, is fragile and warps because it is used in the green state and has very little mechanical strength.

From the point of view of *standardization*, shortcomings can be detected, among other things, the absence of standards not only for wood but also for other building materials. In the case of wood there are problems of nomenclature and harmonization of measurement units, since wood is still frequently sold by length in feet and *varas* (= rods), by thickness in inches and by width in centimetres.

TABLE 2.07

COMPARATIVE STUDY OF BOARDS FOR CONCRETE WALLS AND SLABS

BOARD		QUANTITY	SUPPLIER	UNIT COST (US$)	TOTAL COST (US$)
01	Matchboard 1.20 x 0.80	3,000	Subcontractor	5.62	16,846
02	Matchboard 1.20 x 0.80	3,000	Subcontractor	6.67	20,000
03	Matchboard 1.20 x 0.80	3,000	Made up on site	5.14	15,423
04	Board 1.0 x 0.80 15 mm plywood	3,000	Made up on site	7.57	22,698
05	Metal panel, monthly hire 1.20 x 0.60	4,166	Bagant	0.82 10 months	34,183

Source: ELEPEVE, building enterprise.

"Mountain timber" for formwork belongs to a group of species that is not classified. There are only two standards in the INEN for metal scaffolding and three others for plywood, but none with specific reference to formwork. Standards are worked out at the request enterprises or associations, for which reason none has been worked out for wooden formwork.

The subject of *training* is one of the most important aspects in any attempt to optimize the use of wood for formwork. In the opinion of the enterprises and institutions contacted, there are limitations "in good building trade practice" with regard to the use of formwork, both at the level of workers and carpenters and also of professionals in architecture and civil engineering.

There are no national textbooks or local technical material in the country referring to the use of wood for formwork, but only those of foreign origin, principally from the United States or in some cases written by Latin American authors specializing in the subject. Training is basically of a practical nature, self-taught and based on the transmission of experience in training centres or on construction sites.

Apparently the traditional programmes of the Ecuadorian Vocational Training Service (SECAP) are not only sporadic but have not given the results expected. This has motivated experiments in direct on-site training in coordination with the building enterprises. Recently, practical courses have been carried out in the Faculty of Architecture of the Central University of Ecuador.

At the universities, no in-depth study is carried out on the subject of formwork with regard to calculation methods and systems for assembling and striking formwork. In general, there is no tradition of treating formwork as a structural element although it initially resists a weight even greater than that calculated for the finished concrete, that is to say, 200-250 kg/m² of live load. Wooden formwork must stand up to the weight of the concrete, namely 400 kg/m², during the time of casting and setting of the material.

On the other hand, no builders are trained at the universities but only civil engineers and architects. Recently courses have commenced at two new universities in Ecuador. A cooperation agreement is also being implemented between the Central University and the Timber Development Corporation (CORMADERA) in order to emphasize the need for teaching regarding wooden formwork in faculties of engineering and architecture.

Finally, the very *use* of wood in construction generates technical problems that must be solved, the main problem being the low level of recycling of the material, which usually ends up as firewood for the building workers. In the case of three-ply the situation is better since it is used slightly more often (8-10 uses) and eucalyptus poles are normally used 10 to 20 times, because they are not in contact with the concrete.

Despite the fact that wood is academically considered as the fifth element of concrete (the others are: cement, water, sand and stone), little attention is devoted to formwork techniques and above all the important problem of striking techniques gives cause for concern. There are no accessories such as double- headed nails, which would facilitate striking, and neither are wedges and non-destructive tools used.

There are problems in the organization of work, responsibility being left to the foremen and overseers, who have learned by experience. This generates problems with regard to the finish and alignment of the structural elements. Though the relatively high cost of plywood is a limiting factor, no effort is made to compensate for the initial investment by using an appropriate modular system in architectural plans or by prefabricating formwork elements.

This situation suggests a number of recommendations which are presented below:

(a) Production of the raw material

- To improve the extraction and processing of wood in general (not only that for formwork), identifying an optimization programme starting at the primary processing stage, to eliminate waste and improve quality control in sawmills. That could facilitate the reduction of costs, using offcuts from boards and battens for the prefabrication of formwork.
- To identify new forest species to replace in quality and durability those that are at present marketed, making exploitation and reafforestation more profitable. Along these lines consideration should be given to the promotion of larger plantations of *guadua* cane to replace eucalyptus poles, which are a valuable export commodity, as well as plantations of low-density and rapid-growth wood, although such wood requires some processing for use in formwork.

(b) Standardization

- It is suggested that a *practical guide* be prepared instead of a standard for formwork, in which instructions could be given for the better use of wood. The practical guide would not have the character of a law but would be a reference document accepted by INEN and that would serve as a guide in tenders and contracts. Reality has shown that standardization action is less effective than training, promotion and the dissemination of good building practice.
- Taking into account the classification by structural groups prepared under projects of the Board of the Cartagena Agreement in earlier years, it would be possible to propose a new specialized group for formwork wood (Group "D" or "C-1"), which would facilitate marketing, treatment and use on site, and would group less widely known species.

(c) Training

- It is necessary to promote conditions to ensure that the Ecuadorian Federation of Construction Chambers, as happens in other countries, should establish a more dynamic relationship with the Ecuadorian Training Service, SECAB, in the training of workers and carpenters with regard to formwork and other building specialities.
- While it becomes necessary to revise the content of present courses on formwork for architects and engineers or for the new profession of builders, it is necessary to carry out periodic extension courses or seminars emphasizing building practices related to new techniques for wooden formwork and for striking formwork.
- It is essential to prepare technical and audio-visual material on wooden formwork systems that can be used at various levels of training. The preparation of a formwork *manual* could be suggested for construction professionals and a practical *primer* for workers, carpenters and self-help builders. These technical documents could serve as a guideline for the preparation of the INEN *guide on practice*.

(d) Technology

- It is necessary to design, optimize and/or adopt new systems for industrially or semi-industrially produced formwork that would permit increased recycling of wood by the use of appropriate release agents and treated wood as well as appropriate formwork striking techniques that would facilitate the utilization of formwork and improve the quality of finish.
- To promote the utilization of new accessories and wood-based formwork materials such as: double-headed nails, plywood boards that are stronger, rigid and have finished surfaces or new products such as wood-cement particle boards (of the Bison type) or such as MDF (Medium Density Board). It is necessary to increase the value-added component of formwork so that the higher initial cost will be compensated for by greater reutilization.
- To improve the quality of formwork, promoting the prefabrication of supports, panels and coffering using new or waste sawn wood in combination with other construction materials.

(e) Market

- To prepare a more thorough study on the use of wood in formwork in Ecuador that would make it possible to identify real volumes of consumptions, supply and demand for formwork and to analyse the trends that could be accepted by the user.
- To stimulate the creation of storage centres, yards or micro-enterprises for renting or hire specializing in wooden formwork that they would chiefly supply to building contractors not working on series production and to self-help builders, thus promoting the reduction of waste and increasing the number of uses of wood.

(f) Promotion

- To promote a competition on new construction systems for wooden formwork not only at the level of professionals but also of workers and site foremen.
- To establish programmes for optimization, information and technical advice in the use of wood for formwork, under the auspices of the wood and construction sectors, professional colleges, universities and SECAB.

Finally, in the light of the conditions in which wood is used for formwork we have identified two programmes of a regional nature that can be implemented with the assistance of international technical cooperation. The first would be related to the identification of joint action between the Latin American training agencies, to homogenize and harmonize levels of training of workers and carpenters, in this case directed towards optimizing the use of wood in formwork.

Bodies such as IMCYC of Mexico, SENA of Columbia, SENAI of Brazil or SENCICO of Peru could take part in this joint project with the support of the International Labour Organization or another technical cooperation agency. The Building Chamber of Quito has already signed a technical cooperation agreement with the Training Institute for the Construction Industry of Mexico (IMCYC), whose principal objective is intensive and accelerated vocational training of workers and intermediate level supervisors in industrial and construction activities.

A second initiative identified as a consequence of the present study is related to the implementation of a "Project for the Optimization of the Use of Wood in Formwork" in the framework of projects of the International Tropic Timber Organization (ITTO), which would enjoy the participation of the forestry and building industry of the Latin American member countries and would be under the auspices of the recently established Andean Forestry Chamber.

3.0 DIAGNOSIS OF ARGENTINA

3.1 THE HOUSING SECTOR

According to the most recent census carried out in 1991, Argentina had a population of 32,608,687 of whom 86.2 per cent were located in urban and 13.8 per cent in rural areas. The housing stock consisted of 8,515,441 houses, that is to say approximately 20 per cent more than those recorded in the 1980 census, i.e. 7,103,853. Table 3.01 shows the housing deficit and the composition of the housing stock as shown by the two most recent housing censuses. According to that table, 26.3 per cent of the houses, or 2,233,520, represent the so-called "operative" deficit, which would be the qualitative housing deficit consisting of type B houses, rented rooms in houses, dilapidated houses and others. Type B houses are considered as substandard because they have some of the following three characteristics: beaten earth floor, lack of sanitation or absence of piped water.

It would be necessary to add to this operational deficit a deficit of 411,848 houses caused by overcrowding since the number of households was greater than the number of dwelling units in 1991 (8,927,289 households in 8,515,441 dwelling units). It would also be necessary to add the quantitative deficit of not less than 50,000 dwelling units which would make an approximate total housing deficit of 2,700,000.

This figure agrees with some reference sources but depending on the various measurement criteria employed it may be greater, and it has been estimated that it can be 3,200,000 units.[1]

It can be observed from the same table that in 1991, breaking down houses by type, 18.2 per cent of the housing stock consisted of apartments which should be interpreted as dwellings located in multifamily buildings of three or more floors in height. The remainder, that is to say 81.8 per cent, is represented by one-family dwellings of types A and B and other types of dwellings.

[1] Analysis of the current situation in the housing sector, Menen-Dualde.

3.2 THE CONSTRUCTION SECTOR

The National Housing Fund (FONAVI) was set up by means of contributions of 5 per cent of total remuneration payable by the employer and of a 20 per cent provisional contribution of self-employed workers. This resource can be estimated at US$ 600 million, on the basis of an average evasion of 30 per cent. In 1992 the administration of FONAVI was taken over by the Provincial Housing Institutes and represents approximately 90 per cent of public investment in housing.

In 1992, 35,661 dwelling units were constructed with FONAVI resources, although in the period 1976-1992 the average construction was approximately 28,000 units. The annual average construction of complete dwelling units apparently does not reach the level of 70,000 units although statistically between 1980 and 1991 128,326 dwelling units were constructed on the annual average including housing facilities, rented rooms and other types of precarious housing. It is estimated that in the period 1990-1995 not less than 215,000 dwelling units per year will be required to control the housing deficit, such units being constructed both by the public and the private sector.

TABLE 3.01

HOUSING DEFICIT BY TYPE OF DWELLING

YEAR	1980		1991	
TOTAL DWELLINGS	QUANTITY	%	QUANTITY	%
Non-defective dwellings:				
- "A" dwellings	3,788,673	53.3	4,727,279	55.5
- Apartments	1,266,357	17.9	1,554,642	18.2
Subtotal: SATISFACTORY	5,055,024	71.2	6,281,921	73.7
Defective dwellings				
- "B" dwellings	1,143,666	16.1	1,409,425	16.6
- Rented rooms	64,363	0.9	47,533	0.6
- Dilapidated dwellings	824,305	11.6	628,940	7.4
- Others and unknown	16,495	0.2	147,622	1.7
Subtotal: UNSATISFACTORY	2,048,829	28.8	2,233,520	26.3
TOTAL DWELLINGS IN THE COUNTRY	7,103,853	100.0	8,515,441	100.0

Source: Argentine Chamber of Construction.

In general, for approximately 15 years (1975-1992) there was a decline in the rate of building in Argentina, and the private sector reduced its share in the period 1984-1988 by 32.9 per cent. If the number of building permits at national level in the period 1974-1990 are analysed, a decrease of 66.4 per cent can be noted, with 142,064 permits granted in 1974 and 47,657 permits in 1990. However, this situation has been reversed in recent years owing to the improved situation of the national economy, greater participation of the private sector and by the fact that FONAVI no longer depends on the Central Government but on the provincial housing institutes.

Table 3.02 shows the predominant materials used in construction according to the most recent statistical information from the 1980 census.

From analysis of that table it can be inferred that the typical dwelling unit in Argentina would consist of the following materials:

FLOORS	mosaic or similar	54.8 per cent
EXTERNAL WALLS	masonry	84.2 per cent
EXTERNAL ROOFING	mosaic, slab or asphalt	47.9 per cent

It can also be deduced that only 6.7 per cent of the dwelling units are constructed of wood, with that material used for their external walls although no less than 52.1 per cent used wood in roofs and roof covering if we take into account houses that use metal sheet, fibre cement sheet and other types of roofing material.

TABLE 3.02

PREDOMINANT BUILDING MATERIALS, 1980 CENSUS

PREDOMINANT MATERIAL	QUANTITY OF DWELLING UNITS
1. Floors:	
• Mosaic or similar	3,892,710
• Wood	981,223
• Cement or brick	1,506,247
• Earth	624,378
• Other materials	99,295
2. External walls:	
• Masonry	5,978,178
• Adobe	435,958
• Wood	475,180
• Other materials	214,537
3. External roof covering:	
• Mosaic, slabs or asphalt roofing	3,401,735
• Metal sheet	2,172,698
• Tiles	432,293
• Fibre cement sheet	463,563
• Other materials	633,564
TOTAL DWELLING UNITS IN THE COUNTRY (1980):	7,103,853

SOURCE: Housing census 1980

3.3 THE FORESTRY SECTOR

Argentina has 36 million ha of forest representing 13 per cent of the country's area, of which 35 million are natural forests and slightly less than 1 million new plantations which account for 45 per cent of forestry exploitation.

In 1989 it was estimated that 768,000 ha of plantations consisted of the following species: eucalyptus 231,000 ha, conifers (*Pinus elliotis* and *saligne*) 372,000 ha, *Silicaces* and poplars 48,000 ha and others 17,000 ha. 77 per cent of the plantations are located in four provinces, the most important being Misiones with 210,000 ha, Corrientes with 120,000 and Buenos Aires with 97,000 ha.

According to the most recent statistics from 1987, there were about 1,300 sawmills, of which according to the Wood Technology Research Centre (CITEMA) only about 1,000 were operating and 44 per cent of these were working at less than 50 per cent of installed capacity.

Table 3.03 shows the production of sawn wood in the period 1983-1987, which averaged 1,015,238 m^3.

TABLE 3.03

PRODUCTION OF SAWN WOOD 1983-1987

Years	PRODUCTION		Logs used m³
	'000 m²	m³	
1983	44,122	1,120,708	2,475,652
1984	36,852	936,036	2,069,816
1985	35,505	901,823	1,953,638
1986	38,510	978,161	2,111,073
1987	44,861	1,139,460	2,417,982

Source: IFONA. 1987 Yearbook of Forestry Statistics

19 of the 440 species available have been studied in respect of their quality and strength. Those most logged in 1987 were the following:

Native species	*Lenga*	59,658 m³
	Anchico colorado	48,012 m³
	Algarrobo	41,814 m³
	Laurel	39,959 m³
Cultivated species	Eucalyptus	203,862 m³
	Alamo	175,350 m³
	Resinous pine	93,651 m³
	Parang pine	21,878 m³

As can be observed the largest quantity of wood intended for the construction sector in general and for formwork in particular comes from conifers cultivated in new plantations, these four species representing 43 per cent of total production.
The remainder of forestry production in 1987 consisted of the following industries related to use in formwork:

TABLE 3.04

PRODUCTION OF BOARDS

	Factories in operation	Installed capacity m³	Production	Utilization %
Plywood	22	91,840	56,813	61.9
Fibreboard	2	424,500	103,395	24.4
Particle board	7	298,207	205,717	69.0

Source: IFONA. 1987 Yearbook of Forestry Statistics

Plywood panels are produced in several qualities, the largest production being that of board with a phenolic coating used for formwork, which represents 25 per cent of the national total (14,450 m³).

3.4 THE USE OF WOOD IN FORMWORK

3.4.1 Traditional formwork

As in all Latin American countries the type of formwork most commonly used is made of wooden boards that are used in 80-90 per cent of houses. Plywood is the second alternative for the surface in contact with a concrete, combined with metal or wooden support structures. Finally, a greater trend can be observed towards the use of plywood or "multilaminates" as they are called, especially for the construction of multifloor and multifamily buildings.

The most commonly used species are *saligne pine*, *elliotis pine* and parana pine, all from plantations. The most common dimensions are 1 x 3", 1 x 5" and 1 x 6", in lengths of 3-5 m in the case of boards and battens, with reutilization three times. The tie-rods or struts have cross sections of 2 x 3" and 3 x 3" and length of 2.8 m, being used up to six times.

The plywood normally used is 15 or 20 mm thick, normally of the phenolic type with plastic coated surfaces. The quality of plywood depends on the quality of origin of the wood and it is not always possible to obtain completely waterproof plywood on the surfaces and edges, that does not warp or become damaged in contact with water unless treated.

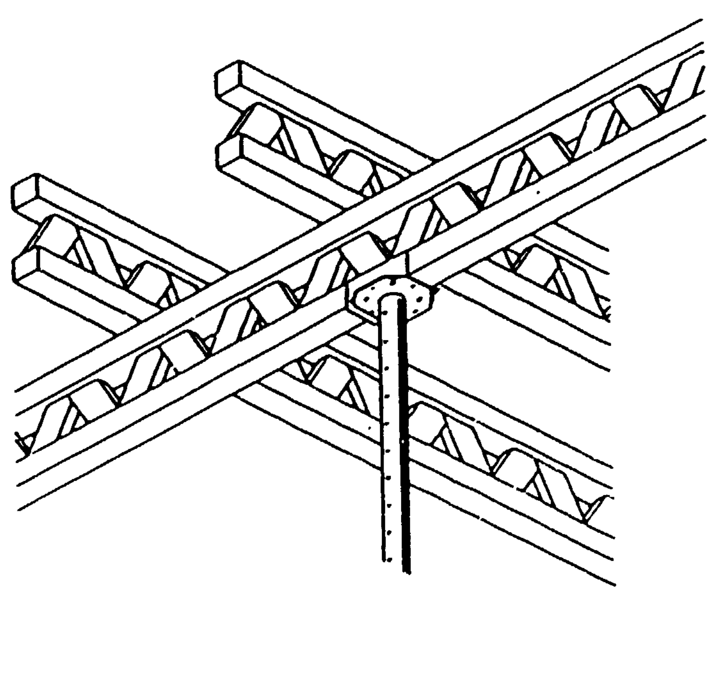
Compressed wood boards consist of sheets of *guayaca*, *peteribi*, pine wood, etc., 1, 2 or 3 mm thick, bonded with phenolic and ureic adhesives and finished with sandpapering or plastic coating. They are normally used 15-25 times, for which purpose polyurethane, epoxy, polyester or neoprene rubber sealing compounds are used. The commonest dimensions are 1.22 x 2.44 m, 1.22 x 2.20 and 1.00 x 2.00 m.

3.4.2 Large wooden formwork

Recently, with the renewal of construction activity, modern wooden formwork of imported origin has begun to be used in Argentina, which represents an upgrading of the value of the material; this basically consists of Warren type wooden beams glued in lattices form or Vierendel solid web type 35-36 cm in height and of various lengths, to which phenolic plywood panels, normally with plastic covered faces, are screwed.

This type of formwork originated from Germany with the Steidle beam, which was first sold commercially in 1959. Almost 10 years later, in 1968, appeared the PERI type beam, which is also a lattice work beam of the Warren type of glued wood, but with flush ends that is to say that the upper and lower beams are of equal length, as compared with the typical form of the Steidle beam, in which one end projects and in addition the diagonal parts are solid.

FIGURE 3.01: PERI formwork system



Beams of glued wood have a number of advantages over their metal equivalent such as:

- The possibility of using them either for roof or wall formwork.
- The total absence of staples, clips, fastenings, etc., that is to say small parts that can easily get out of line on the site, which are necessary for fixing the formwork lining to the metal beam in the case of walls.
- The lightness of prefabricated formwork panels of up to 20 m^2, which can be moved on the site with normal tower cranes of 600 kp capacity at the end of the boom.
- Lightness of the beam as compared with metal beams so that one man can handle it (they weigh 6-8 kg per linear meter).
- The great durability reaching 180-200 uses for normally handled beams with the absence of maintenance costs which are expensive in the case of metal beams.
- Savings in labour costs of the order of 30 per cent.
- Savings in investment per m^2 of complete formwork as compared with metal formwork.
- Elimination of specialized labour for metal formwork of a type that is difficult to find, requiring a blend of carpentry and metal working skills, thus encouraging traditional wooden formwork, the material of which is best suited for good casting of the concrete and for giving it an adequately rough surface, but constituting modernized and more developed formwork.

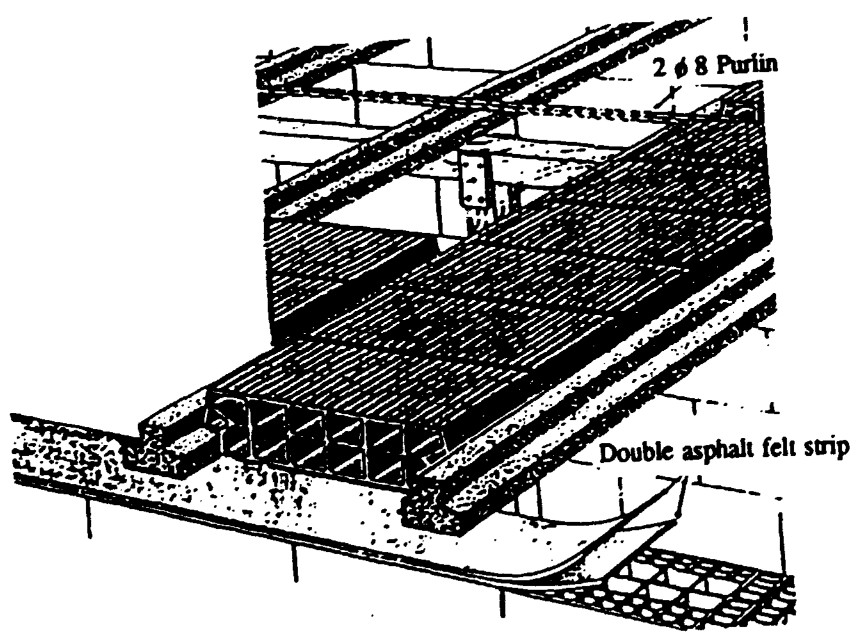
3.4.3 Other types of formwork

Various types of formwork using different materials have been used in Argentina, especially flat metal types semi-tunnel and tunnel types, with which large multi-floor buildings and blocks of apartments have been constructed. In these cases both the structure proper and the formwork surfaces are of metal. The structure consists of steel or bent sheet beams while the contact surface consists of steel sheets 3 mm to 6 mm thick which can be used between 500 and 1,000 times. Also, climbing forms and sliding forms are used and aluminium formwork is also been employed.

3.4.4 Construction systems that eliminate formwork

Just as in Mexico and Ecuador, the system of prefabricated ceiling structures with light concrete slabs, consisting of reinforced concrete beams and ceramic blocks is being increasingly used. This type of construction system significantly eliminates the use of wood for formwork, wood being needed only for posts or uprights and beams that are not in contact with concrete. Thus, only some boards are needed for the braces or beams on the perimeter.

FIGURE 3.02: System of pre-stressed beams



The system uses pre-stressed beams (single or double according to the span to be covered) which support ceramic blocks of 9, 5, 12 and 19 cm, so that it is possible to construct ceilings of 13 to 35 cm thick for spans of up to 7 m with permissible overloading of 200 kg/m^2. This type of ling slab is replacing the lightweight ceilings constructed *in situ* and reinforced concrete roofs.

3.5 CONSUMPTION OF WOOD IN FORMWORK

Table 3.05 presents the analysis of the consumption of wood in 5 multi-floor buildings and a multifamily building obtained from 3 construction enterprises in Buenos Aires, using the traditional system, plywood and the rationalized PERI system.

TABLE 3.05

RATES OF CONSUMPTION OF WOOD

TYPE OF DWELLING	CONSTR. AREA m^2	AREA OF FORMS m^2	VOLUME OF CONCRETE m^3	VOLUME OF WOOD m^3	CONSUMPTION OF WOOD		
					$\frac{m^3 \text{ wood}}{m^3 \text{ concr}}$	$\frac{m^3 \text{ wood}}{m^2 \text{ cons}}$	$\frac{\text{bd ft}}{m^2 \text{ cons}}$
A.T.C. 12 floors [1]	8,027	na	1,816	187.8	0.10	0.023	10
A.T.C. 47 apts [1]	5,764	na	1,377	200.6	0.15	0.035	15
A.T.C. 16 apts [1]	3,260	na	866	137.7	0.16	0.042	18
KOCOUREK 02 floors [2]	4,222	na	717	59.2	0.08	0.014	06
KOCOUREK 3S 23 floors [1]	34,800	80,400	17,300	1,330.9	0.08	0.038	16
P.MIGLIORE 2S. 34 floors [1]	27,400	73,765	9,840	260.0	0.03	0.010	04
AVERAGE, MULTIFAMILY BUILDINGS					0.10	0.030	13

Source : Building enterprises
na : Information not available.
[1] : Concrete portals, masonry walls and massive concrete floor.
[2] : Masonry walls, concrete columns, concrete floor structure and wooden roof.

The consumption of wood in formwork for one-family dwellings is 0.083 m^3 wood/m^3 conc and 0.014 m^3 wood/m^2 construction area (6 bd ft/m^2). Consumption is greater in the case of multistorey buildings and averages 0.10 m^3 wood/m^3 conc and 0.030 m^3 wood/m^2 construction area, that is to say 13 bd ft/m^2 of construction area.

3.6 COST OF FORMWORK

The impact of building labour on unit costs is rather high in Argentina, and can represent about 50 per cent of the cost of the structure.
Table 3.06 presents the costs, the impact of formwork costs on direct project costs for one dwelling and three multifamily buildings.
The average impact of the cost of formwork in multifamily buildings in relation with the total cost of the project averages 9.4 per cent. The average cost of formwork is US$ 56.10/m^2 of construction area. As a reference, the PERI wooden formwork system has a cost of US$ 37.92/m^2 of the structure and has a 5.1 per cent impact on the total cost of the project.

TABLE 3.06

IMPACT OF FORMWORK COST

TYPE OF DWELLING	CONSTR. AREA m^2	COST OF FORMS US$	TOTAL DIRECT COST	IMPACT %	COST OF FORMS m^2 constr.
One-family dwelling 02 floors	211	5,541	155,130	3.57	26.26
Multifamily building 25 floors	34,800	1,545,946	34,640,000	4.46	44.42
Multifamily building 12 floors	8,027	372,632	2,758,000	13.5	46.42
Multifamily building 36 floors	27,400	2,121,261	20,550,000	10.3	77.42
AVERAGE FOR MULTIFAMILY BUILDINGS				9.4	56.10

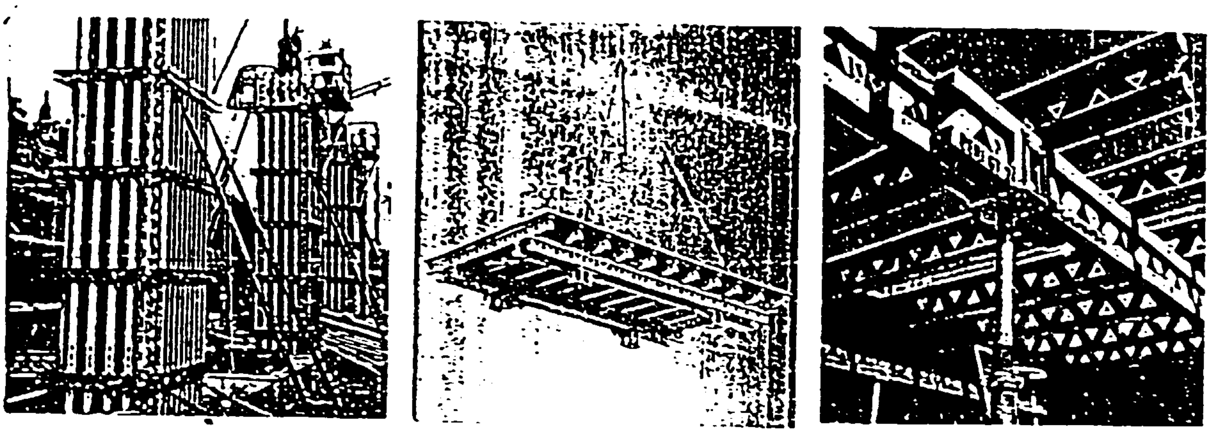
Source: Building enterprise

3.7 COMPARATIVE STUDY OF FORMWORK COSTS

3.7.1 Introduction

A comparative analysis of the costs of two types of wooden formwork utilized in Argentina is presented below, one the traditional type with plywood panels and sawn wood and the other a rationalized wooden system, that is to say the PERI system explained under point 3.4.2 of this report.
The study specially prepared for the present report was elaborated by the company Pablo Migliore Construcciones S.A. in November 1993. Its purpose was to compare a rationalized system using imported wood (the PERI or MILLS system) with the traditional formwork system.
In general, the PERI or MILLS formwork systems rationalize the use of wood by using standard elements such as framework beams which can be reused 200 times, joined by aluminium sections, metal uprights, standardized fasteners and specially designed scaffolding.
By combining these parts, climbing formwork is constructed for the vertical elements, using beams and uprights for the ceilings. The formwork surfaces consist of phenolic plywood panels with special surface treatment guaranteed for 20 uses. The rationalized PERI system, was assumed for the purposes of the study to have an amortization value of 50 per cent, that is to say half for each of the two towers to be constructed.

FIGURE 3.03: Details of the PERI formwork system



3.7.2 Project characteristics

For the purpose of economic evaluation of the two alternatives envisaged, a project consisting of two towers of dwellings, each one with two basements, a ground floor with mezzanine and 34 typical floors, giving a covered area of approximately 55,000 m².

For the purposes of analysis, the figures for one of the twin towers are taken. An exchange rate of 1 Argentine peso = 1 American dollar and the following characteristics were assumed:

PROJECT	Multifamily building (37 floors)
CONSTRUCTION AREA	27,400 m²
CONSTRUCTION SYSTEM	Concrete portals, masonry walls and solid concrete slab.
VOLUME OF CONCRETE	9,840 m³
AREA OF FORMWORK	73,765
REINFORCEMENTS	1,138 t

PERI-MULTIFLEX SYSTEM

A. Execution with rationalized system

1.	Cost of reinforced concrete			
	Concrete H30 Pesos/m³	110,000 x Pesos 9,840/m³	Pesos	1,082,400
2.	Cost of labour			
	h formwork m²	73,465 x 1.30 h/m²	h	95,504
	h reinforcement t	1,138 x 85.00 h/t	h	96,730
	h casting m³	9,840 x 3.00 h/t	h	29,520
		Total hours	h	221,754
	Estimated hourly cost Pesos/m-h 6.85			
	TOTAL COST OF LABOUR		Pesos	1,519,015
3.	Cost of formwork materials			
	Special phenolic m²	4,700 x Pesos 13.50/m²	Pesos	63,450
	Bracing 3 x 3"	lm 2,700 x Pesos 0.92/lm	Pesos	2,484
	Hardware		Pesos	19,000
		Total formwork materials	Pesos	84,934
4.	Cost of rationalized system			
	Total cost installed at Bs.As. Pesos 600,000			
	Amortization 50 per cent		Pesos	300,000
5.	Indirect project costs		Pesos	1,050,000

B. Execution with traditional system

1. Cost of reinforced concrete			
Concrete H30 Pesos/m³	110,000 x 9.840/ m³	Pesos	1,082,400
2. Cost of labour			
h formwork m²	73,465 x 4.00 h/m²	h	293,860
h reinforcement t	1,138 x 85.00 h/t	h	96.730
h casting m³	9,840 x 3.00 h/t	h	29,520
	Total hours	h	420,110
Estimated hourly cost Pesos/m-h 6.85			
TOTAL COST OF LABOUR	Pesos 2,877,753		
3. Cost of formwork materials			
Ordinary phenolic m²	7,000 x Pesos 10.00/m²	Pesos	70,000
Bracing	21,000 lm x Pesos 0.92/lm	Pesos	19,320
Hardware		Pesos	19,000
	Total formwork materials	Pesos	108,320
4. Indirect project costs		Pesos	1,050,000

The following table shows the comparison of costs:

TABLE 3.07

COMPARATIVE COSTS OF FORMWORK

DESCRIPTION	PERI FORMWORK US$	TRADITIONAL FORMWORK US$
Cost of reinforced concrete	1,082,400	1,082,400
Cost of labour	1,519,015	2,877,753
Cost of material/formwork	84,934	108,320
Cost of imported formwork	300,000	--------
Indirect work costs	1,050,000	1,050,000
TOTAL COSTS	4,036,349	5,118,473
COST/ m³ CONCRETE	410.20	520.17

Source: Pablo Migliore Construcciones S.A.

As can be seen, the values obtained make it possible to identify the advantages of the PERI type rationalized system and show that owing to the improvement of labour output alone, savings are achieved that make it possible to amortize in two towers the import of formwork equipment of this type. That is particularly practical in a country like Argentina, where the cost of building labour is rather high.
Two comparative figures of labour output are:
- Rationalized system 221,754 m-h/9,838 m³ conc = 22.50 m-h/m³ conc
- Traditional system 420,110 m-h/9,838 m³ conc = 42.70 m-h/m³ conc
The standard output in Argentina is considered to lie between 40-45 man-hours per m³ of concrete.

3.8 CONCLUSIONS AND RECOMMENDATIONS

In general, the situation in Argentina with regard to the use of wood and wood-based products in formwork can be considered as optimal, owing to a reasonable use of the resource, which is due partly to the fact that it comes from reafforestation, and the necessity for builders to systematize its use owing to the high cost of labour. This circumstance compels building enterprises to attach appropriate importance to wooden formwork, rationalizing its use and raising the technical level of the systems employed, with the aim of controlling the impact of these elements on the direct costs of projects.
Similarly, the revival that can be noticed at present in the construction industry, after more than 15 years of stagnation, make possible better programming and distribution of fixed costs, and has even made it possible for

some years to import modern and more efficient formwork systems in which better use is made of wood in combination with other building materials.

As an illustration of the level of development of the use of wood in formwork, there are about 21 factories producing formwork, principally in the province of Buenos Aires (including Gran Buenos Aires and the Capital) as well as in Chubut and Rio Negro. Similarly, there are about 35 enterprises for the distribution of formwork, both for hire and sale, in the Provinces of Buenos Aires, Córdova, Choco and Misiones. In general, there is great specialized activity in the field of formwork.

However, some aspects have been identified that could be improved by the implementation of specific short and medium-term action.

With regard to the production of raw material, the type of wood most used is *Pinus saligne* (three to four uses) and parana pine (*Pinus elliotis*) which is used more often as the quality of finish improves, especially in fair-faced concrete. However, untreated wood is used, in the green state and without planing (except for fair-faced concrete), which increases warping and losses. Nor is their much standardization of dimensions, especially regarding length and widths. In general, there is no intermediate processing between the sawmill and the actual project.

From the point of view of training of manpower, there has always been a tradition of good quality among workmen in Argentina owing to European immigration, specially from Poland. However, the paralysis suffered by the construction industry for more than 15 years until its recovery from 1992 affected continuity in enterprises, which prevented professionalization of workers. As an illustration, 700,000 operatives were registered in 1978 but 60,000 in 1985, while the number has now risen to 400,000.

This situation affects enterprises, which were not able to maintain their staffs, losing skilled workers. The construction enterprises subcontract all the work and therefore do not concern themselves with the training of staff since what they are offered is good labour output and fulfilment of deadlines for the work. The two principal concerns with regard to output are formwork and the bending of reinforcement rods.

The average output for wooden formwork is 3.7 - 4.4 m-h/m^2 of roofing for which reason modern formwork is gaining ground in construction by producing output of 0.8 - 1.2 m-h/m^2 of roofed-over area. This aspect is extremely important because building wages have risen from US$ 50/month to US$ 1,200/month, so that the actual cost of formwork is not due to the cost of the wood but to the cost of labour.

with regard to standardization, there are no technical specifications or standards for the use of wood in formwork although this does not seem to be a problem with regard to quality. The Secretariat for Housing and environmental Regulations of the Ministry of Health and Social Welfare grants technical aptitude certificates valid for 1 -3 years and renewable, for constructional systems.

With regard to the utilization or use of appropriate technology, wooden formwork is still the predominant material in the construction of 80 - 90 per cent of cases. The sectors that make most use of formwork constructed of sawn wood or coated plywood are the medium-sized sectors in multifamily buildings. In one-family dwellings they are used very little. Low-cost or self-help housing uses prefabricated floors, with masonry support structures and pre-stressed beams, which hardly ever use formwork.

The wooden formwork systems have practically not changed over the last 15-20 years. It is now the intention to design work with the use of more massive concrete slabs and few recessed beams, in order to reduce the costs of formwork, which represents between 3 and 14 per cent of the cost of the work.

Metal formwork is justified only in large projects because it saves labour and working time although the initial investment is very high. Contractors consider that plywood competes with metal sheet owing to its lighter weight, the fact that surfaces of the same aspect are obtained, the fact that less air pockets are present, the ease of positioning and the greater thermal protection of the concrete.

Plywood panels are considered more sophisticated and costly than sawn wood and are used efficiently in fair-faced surfaces and in "underpinning" (retaining walls). Sawn wood or board is considered a more flexible module than phenolic plywood because it can be better adapted to the modular coordination used in house construction.

Owing to the cost of manpower a low level of maintenance of wooden formwork is noted, since, because wood is relatively cheaper than labour, no care is taken nor is it cleaned for recycling, being used on the average three times. Neither are appropriate oils or release agents used, except in the case of fair-faced concrete. Likewise it is considered that metal accessories are little developed in Argentina, which makes it more difficult to develop more efficient formwork systems.

Finally, from the point of view of the market, it was found that there are a large number of enterprises manufacturing and distributing formwork, and that the import of formwork of European and American origin is becoming increasingly common. Finally, and in the framework of MERCOSUR, phenolic plywood is being

imported from Brazil and also from Chile, a trend which should increase in the future. Complete prefabricated formwork systems have been imported from the company Industrias MADEIRIT S.A. of Sao Paulo, Brazil.
On the basis of the situation in the use of wood in formwork, the following specific actions are proposed:

(a) Production of raw material

- To identify new forest species that do not appreciably warp, are chemically inert to the action of concrete, do not stick strongly to concrete and resist abrasion during casting.
- To stimulate increased quality control during the processing of the raw material to guarantee greater durability and thus recycling of wood.
- To increase value added of wood during the marketing process, offering for example formwork that has already been impregnated with a release agent to increase the number of uses and durability of the wood.

(b) Standardization

- To ensure the elaboration of technical specifications of standards for wooden formwork to which technical suitability certificates have been awarded, such as those that are granted for new construction systems by the Secretariat of Housing and Environmental Regulations of the Ministry of Health and Social Welfare.
- To promote the creation of groups of species of wood for formwork that would be offered in the market in different qualities and with different value-added components which would permit various options regarding finish and durability at prices corresponding to the quality of the product.

(c) Training

- To prepare technical and audio-visual material on wooden formwork that compile the good practice of skilled manpower, intended for technical staff, university students and building professionals. A kind of "Technical Manual for Wooden Formwork in Construction" could be developed.
- To resume the training of operatives and foremen, making use of the experience of skilled manpower of national and foreign origin. This training should be transferred to training centres in other countries of the region.

(d) Technology

- To increase the industrial production of traditional wooden formwork, improving its present artisanal characteristics. It is possible to promote the prefabrication of boards measuring 50 x 50 or 60 x 60 cm, using cut wooden panels which can be reutilized many times.
- To promote better use of simple or phenolic plywood in formwork surfaces, combining them with metal support structure of great durability and ease of manipulation.
- To improve the quality of release agents for wood by agreement between producers and consumers of wooden formwork, with manufacturers of this type of chemical for construction work.

(e) Market

- To lay the basis for harmonizing the characteristics and quality standards for wood, plywood and formwork itself, with the aim of stimulating more intensive trade between Brazil, Paraguay, Uruguay and Argentina, making use of the integration advantages offered by MERCOSUR.
- To disseminate the manufacture, hiring or sale of modular elements and components for formwork for columns and beams that would make possible mass production and adaptation to different types of modular coordination in buildings.

4.0 DIAGNOSIS OF CHILE

4.1 THE HOUSING SECTOR

In 1992, Chile had a population of 13,417,900; according to the preliminary results of the Vth housing census carried out in April 1992, the housing stock was 3,260,674 dwellings, 99.6 per cent of which were private dwellings and the rest had been constructed under communal housing schemes. Between the 1982 and 1992 censuses, more than 700,000 dwellings were built, which supposes 77 per cent growth, taking into account various types of dwellings.

The housing deficit varies according to the various sources consulted between 450,000 and 1,000,000 dwelling units; according to the Ministry of Housing and Urban Development (MINVU), it is about 700,000 units. The assessment of this deficit is based on requests or demands for various types of housing on the part of savers who lack housing. Given the annual rate of building, it is envisaged that the housing deficit will be eliminated by the year 2002.

These results are the consequence of the implementation over almost 15 years of a housing programme which offers various systems of access to housing, largely financed by the private sector. Accordingly, policies have been implemented that continue to stimulate personal and family savings for the construction or purchase of housing, at the same time encouraging investors to channel resources to the sector and guaranteeing the saver or investor the recovery of his investment with appropriate profitability in real terms.

Investors use various financial instruments for saving and investment, the instrument most commonly used in Chile being "mortgage bonds", which are bought on the free market owing to their return and are backed up by mortgages on the real property.

Public resources are voted in the annual national budget and are channelled by the Ministry of Housing and Urban Development towards financing direct subsidies for the sectors that require some type of assistance in acquiring housing. These subsidies, which are granted only once, are progressive, that is to say that families with less relative resources receive a larger amount and, within the total distribution, public resources benefit the relatively most needy strata.

Between 1973 and 1992 investment in housing grew by 108 per cent in real terms, and that target was reached with a public investment that was 41 per cent lower than that required in 1973, whereas private investment increased more than five-fold in the period. The number of houses on the basis of building permits rose from an average level of 36,000 units per year to more than 100,000 in 1992.

Table 4.01 shows the development of house-building in the formal sector. The alternatives or programmes in the housing access system are six in number:

- Progressive dwellings
- Basic dwellings
- Rural subsidies
- Special programmes for workers
- Standardized subsidy and
- The market system.

The monthly net income of applicants varies from less than US$ 50 to more than US$ 2,100 and the dwellings that can be acquired vary from 31 m^2 to 120 m^2 in area. The price of the dwelling fluctuates between US$ 4,400 for the smallest to US$ 73,200 for the largest. For the year 1993, the construction of approximately 100,000 dwelling units is projected.

TABLE 4.01

RESIDENTIAL CONSTRUCTION 1973 - 1992

YEAR	HOUSING AUTHORIZED		
	No.	'000 m^2	m^2/dwelling
1973	37,863	2,341	61.83
1974	23,756	1,873	78.84
1975	18,575	1,439	77.47
1976	37,394	2,217	59.29
1977	25,043	1,709	68.24
1978	23,226	1,645	70.83
1979	37,615	2,413	64.15
1980	46,284	3,214	69.44
1981	54,550	3,929	72.03
1982	27,336	1,501	54.91
1983	37,724	2,023	53.63
1984	46,769	2,396	51.23
1985	59,174	2,983	50.41
1986	52,082	2,897	55.62
1987	60,316	3,554	58.92
1988	77,501	4,014	51.79
1989	83,891	4,827	57.54
1990	78,904	4,495	56.97
1991	88,481	5,213	58.92
1992 [1]	105,669	6,877	65.08

Source : National Statistics Institute

[1] Provisional estimate

Table 4.02 shows the breakdown of the housing programmes from 1989 to 1993 by type of dwelling.

TABLE 4.02

COMPOSITION OF RESIDENTIAL CONSTRUCTION

	NUMBER OF DWELLINGS				
TYPE OF DWELLING	1989	1990	1991	1992 [1]	1993 [2]
- Progressive	5,406	2,185	2,483	8,169	14,000
- Basic	15,537	18,895	25,322	25,862	26,000
- Spec. wrkrs' programme					
- Rural subsidy	16,379	15,640	16,252	16,218	16,000
- Unit urban subsidy	8,088	6,307	4,912	8,485	7,000
- Market princ. dwellings					
	22,551	21,970	19,519	19,734	26,000
	15,930	13,906	19,993	27,201	11,000
TOTALS	83,891	78,904	88,481	105,669	100,000

[1] Provisional INE Estimate

[2] Projection by Chilean Chamber of Construction

Under the housing subsidy system, 330,000 subsidies were granted between 1978 and 1991 (240,000 were paid); in that context, 75 per cent of the public contribution favoured families with incomes lower than US$ 200.

The number of housing savings accounts, which were a requirement for application to subsidies up to 1992, exceeded 700,000 and the accumulated savings were almost US$ 300 million. In 1993, the number of operations with mortgage bonds was calculated at 40,000, which signified loans of about US$ 425 million. This great impetus to building activity was intensified with the implementation of a housing leasing scheme, a mechanism of rental and purchase of housing that has enormous potential.

4.2 THE CONSTRUCTION SECTOR

From 1985 to 1992, the gross domestic product of Chile grew at an average rate of 7 per cent per year, representing a cumulative increase of more than 60 per cent over the period, exceeding the per capita threshold of US 3,000 in 1992.
Over the same period the value added in building registered a real annual average increase of 9.3 per cent, with cumulative growth of 86.5 per cent so that its contribution to the GDP rose from 4.9 per cent in 1985 to 5.4 per cent in 1992. Investment in housing recorded in 1992 was equivalent to 2.66 times that recorded in 1985 and investment in non-residential building rose by a factor of 2.76. However, investment in civil engineering grew by only 20.8 per cent over 1985.
The target of 100,000 dwellings authorized was exceeded in the housing subsector in 1982, and 105,669 units were approved, not including sanitation improvement, a figure that represents growth of almost 80 per cent over the 1985 level. For the year 1993, approximately 100,000 dwelling units are projected, and at that rate it is expected that the housing deficit will be under control by the end of the present decade.
During 1992, 9,454,052 m^2 were built, 72.7 per cent of which represented dwelling units (average 65.08 m^2 per unit), 22.5 per cent industrial, commercial and financial establishment building and the remaining 4.8 per cent service buildings.
The Vth Housing Census of 1992 did not indicate the predominant building materials in the new housing constructed, but table 4.03, which was prepared with statistical information from the Chilean Chamber of Construction for the period 1987-1989, states the predominant material for flooring, walls and roofing of the new housing constructed.
The "typical" Chilean dwelling unit is constructed with cement floors, masonry walls and corrugated asbestos cement roofing. In the case of roofs no distinction is stated regarding the type of structural material used, although in view of the type of material used it can be deduced that not less than 80 per cent of the houses have wooden roof structures. In the case of walls, wooden structures, that is to say houses made completely of wood, represent approximately 20 per cent of total new dwelling units.

TABLE 4.03

PREDOMINANT CONSTRUCTION MATERIALS 1987-1989

	1987	%	1988	%	1989	%
TOTAL HOUSING CONSTRUCTION	60,316	100	77,501	100	83,891	100
Floors: cement finish	39,369	65.3	53,652	69.2	50,330	60.0
Walls: masonry, brick	35,484	58.8	44,652	57.6	36,227	43.2
Roofing: corrugated asbestos cement	21,989	36.5	34,898	45.0	30,748	36.7

Source: Chilean Chamber of Construction

4.3 THE FORESTRY SECTOR

4.3.1 Introduction

Chile is a well-wooded country which, owing to its characteristics and geographical location, has comparative advantages for the growth of its forests. The country has two forest masses, the first consisting of native

species, almost all broad-leaved trees, with an area of 4,100,00 ha. The second is made up of plantations of *Pinus radiata* and eucalyptus, which together cover more than 1,400,000 ha.
The forestry sector is one of the most dynamic in the country. Its contribution to the national product and the balance of trade is continuously increasing, representing 10 per cent of exports in 1990. The projections of both production and marketing are extremely provisional.

4.3.2 Availability of raw material

The country has two forest masses. The first, consisting of the native forests, has an area of 4 100,000 ha, of which only 800,000 are of commercial interest. The second, consisting of plantations of exotic species, principally *Pinus radiata* (1,243,293 ha and 152.5 million m^3) and eucalyptus (101,700 ha and 20 million m^3). Table 4.04 shows the rate of growth of plantations in the past 13 years. The native forest consists almost exclusively of broad-leaved trees (oak, *coihue*, *ruali*, *tepa*, *lingue*, laurel, elm, others). Only 10 per cent is represented by conifers (larch, *araucaria*, cypress, *mañiu*), all of which are of great commercial value. Plantations of exotic species consist principally of *Pinus radiata*, a conifer originating from California, USA, which was introduced in Chile at the beginning of the century. This species develops more rapidly than in other latitudes, its cycle of rotation being 25 years and its growth having a mean rate of 25 m^3 per year and ha.
It can be appreciated that the volume of exotic plantations is quite constant (81,215 ha on the average) and that other species, specially eucalyptus, are beginning to become more important (in 1991 they represented 29 per cent of the total planted). Eucalyptus is intended principally for the manufacture of short-fibre pulp.

TABLE 4.04

PLANTATIONS, BY SPECIES 1978-1991

Year	Total	*Pinus radiata*	OTHER SPECIES
1978	77,371	65,413	11,958
1979	55,226	48,869	3,357
1980	72,164	60,086	12,078
1981	92,781	88,529	4,252
1982	68,586	61,637	6,949
1983	76,280	63,884	12,396
1984	93,602	76,982	18,620
1985	96,278	80,630	15,648
1986	66,195	55,058	11,137
1987	65,441	55,386	10,055
1988	72,944	61,841	11,103
1989	86,705	65,587	21,118
1990	94,130	61,310	32,820
1991	107,500	68,471	39,039*

* 31,672 represented by eucalyptus.
Source: *Informe sobre la Industria Forestal Chilena* (Report on the Chilean forestry industry) UNDP, UNIDO

The forestry institute carried out a simulated calculation on the future availability of raw material. This is shown in table 4.05, which is based on various options regarding plantations, management and according to three distinct criteria as to supply, up to the year 2019.

TABLE 4.05

AVAILABILITY OF *PINUS RADIATA* TIMBER
BY TYPE OF PRODUCT AND TRIENNIUM
(million m³ per year)

TRIENNIUM	TOTAL	FOR PULPING	FOR SAWING
1990-92	15.1	6.7	8.4
1993-95	17.2	7.9	9.3
1996-98	17.7	8.6	9.1
1999-01	22.2	9.3	12.9
2002-04	23.3	10.0	13.3
2005-07	22.9	9.6	13.3
2008-10	23.1	9.1	14.0
2011-13	23.1	8.8	14.3
2014-16	30.1	10.1	20.0
2017-19	36.9	11.0	25.9

Source: *Informe sobre la Industria Forestal Chilena* (Report on the Chilean forestry industry) UNDP, UNIDO

The analysis according to the various criteria employed confirms the important growth of this resource, which will double as from the year 2015.

4.3.3 The forestry industry

Comparing the sawmill industry with others in the forestry sector (pulp, chips), a relative lack of dynamism can be noted. In 1981 almost the same quantity was exported as seven years later. Only from 1990 can greater production and export be noted.

Of the 1,618 sawmills in Chile in 1990, the 19 largest produced 1,345,741 m³, representing 40 per cent of total production. Table 4.06 shows the output of sawn wood over the period 1981-1990.

TABLE 4.06

PRODUCTION, EMPLOYMENT, EXPORT AND APPARENT CONSUMPTION
OF SAWN WOOD 1981-1990

YEAR	PRODUCTION '000 m³	EMPLOYMENT Persons	EXPORTS '000 m³	APPARENT CONSUMPTION '000 m³
81	1,732	16,400	865	863
82	1,172	12,700	619	551
83	1,606	13,800	755	847
84	2,001	14,200	886	1,099
85	2,190	17,900	706	1,410
86	2,025	16,800	866	1,032
87	2,677	18,100	1,020	1,434
88	2,710	18,900	906	1,489
89	2,680	18,800	890	1,791
90	3,060	21,500	1,052	2,275

Source: Census of the sawmill industry, 1990. Forestry Institute.

In 1988, *Pinus radiata* sawn wood represented 87.8 per cent; that percentage was maintained during the years 1989 and 1990.
Sawn wood, especially for the domestic market, is neither given impregnation treatment nor kiln-dried. In 1988, only 9.5 per cent of all sawn wood was kiln-dried, most of which was exported, and less than 1 per cent was impregnated by appropriate methods, apparently owing to a problem of costs. The principal market for sawn wood is the building sector in general and for house building in particular.
Table 4.07 shows the development of production of panels and boards, during the period 1986-1990.

TABLE 4.07

PRODUCTION, EXPORT AND NATIONAL CONSUMPTION OF PANELS AND BOARDS ('000 t)

YEAR	PRODUCTION	EXPORT	APPARENT CONSUMPTION
1986	164.6	43.4	121.3
1987	179.9	45.9	134.0
1988	187.2	49.4	137.8
1989	217.2	59.2	158.0
1990	272.1	85.2	186.9

Source: Census of the sawmill industry, 1990. Forestry Institute.

4.4 UTILIZATION OF WOOD IN FORMWORK (MOULDS/MOULDING)

In the course of time, the form in which wood has been used in formwork systems has changed from the traditional sections to plywood panels, passing through the intermediate stage of particle board and pressed board. Plywood is most commonly used in panel form to improve the quality of cast surfaces.

4.4.1 Traditional formwork

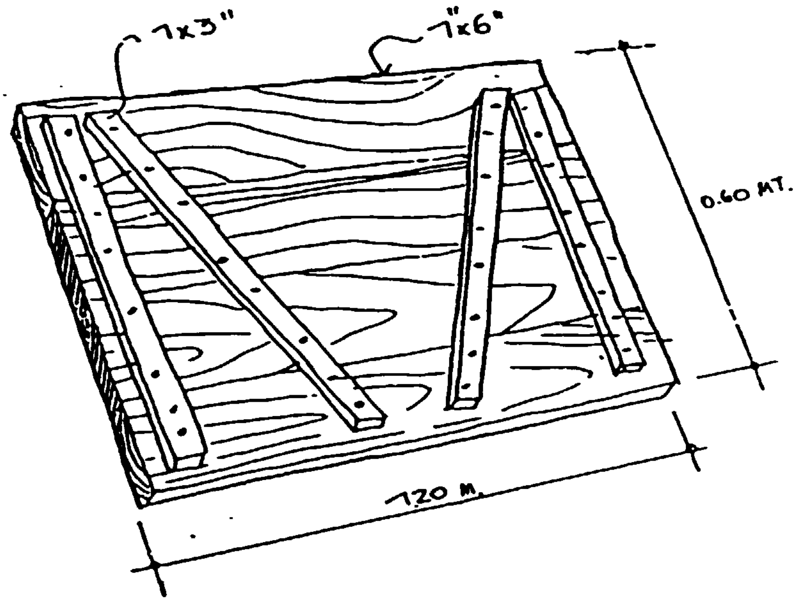
At the present day, traditional formwork is no longer considered for large buildings owing to its low efficiency, both in materials and labour. The output that can be obtained with this system is low in terms of cost and the expenditure of time. In the case of the material (wood), the maximum number of uses that is possible to obtain on the average does not exceed three or four, principally owing to the large losses occurring in striking the formwork. Furthermore, each stage of the process (fabrication, assembly and disassembly) requires intensive use of manpower, which is reflected in higher costs and unsatisfactory utilization of resources.
The resultant quality also has disadvantages, since neither precision in dimensions nor the quality of the cast surfaces match the level of resources that is necessary to employ. Furthermore, the fact that the system is little used is due to the increase in demands on formwork with regard to the system of calculating breakages in structures.
Nevertheless, wooden formwork, owing to its versatility and easy availability is the material most used in one-family houses. It also has great advantages as formwork for elements with "difficult" geometry (especially with curves) which are often part of a concrete structure.

4.4.2 The Donath modular panel system

This is a type of formwork that was introduced in Chile more than 25 years ago and was for a long time the most popular formwork system for large buildings. The history of the Donath panel and the reason for its name go back to the year 1966, when Reuben Donath, an International Labour Organization expert, proposed the system at a Seminar on Efficiency and Productivity in Construction. Since then, many buildings, such as that of ECLAC in Santiago de Chile, have been constructed by using Donath panels.
Donath panels are manufactured with *Pinus radiata* wood and less and less with poplar and measure 0.60 x 1.20 m; they are manufactured to accurate dimensions with two 1 x 6" tongue and groove boards

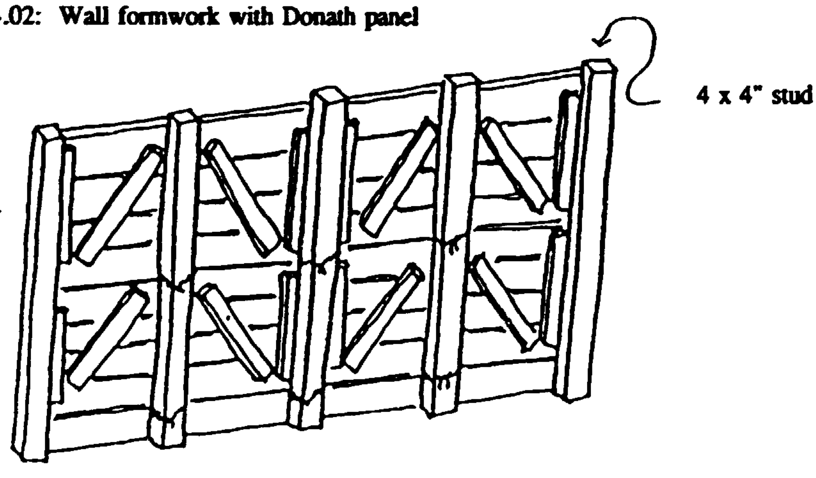
3.20 m in length, equivalent to 1.2 board inches[1]. Cutting up the boards yields four pieces 1.2 m in length; two pieces 80 cm long are left over, which are cut, one to a length of 57 cm and the other to 65 cm. The two parts are again cut lengthwise into two halves, giving the 1 x 3" cross-section battens for the panel.
To sum up, the panel consists of four 1 x 6" boards 1.20 m long and four 1 x 3" battens; two of the latter measure 57 cm and are fixed perpendicular to the board and the other two, measuring 65 cm, are located diagonally. The purpose of fixing the central battens (diagonals) at an angle is to stiffen the panel, avoiding angular distortion of the module and furthermore facilitating the process of striking.

FIGURE 4.01: Sketch of the Donath panel



In the case of formwork for walls, the panels are fixed by means of 2 x 4" or 4 x 4" studs that are located in the free spaces left between the diagonal and perpendicular battens. To avoid piercing the panels, the system is fixed by means of flattened wires braced with diagonals resting on horizontal beams.

FIGURE 4.02: Wall formwork with Donath panel



The system for use of the panels for casting slabs is similar to that for other formwork methods. The panels rest on beams consisting of a 1 x 4" board lying flat and a 2 x 4" board placed end on. These beams are distributed along the length of the slab and are spaced 1.2 m apart.

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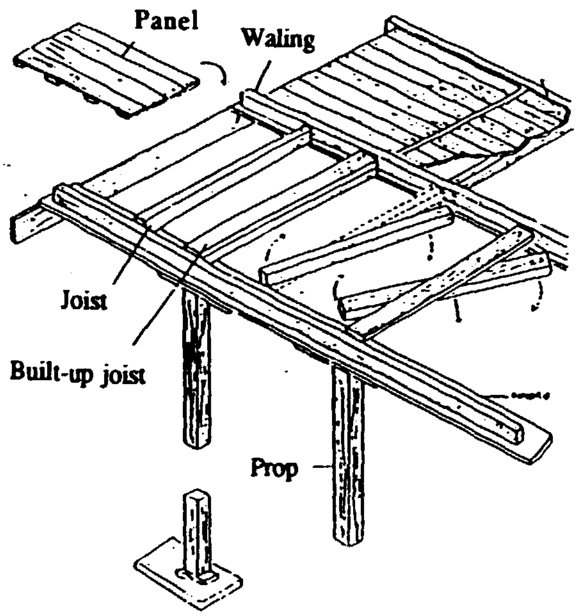
1 The board inch is a unit of volume of 1" thickness x 10 inch width and 3.2 m length in pine or 3.6 m in native wood.

On the beams, and perpendicular to these, are located the 2 x 3" or 2 x 4" joists or *fosforos*, which are spaced 60 cm apart so that they coincide with the spaces defined by the diagonal and perpendicular battens. A joist is located edge on between the diagonal battens and a built-up joist consisting of two joists placed horizontally runs between the perpendicular battens. These elements facilitate striking and make it possible to recover the Donath panels every three or four days without the necessity to remove the beams or studs which remain for up to 21 days or more.

The advantages of the Donath formwork system are as follows:

- Facility of transport, handling and storage owing to their module and weight;
- Flexibility for adaptation to various architectural modular systems;
- The structure of the board has greater strength than boarding;
- Greater economies and better productivity owing to the prefabrication system and the number of uses (10 uses at a conservative estimate);
- Maximum utilization of the commercial dimensions of wood;
- Reduction of time for execution of the work and clean working;
- Ample free spaces that do not alter internal circulation;
- Facility of striking owing to the characteristics of the system and the size of the module which has a small contact surface.

FIGURE 4.03: Formwork for a slab with Donath panel



4.4.3 Prefabricated wooden modular formwork

This could be a more sophisticated version of the Donath panel system that uses similar techniques although in combination with metal elements. Merely by including modulation and prefabrication in wooden formwork, it is possible to achieve a substantial improvement of results, both with regard to output and the quality of the product.

On the one hand prefabrication makes it possible to obtain a greater output from materials in the fabrication process; the use of a modular system makes it possible to increase the number of uses of the various elements. On the other hand, fabrication labour output increases substantially with prefabrication and the same is true of labour for assembly on the site and for striking of the elements.

The system that is analysed consists basically of wooden boards of standard dimensions that are set vertically or horizontally, as the case may be, by means of extensible metal stanchions. The boards are fastened together, both in walls and in columns, by means of metal parts for tightening wall ties, etc.

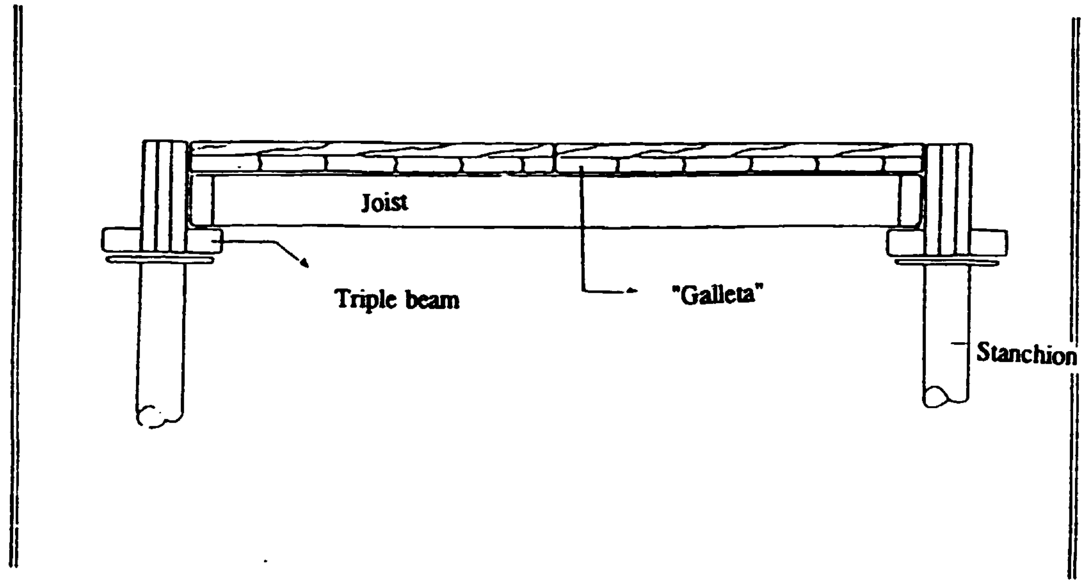
4.4.3.1 Formwork for slabs

This consists of a support structure consisting of triple beams held up by extensible metal stanchions. The joists are located at right angles to the beams and the contact surface, consisting of a double layer of tongue and groove wood boards (*galletas*), rests on them.

To assemble the system, the triple beams are first positioned, their ends resting on load-bearing wooden members located lengthwise along the line of the formwork for the concrete beam; then the support structure is positioned with the studs, and finally the joists and the tongue and groove board are placed in position.

For striking, the joists and then the tongue and groove board are first removed. The studs and the beams can, if desired, remain in place for the period that is necessary for support of the slab.

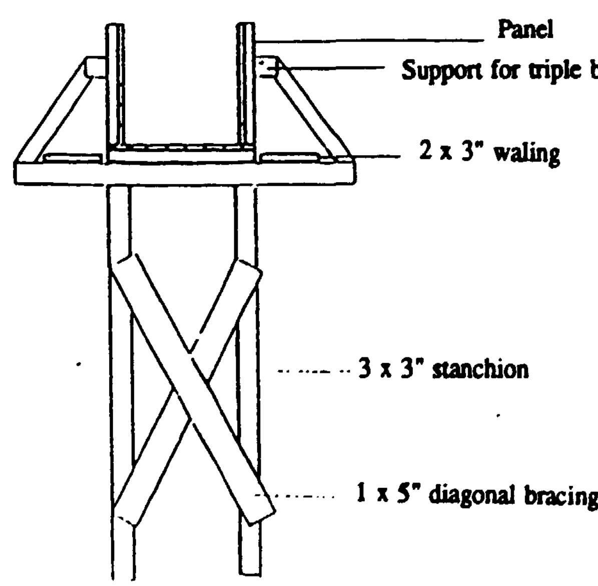
FIGURE 4.04: Sketch of formwork for slabs



4.4.3.2 Formwork for beams

The contact surface consists of panels with a frame of 2 x 3" parts and 1 x 4" boards. The support system consists basically of two 3 x 3" stanchions and a beam of the same cross-section, as can be seen from the detailed drawing.

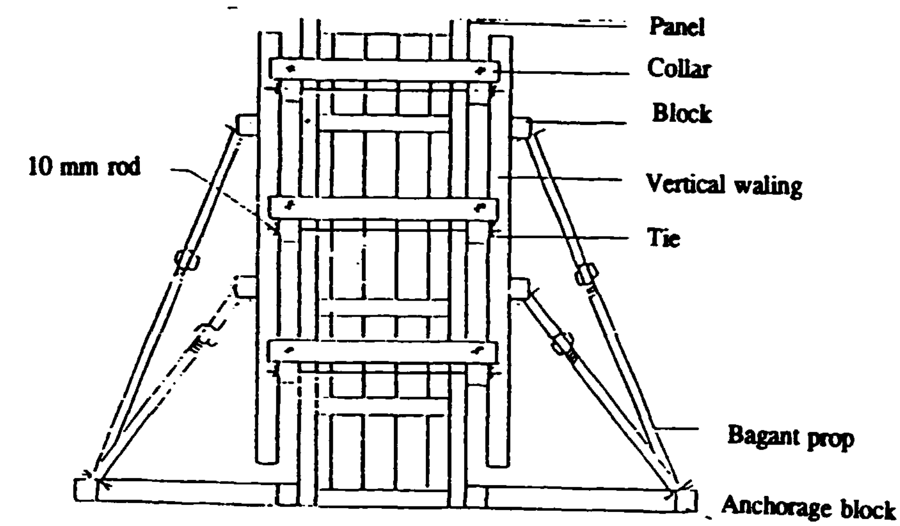
FIGURE 4.05: Sketch of formwork for beams



4.4.3.3 Formwork for columns

This consists of panels similar to those used for beams, which are fixed together by means of collars located at different heights and braced with metal diagonal members. The collars (two per level) consist of two pieces of 3 x 3" wood with holes at the end through which a rod can be passed and can later be tightened up and fixed with metal clamps.

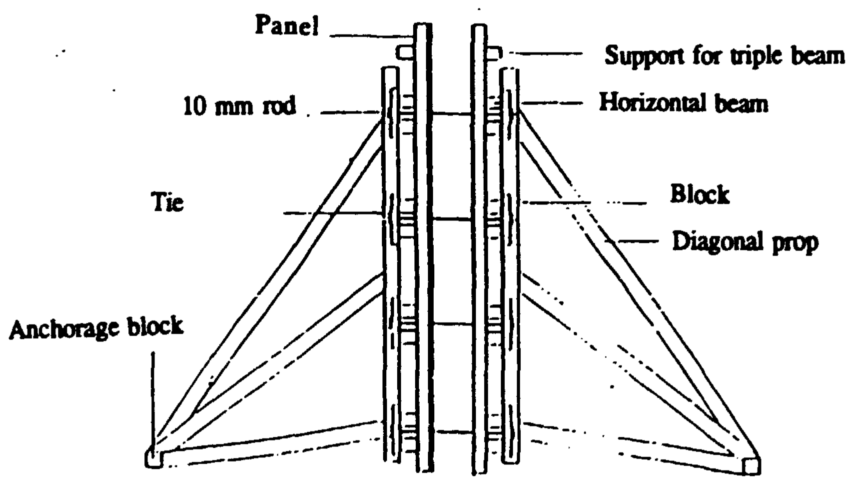
FIGURE 4.06: Sketch of formwork for columns



4.4.3.4 Formwork for walls

The contact surface consists of panels of the same type as those mentioned above, placed vertically and joined by mean of nails. To obtain longitudinal rigidity, four built-up beams are located at different heights, each consisting of two 2 x 3" pieces separated by blocks of the same cross-section. The triple beams rest on these blocks. The rigidity of the two surfaces that make up the formwork for the wall is achieved by means of metal bolts, with metal diagonal bracing.

FIGURE 4.07: Sketch of formwork for walls



4.4.3.5 Mixed formwork systems

These normally consist of a metal framework with a plywood panels, whose contact surface is coated with plastic in order to increase its useful life. The fastening systems are similar to those used for metal panels. Steel-and-wood formwork systems are of the type that was analysed under Section 3.4.2 in this report on Argentina, that is to say, the German PERI system which is characterized by the use of wooden open web or solid web beams. These beams are manufactured with a finger joint system which gives them great load-bearing capacity, in contrast to their own moderate weight.

However, in aluminium-and-wood formwork, plywood panels are also used although the utilization of planed wood is also possible. The other elements are of aluminium, which reduces weight and facilitates handling. They are considered as being more expensive and vulnerable in use than steel formwork elements.

4.5 CONSUMPTION OF WOOD IN FORMWORK

Below we present one example of a one-family dwelling and six examples of buildings constructed by three building enterprises in Santiago de Chile and Puerto Montt, most of them using the Donath type panels described above.

TABLE 4.08

CONSUMPTION RATES: SAWN WOOD

TYPES OF HOUSING	CONST. AREA m^2	FORM-WORK AREA m^2	VOL. OF CON-CRETE m^3	VOL. OF WOOD m^3	CONSUMPTION OF WOOD		
					$\frac{m^3\ wood}{m^3\ conc}$	$\frac{m^3\ wood}{m^2\ constr}$	$\frac{bd\ ft}{m^2\ constr}$
INGETASCO Ltda. 2 floors [1]	2,290	6,700	730	124.6	0.17	0.054	23
INGETASCO Ltda. 1 basement 10 floors [2]	5,500	13,800	1,730	257.5	0.15	0.047	20
INGETASCO Ltda. 1 basement 6 floors [2]	1,722	5,316	663	98.0	0.15	0.057	24
C. Cerro Moreno Ltda. [3] 1 floor	45	na	1.5	0.26	0.17	0.006	2.4
C. Cerro Moreno Ltda. [2] 6 floors	1,833	6,239	630.1	93.1	0.15	0.051	22
C. Cerro Moreno Ltda.[2] 9 floors	6,594	14,834	2,259	319.1	0.14	0.048	21
Constructora AIRES 4 floors [2]	7,200	20,000	2,500	373.2	0.15	0.052	22
AVERAGE MULTIFAMILY HOUSES					0.15	0.052	22

Source : Building enterprises

na : Information not available
[1] : Reinforced masonry and solid concrete slabs
[2] : Reinforced concrete
[3] : Reinforced masonry and wooden roof

The six buildings analysed were constructed by using sawn wood Donath panels for formwork. The average consumption was: 0.15 m^3 wood/m^3 concrete or 0.052 m^3 wood/m^2 construction area = 22 bd ft/m^2 construction area. Details are given below of the consumption of wood in formwork for three other multifamily buildings and a one-family dwelling which used plywood panels as formwork, with metal frames.

TABLE 4.09

CONSUMPTION RATES: PLYWOOD PANELS

TYPE OF STRUCTURE AND NUMBER OF FLOORS	CONST. AREA m^2	VOLUME OF CONCRETE m^3	VOLUME OF WOOD m^3	CONSUMPTION OF WOOD		
				$\frac{m^3 \text{ wood}}{m^3 \text{ concr.}}$	$\frac{m^3 \text{ wood}}{m^2 \text{ const.}}$	$\frac{\text{bd ft} \quad m^2}{\text{const.}}$
Building (10 floors)	4,340	1,709	99.9	0.058	0.023	9.8
Building (7 floors)	3,025	1,114	64.6	0.058	0.021	9.1
Building (10 floors)	4,940	1,780	115.2	0.065	0.023	9.9
House (2 floors)	70.38	17.97	1.09	0.061	0.016	6.6
AVERAGE FOR MULTIFAMILY HOUSING				0.60	0.022	9.6

Source: Building enterprises

In this case it can be observed that less wood is consumed owing to the larger number of uses of plywood and the presence of metal frames.

The average consumption was:

$$0.060 \ \frac{m^3 \text{ wood}}{m^3 \text{ concr}} \quad \text{or} \quad 0.022 \ \frac{m^3 \text{ wood}}{m^2 \text{ constr}} \quad = \quad 9.6 \ \frac{\text{bd ft}}{m^2 \text{ const}}$$

4.6 COST OF FORMWORK

Table 4.10 presents an analysis of the cost of formwork in five buildings and its impact on the total cost of the structures.

Of the buildings analysed, the impact of formwork is 8.3 per cent of the total direct cost of the structure and the average cost is US$ 19.38/m^2 of construction. As a comparison, the cost of renting metal formwork for a building of 18 floors in Santiago de Chile represented 7.3 per cent of the value of the structure, without considering the cost of labour. The cost of metal formwork was US$ 18.18/m^2 of roofed-over area without including the cost of labour.

TABLE 4.10

IMPACT OF FORMWORK COSTS

	CONST. AREA	FORMWORK COST US$	TOTAL DIRECT COST US$	IMPACT %	US$ / m^2 constr
Building 2 floors	2,290	41,250	563,750	7.3	18.01
Building 11 floors	5,500	50,000	592,500	8.4	9.09
Building 7 floors	1,722	34,500	665,000	5.2	20.03
Building 6 floors	1,833	49,844	490,413	10.1	27.20
Building 10 floors	6,594	148,858	1,430,623	10.4	22.58
AVERAGE				8.3	19.38

Source: Building enterprises

4.6.1 Analysis of costs between a prefabricated modular system and an EFCO prefabricated metal formwork system.

The costs of these two types of formwork are compared for a slab of 6.6 m span and 6.0 m length, analysing separately the costs of formwork for a slab, beam, columns and walls. The costs are expressed in terms of US$/$m^2$/use. The following aspects were taken into account in analysing the costs of the formwork:

(a) *Analysis in the light of structural factors*: it was verified that the two systems satisfactorily met the structural design requirements for the building.

(b) *Programming the utilization of formwork*: both systems are manual, so that they require similar equipment for assembly. The difference between them is in the use of labour, in which respect the wooden system is more labour-intensive.

(c) *Analysis of costs*: prefabricated wooden modular formwork is cheaper, making it possible to obtain a good price per m^2 and appropriate reutilization (eight uses for slabs and six uses for beams, columns and walls). The sole exception is formwork for columns, in which case the EFCO solution is in fact optimal, although the possibility of combining both systems is not discarded.

Table 4.11 shows the comparative costs.

Except in the case of formwork for columns, wooden formwork is more economical. Even considering the option of buying metal formwork, the latter would be slightly higher in costs than wooden formwork.

TABLE 4.11

COST COMPARISON BETWEEN WOODEN AND METAL FORMWORK

STRUCTURAL ELEMENT	PREFABRICATED MODULAR, WOOD		EFCO: INDUSTRIALLY PRODUCED [1]	
	Efficiency: h/m²	Unit price US$/m²/uses	Efficiency: h/m²	Unit price US$/m²/uses
Slab	5.29	8.18	3.00	13.07
Beam	4.62	9.33	3.00	15.47
Column	4.78	10.08	1.50	5.88
Wall	4.40	8.85	2.80	9.01

1 Considering rental of the equipment as an alternative.

Source: University of Santiago de Chile. *Sistemas de Moldaje para Hormigón Armado* (Formwork systems for reinforced concrete)

4.7 CONCLUSIONS AND RECOMMENDATIONS

As in the other countries studied, wood is still the predominant material for formwork in construction especially in one-family dwellings and medium-sized structures. There are two reasons for which no other type of formwork is yet being used on a large scale: the first is related to the lower cost of traditional wooden formwork, though the cost of wood and labour has risen. The second reason is the greater initial investment for metal formwork, which makes amortization over time more difficult, with the risk of unproductive investments that can unnecessarily increase the operational costs of a building enterprise.

Donath panels have been used for more than 25 years and only recently have they become less common in view of the emergence of melamine-coated plywood and particle board, especially water-resistant types that guarantee not less than eight uses as against the three-to-four uses for traditional Alamo or *Pinus radiata* formwork. *Pinus radiata* accounts for 90 per cent of consumption. Finally, in the south of the country, logs obtained by forest thinning are being used 10-12 times as studs.

The high rate of construction achieved in recent years (approximately 100,000 houses in 1992 and the same amount projected for 1993) has not necessarily increased the consumption of wood for formwork, since large structures use industrially produced formwork or structural systems that do not require formwork (prestressed concrete beams and hollow bricks) except in the foundations and tie-beams of the walls. Wooden trusses are used in a large percentage of houses and in many cases are manufactured with the same boards as are used for concrete formwork. The use of wooden trusses is also common on concrete slabs in order to guarantee the waterproofing of the roof.

As was mentioned before, industrially produced formwork is used relatively little, although it is already being imported from the United States, Brazil and Spain. In the construction market, there are about 15-20 enterprises that supply metal or aluminium formwork, and there are apparently no enterprises that hire out wooden formwork, for which reason wood is bought for each new house, thus reducing the possibilities for recycling the material.

Though the level of consumption of wood and wood-based products in formwork can be considered as optimal in comparison with other countries, some aspects have been identified that could be improved.

From the point of view of *production of the raw material*, the extensive plantations of *Pinus radiata*, which is the species most used in formwork, make this wood a relatively cheap material so that no care or little care is taken of it. As in Argentina and Ecuador, waste from formwork is very commonly used to heat the workers' meals in meal breaks, so that there is not much interest in devoting much attention to the recycling of wood.

With regard to *standardization*, there are no quality standards for the classification of wood and, though no criticisms have been observed with regard to the quality of wood, it is expected that it might be better to standardize or specify a number of quality grades for wood offered on the market. Perhaps the relatively low cost of wood counterbalances demands for a better product.

In terms of *training*, there are no specialized training programmes for site carpenters in the area of formwork, although various efforts are being made to improve the technical qualification of site staff. The Corporation for

Training in construction, which is an integral part of the company network of the Chilean Construction Chamber, gives structured courses for the training of carpenters as assistants, master craftsmen and foremen, some of which are related to the use of wood in formwork.

Similarly, the University of Chile has for 12 years been offering elementary distance learning courses on building which have been followed by more than 3,000 students. This effort is supplemented with regular night-school courses which have been in operation since 1938 and are intended for construction workers at various levels.

Another important effort is the one carried out by the Chilean Institute for Cement and Concrete, which has programmed for 1994 both seminars and research on concrete formwork, especially for fair-faced concrete. Apparently the low level of use of concrete for facing is due to the low quality of the formwork, although the dark colour of sand and gravel, which affects the colour of the concrete, is also a limiting factor. Apparently, after the depression in construction in the years 1983-1984, the quality of labour substantially decreased, assistants being promoted to the level of master craftsmen without having the necessary qualifications.

From the point of view of the *utilization* of wood in formwork in Chile, there is adequate technology for the appropriate use of the material. In general, there are no problems in the use of wood and each enterprises finds solutions for its formwork needs. There is concern over quality, costs, and productivity in construction and accordingly formwork is a matter of permanent concern.

However, there is large-scale wastage of wood for formwork. Apparently, knowledge of striking technique has been lost and it is here that most wastage of wood occurs. Recently, for two years now, double-headed nails have begun to be used; these are a basic necessity for reducing the loss of material during striking.

Finally, from the point of view of the *market*, there is a favourable economic situation in Chile for improving the use of wood in formwork, since two of the three enterprises that manufacture cement in the country have investments in forests, sawmills, and also in a factory for plywood panels, so that it is possible to establish competitive strategies of mutual interest.

The analysis makes it possible to identify some specific recommendations of a national and regional character described below:

(a) Production of raw material

- To increase the value added component of wood for formwork, establishing quality grades, using kiln drying and offering planed wood and not simply sawn wood. The presently relatively low cost of *Pinus radiata* could make it possible to increase the quality and durability of wood, without substantially affecting the impact of the cost of formwork on the direct costs of the structure.

(b) Standardization

- To work out quality standards, establishing rules for the visual classification of wood according to different grades of finish. It is necessary to expand the present standardization system for sawn wood developed by the National Standards Institute.
- To develop technical specifications for what could be "improved Donath panels", incorporating the modifications and improvements that have been made to this type of formwork in the last 25 years.

(c) Training

- To restructure and introduce modifications in present training courses for carpenters, training them to do quality work at the stage of both rough work and finish. At present, separately qualified staff are used for each of the construction stages.
- To develop descriptive handbooks on the use of wood in formwork, intended for the technical training of both workers and carpenters and for students in civil engineering, architecture and construction.

(d) Technology

- To propose new industrially produced systems for wooden formwork, stimulating better proposals by means of competitions of ideas or support for specialized university theses on the subject. There are many institutions that might be interested in sponsoring this type of activity.
- To develop better techniques for striking wooden formwork, promoting the use of new types of release agents and methods of use that would prolong the useful life of formwork and reduce labour for maintenance or cleaning. The principal cause of wastage of wood is related to striking operations.

(e) Market

- To promote an association of dealers in lumber for formwork purposes that would specialize in a new form of marketing including the hiring of wooden formwork.
- To stimulate the establishment of enterprises that would offer comprehensive formwork services, that is to say, advice, hiring, specialized labour and assembly on a sub-contracting basis for building enterprises on the most advantageous conditions.

(f) Institutional support.

- To implement a Latin American regional programme, with the support of UNDP, among the institutions belonging to the Inter-American Cement Federation - FICAM, since the use of wooden formwork is a subject of mutual interest to lumber dealers and cement and concrete institutions. The programme could be established on the initiative of the Chilean Cement and Concrete Institute and the Chile Foundation.

5.0 DIAGNOSIS OF BRAZIL

5.1 THE HOUSING SECTOR

According to the most recent population census of 1991 published in the Brazilian statistical year book - 1992, the country had a population of 146.9 million, distributed in an irregular manner, with concentrations in the large urban centres of the coast and the South and South-east regions as well as in a number of centres in the interior, in which there has been accentuated growth and development during recent decades. The rate of population growth in the period 1951-1991 dropped from 2.99 per cent to 1.89 per cent, the average size of families being 4.21 persons.
A publication of the Fundacion João Pinheiro entitled *Diagnóstico Nacional de la Industria de la Construcción* (National diagnosis of the construction industry) of 1984, states that estimates of the country's housing deficit and needs for new housing are not easy to elicit. Table 5.01 shows the quantitative deficit in the light of population growth as well as the qualitative deficit in terms of replacement or repair estimated over the period 1986-1990.

TABLE 5.01

ESTIMATED HOUSING NEEDS
1986-1990

YEARS	ESTIMATED DEFICIT ('000 units)		
	POPULATION GROWTH	SUBSTITUTION OR REPLACEMENT	TOTAL
1986	911	318	1,229
1987	947	331	1,278
1988	985	344	1,329
1989	1,024	358	1,382
1990	1,066	372	1,475
TOTAL	4,933	1,722	6,655

Source: Fundación João Pinheiro

The distribution of the housing deficit by regions is as follows:

- South-east (45.2%)
- North-east (26.2%)
- South (14.1%)
- Central West (9.5%)
- North (5.0%)

According to the most recent census, a housing stock of 35,578,857 dwellings was estimated for 1990, of which 76.7 per cent wee located in urban areas and 23.3 per cent in rural zones, as is shown in table 5.02.
As can be seen, approximately 10 per cent of the dwellings were located in apartment buildings and the remaining 90 per cent were one- or two-storey one-family houses, rooms or rural dwellings, most of the latter requiring replacement or improvement.

TABLE 5.02

NUMBER OF DWELLINGS BY LOCATION IN THE COUNTRY

CHARACTERISTICS OF DWELLING	TOTAL	LOCATION OF DWELLING	
		URBAN	RURAL
TOTAL	35,578,857	27,279,586	8,299,271
- HOUSE	29,577,090	22,613,416	6,963,674
- APARTMENT	3,595,699	3,529,203	66,496
- RURAL DWELLING	1,903,659	666,619	1,237,040
- ROOM	502,409	470,348	32,061

Source: Brazilian Institute for Geography and Statistics (IBGE) 1992

5.2 THE CONSTRUCTION SECTOR

5.2.1. Participation of the sector in the GDP

Indisputably, the construction industry plays a prominent part among macro-economic aggregates in Latin America in general and Brazil in particular. In the Brazilian economy, the share of the construction industry fluctuated around 7.4 per cent in the period 1980-1991, although, as is shown in table 5.03, two distinct stages can be noted in recent years, separated by the period 1983-1985 in which the sector's share fell to a low point of 6.0 per cent. A recovery was observed as from 1986, when its share reached its highest level, namely, 9.2 per cent, in 1989.

TABLE 5.03

SHARE OF THE CONSTRUCTION INDUSTRY IN THE COUNTRY'S GDP

YEAR	Const. sector/GDP %	YEAR	Const. sector/GDP %
1980	7.2	1986	7.1
1981	7.7	1987	8.4
1982	7.6	1988	8.0
1983	6.6	1989	9.2
1984	6.2	1990	7.8
1985	6.0	1991	7.1

Source : Brazilian Institute for Geography and Statistics (IBGE) 1992

As an illustration, the construction industry accounted for 6.15 per cent of the country's economically active population in 1990, that is to say 3,823,154 workers, representing one-third of the industrial labour force.
At the moment, three subsectors can be identified in the construction industry: the heavy infrastructure, industrial buildings and the general building subsector. The general building subsector includes among its activities the construction of commercial buildings and above all one-family and multifamily houses. National private capital dominates the general building subsector, and this trend has consolidated during the development of the civilian construction sector in the country.

The share of the public sector, particularly that of the Federal Government, in housing construction is limited to financing housing through the Housing Finance System - SFH. In the years 1980-1982, the SFH financed an average of 540,000 units/year. In the period of the major recession (1983-1985) this average fell to 80,000 units/year, rising to 200,000 per year by the end of the 1980s. According to these figures, the annual average for building financed by the SFH in the 1980s was 270,000 units per annum, representing 30 per cent of the annual average construction at the national level, which is presented in table 5.04.

TABLE 5.04

ANNUAL AVERAGE RATE OF HOUSING CONSTRUCTION

MAJOR REGIONS	1950-1960	1960-1970	1970-1980	1980-1990
North	9,933	13,812	45,861	88,252
North-east	66,343	90,774	160,955	208,732
South-east	174,062	182,689	378,327	380,201
South	74,024	87,850	110,237	139,044
Central West	20,800	37,962	63,014	65,926
BRAZIL	345,162	413,087	758,394	882,157

Source : Brazilian Institute for Geography and Statistics (IBGE) 1992

Though table 5.04 indicates the number of dwelling units constructed in each decade, such data are of value rather for census purposes, since the rented rooms, "precarious" housing or housing requiring replacement, which must represent not less than 10 per cent of the housing stock, are also considered statistically as dwellings. Accordingly, and adding the 30 per cent share of the public sector, the private sector must contribute the remaining 50 or 60 per cent of the total housing construction in the country.
Finally table 5.05 shows the predominant building materials in Brazil, according to the most recent information available from the 1970 census.

TABLE 5.05

PREDOMINANT WALL AND ROOFING MATERIALS ('000 units)

WALL MATERIALS	TOTAL	PREDOMINANT ROOFING MATERIAL					
		Concrete slabs	Clay roofing tiles	Asbestos roofing	Zinc	Straw	Other
Masonry	12,266	313	11,472	145	99	151	86
Wood	4,259	—	3,382	38	130	321	389
Mud	3,341	—	2,179	3	19	984	156
Other	1,198	—	489	5	11	537	156
TOTAL	21,064	313	17,522	191	259	1,993	787

Source: Real estate census, Brazil, 1970.

As can be deduced from the results of the 1970 census, the typical Brazilian house consists of the following elements:

- Cement floor (20.9%)
- Masonry walls (58.2%)
- Wooden roofs (93.6%)
- Clay roofing tiles (83.2%)

Houses with wooden walls are found in 29.2 per cent of cases, and roofs with a wooden structure (taking into account various types of roofing) are present in almost 95 per cent of the housing stock in Brazil.

5.3 THE FORESTRY SECTOR

5.3.1 Forest resources

The Amazon forest represents the largest reserve of tropical forests in the world. It has a total area of 630 million ha distributed over seven countries, among which Brazil possesses 63 per cent of the total, that is to say 400 million ha. The tropical forest in Brazil in turn represents 80 per cent of the total forests available in the country.

Brazilian forestry potential is estimated at 15,400 billion m³, consisting of approximately 3,000 species, only 230 of which are used by industry. 80 per cent of timber production is accounted for by less than 50 forest species. Up to the year 1988, about 25 million ha of forests had been felled representing 5.2 per cent of what is considered as "Legal Amazonia" (Cunha, R.P., 1989). Also, industrial plantations were initiated from the beginning of the present century and especially during the 1940s and the beginning of the 1950s, principally owing to the reduction of supplies of parana pine.

From 1966, with the implementation of fiscal incentives, reafforestation became a large-scale activity in Brazil. According to information from the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA, formerly IBDF), reafforestation projects using fiscal incentives totalled approximately 6.2 million ha up to 1986, comprising 52 per cent eucalyptus and 30 per cent pine.

Table 5.06 shows the annual rate of plantations in the period 1978-1986.

At present, almost all the wood from plantations is used for the production of pulp and paper, plywood, fibre panels and particle board, satisfying 31 per cent of current demand for wood in Brazil in 1991. The fiscal incentives were abolished in 1987 and at present alternatives are being thought to guarantee appropriate supplies of industrial timber.

TABLE 5.06

REAFFORESTATION WITH FISCAL INCENTIVES 1978-1986
('000 ha)

YEAR	PINE	EUCALYPTUS	OTHER	TOTAL
1978	141	228	43	412
1979	118	283	73	474
1980	89	272	75	436
1981	117	230	71	418
1982	158	187	86	431
1983	74	91	50	215
1984	71	124	91	286
1985	65	13	89	285
1986	85	174	150	409
Subtotal Average	918	1,720	728	3,366

Source: IBDF-IBAMA, 1988

5.3.2 The forestry industry

There are about 14,000 sawmills distributed throughout the country. In 1991, the apparent consumption of sawn wood was 9.7 million m³, while production was 10.4 million m³. Table 5.07 shows apparent consumption over the period 1987-1991, by the type of species produced.

TABLE 5.07

CONSUMPTION OF SAWN WOOD ('000 m^3) 1987-1991

YEAR	BROAD-LEAVED SPECIES	PARANA PINE	OTHER CONIFERS	TOTAL
1987	9,530	395	1,235	11,160
1988	9,680	340	1,520	11,380
1989	9,500	346	1,915	11,761
1990	6,826	353	2,370	9,549
1991	6,476	232	2,988	9,698

Source: FAO-ABPM-STCP

It should be emphasized that, at the beginning of the 1970s, approximately 50 per cent of all sawn wood consumed in Brazil was parana pine. In 1991 this species represented only 2.4 per cent of total consumption, having been replaced by broad-leaved species and above all by other coniferous timber from reafforestation. National consumption of plywood panels is shown in the following table:

TABLE 5.08

CONSUMPTION OF PLYWOOD PANELS: 1987 - 1991
('000 m^3)

YEAR	CONSTRUCTION GRADE	INTERIOR GRADE	TOTAL
1987	423	548	971
1988	414	639	1,053
1989	400	730	1,130
1990	359	689	1,048
1991	400	531	

Source: FAO-ABPM-STCP

The group of construction grade panels is almost exclusively intended for concrete formwork or moulds and the interior grade panels include veneer for the furniture industry.

5.4 UTILIZATION OF WOOD IN CONCRETE FORMWORK

5.4.1 Historical development

Speaking of formwork in Brazil is tantamount to speaking of wood, which was and continues to be the principal raw material used in the manufacture of formwork for concrete. The first change observed from the traditional form of pinewood boards was due to the advent of plywood board at the end of the 1940s. In this development pine wood panels were simply replaced by plywood, using the same processes for assembly and formwork techniques as for sawn wood. The resultant appearance of the concrete was not so important, and only the number of reuses that each product offered was taken into account.

From 1960, a more determined effort began for rationalization in the manufacture and use of formwork for concrete, with the preparation of specific formwork designs for each type of structure. The aim was then to replace the so-called conventional system, in which the site superintendent or the carpentry supervisor produced and used the moulds, based exclusively on practical experience. This was in reality lack of experience and caused great wastage, specially in striking, owing to the excessive use of nails and the indiscriminate use of crowbars.

Accordingly, with projects for the prefabrication of formwork it became possible to reduce costs owing to better utilization of the raw material and owing to rising labour productivity. Each part was accurately dimensioned, detailed and codified, enabling the site superintendent, with the assistance of the formwork designer, to monitor work output, and to direct assembly according to a planned timetable.
From the second half of the 1970s, the third great transformation in formwork for concrete occurred. The industrial manufacture of specially designed panels and formwork began. With manufacture, the advantages offered by rationalized products increased, eliminating wastage on site and reducing the number of carpenters needed. In the same period, principally due to the great incentive given by the BNH to the mass construction of housing, metal formwork, initially imported, came on to the market.
In recent years, owing to the demands of the consumer market, some improvements have occurred in the area of formwork design. Projects that were formerly designed exclusively for the typical plans of a building began to cover the design of atypical plans also. This was possible thanks to the establishment of specialized companies that made efforts to standardize and permit repetitive use of almost all the formwork in structures, from the pouring of the foundation in the first level to the upper floors.

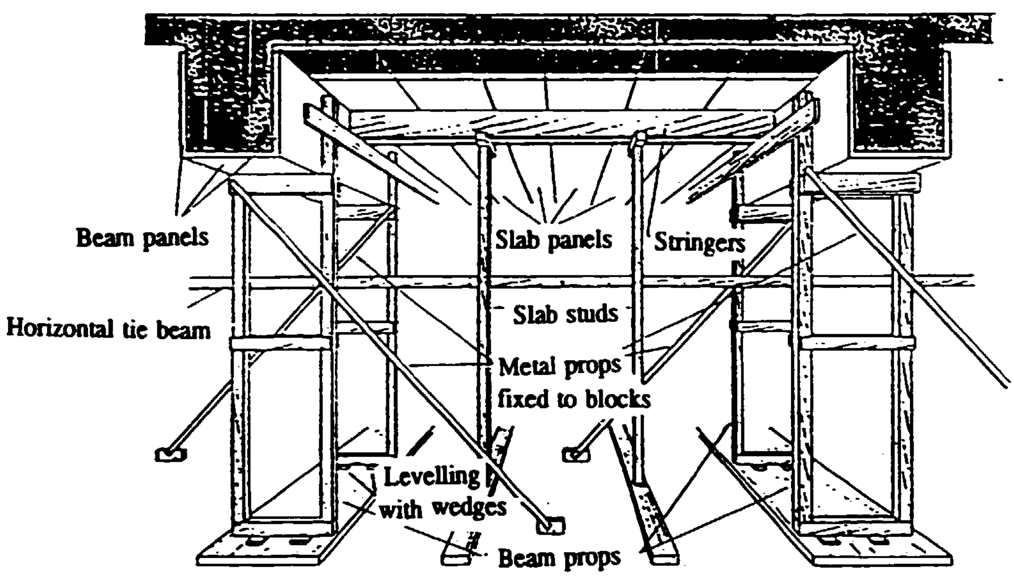
5.4.2 "UENO" type wooden formwork

There are various systems for wooden formwork on the market, all of which are designed taking into account working times required, costs and quality of finish. Within this range of alternatives there is one formwork system which, being a pioneer, served as a basis for other variants currently being used in Brazil.
This system is fairly well known as "UENO-type" formwork in honour of its inventor, Ing. Toshio Ueno, who as one of the first students of formwork made a decisive contribution to progress in the country's civilian construction sector.
The system is particularly advantageous for civilian building work, especially high buildings that have the following characteristics:

(a) Formwork can be used a large number of times (from 10 to 25 times);
(b) The dimensions of the structural elements (columns, beams and slabs) are relatively small, and compatible with the mechanical strength of wood;
(c) The building site is normally small in size, restricting the use of cranes or other types of mechanical transport.

The principal characteristic of UENO type formwork is the simplicity of its design, so that it can easily be fabricated on the site with the help of a detailed plan. It uses only building materials available on the market: plywood panels, boards and wooden studs.
Assembly is simple and is easily learned by workers, who need not be highly skilled, since all the modules are prefabricated, reducing the work to that of assembling modules side by side, without the need for additional sawing.
All the modules are small, easy to transport by hand, thus ensuring an appropriate level of labour productivity by comparison with other operations on the site. Also, the system makes it very easy to replace damaged parts, since wood is a common material used in every structure.
Finally, it is a formwork system that is compatible with the inherent weight of the relatively light structures that are planned in high buildings, giving a very efficient cost-benefit ratio.

FIGURE 5.01: UENO type formwork system



5.4.2.1 Formwork for columns

Formwork for columns consists basically of four panels, two at the sides and two at the other faces, which can in turn be subdivided into two or more panels, according to their dimensions. They are generally made of plywood, reinforced with wooden frames. The assembly of column panels must meet three basic requirements: positioning, levelling and verticality. The columns are located on the concrete surface. The function of the sills is to serve as reference levels for the formwork and their location is defined during the repositioning phase, following instructions on a location plan.

The columns are levelled by means of two guide studs located vertically above the sills, thus permitting the alignment of the first panel. Finally, verticality is ensured once all the panels, duly fixed and stiffened with wood or metal diagonal braces, have been positioned.

In the case of the column formwork system, the utilization of nails is kept to a minimum and the plywood panel is never nailed through, but only the wooden reinforcements, which facilitates not only assembly but above all the disassembly of panels without wastage of wood.

5.4.2.2 Formwork for beams

The formwork is assembled out of three panels, two at the sides and one at the bottom. They rest on *garfos*, which consist of two studs and cross-members, of U-shape at the top, to support the three beam panels. These *garfos* give rigidity to the lateral panels of the beam formwork and support a built-up wooden beam called a *longarina*, on which the slab panels rest.

The assembly of the beam panels is such that it permits the striking of the column panels without interference. Even the lateral panels of the can be withdrawn, leaving only the bottom of the beam, supported by the *garfos*. As in the case of columns, the formwork for beams is made in one day if it is intended to cast one slab per week.

5.4.2.3 Formwork for slabs

The slab is assembled with the use of three basic parts: the slab panels, the beams or *longarinas* and the studs or *escoras*.

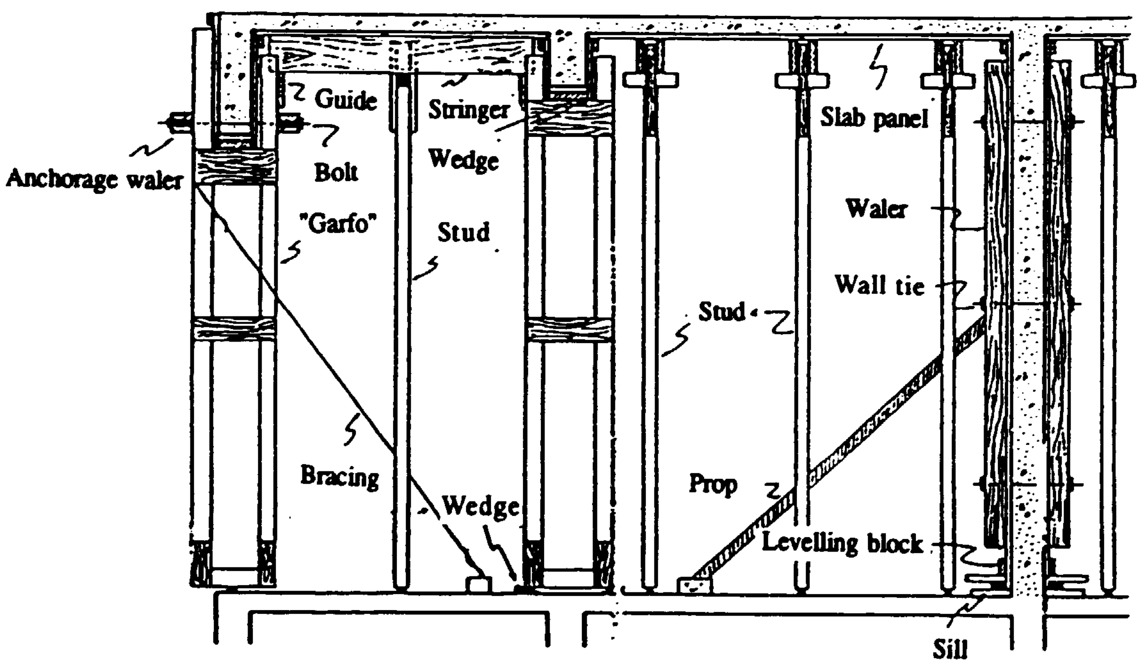
The slab panels are frequently plywood boards strenghened with rectangular wooden frames, which facilitates handling and striking. They are mounted on all the other parts and thus are the last to be struck.

The *longarinas* are built-up beams consisting of two elements whose dimensions are determined by the span and the load to be supported. Owing to their compound form, they have inherent stability, rest on the supports of the *garfos* and support the slab panels.
The studs or *escoras* are wooden stanchions that are housed in the *longarinas*. They are kept rigid by means of wedges at their feet, which makes it possible, if required, to impart a specific camber to the slab.
The slab panels are distributed in such a way that support lengths, similar in width to the beam panels, are left at regular intervals and serve to keep the shoring of the slab in place once the principal plywood panels have been removed.

5.4.3 Industrially produced wooden formwork

These are wooden formwork systems prefabricated in the plant and not on the site, consisting of panels, studs and braces which are designed and manufactured specially for each building. This type of formwork permits many reuses, optimizes the final quality of the structure and permits more creative and economic solutions. It requires specialized equipment and labour, reducing waste on site with the use of prefabricated and graded element ready to be assembled according to a pre-established timetable.
In the present study on formwork that was carried out in the six Latin American countries the level of technological implementation found was nowhere as developed as that in Brazil, at least with regard to the rational use of wood as a predominant material for concrete formwork.

FIGURE 5.02: The FORMA PRONTA formwork system



We refer specially to the FORMA PRONTA construction system of Industrias Madeirit in Sao Paulo. This system which originated from the "UENO" type wooden formwork explained above combines the characteristics and advantages of previous experience with the advantage of industrial production of the formwork to specified dimensions in the factory so that it is ready for assembly on site.
This type of industrially produced system has become an excellent alternative for structures on small sites where the *in situ* fabrication of formwork could not easily be planned and carried out. It is also an appropriate

alternative for reducing wastage of wood for formwork since losses owing to sawing and re-sawing of the wood are totally eliminated.

The industrial production of formwork permits an improvement in quality because all the necessary equipment can be available in the plant, which would be impossible on the site. All types of formwork and details can be produced, from the most simple to the most complex, with industrial precision.

The case of Industrias Madeirit, is perhaps rather special from the point of view of industrial integration and the rational use of forest resources. It is a consortium of enterprises which has a complete timber chain, including a 22,000 ha reafforestation plantation in which 1,000,000 *Pinus elliotis* seedlings are planted every year; they are used as from the seventh year of growth and supply 70 per cent of the raw material.

The entrepreneurial group also produces plywood and was a pioneer in its manufacture from the year 1946, so that plywood of other makes are known by the name of MADEIRIT. In addition it produces supplementary metal systems, offers an advisory and consultancy service on formwork, manufactures sealing stains and release agents for formwork, among other supplementary accessories.

It was the leading enterprise in the introduction of prefabricated wooden formwork, supplies a substantial part of the market in Brazil and has in recent years begun to export plywood and prefabricated formwork to several Latin American countries. It could be said that it is a rather special case and one that is difficult to imitate, but in any way it is an excellent example of sustainability, conservation and the development of forest resources.

5.5 CONSUMPTION OF WOOD IN FORMWORK

The figures for the actual consumption of wood in a building constructed in Sao Paulo and six buildings constructed in Curitiba are given below. Also, the results of a study at national level covering eight cities of the five regions of Brazil are compared, in relation with the consumption of wood in the construction sector. Later the consumption figures for eight multifamily buildings that used plywood panels for formwork are presented.

TABLE 5.09

CONSUMPTION RATES: SAWN WOOD

TYPES OF HOUSING		CONST. m^2	FORM-WORK m^2	CONCRETE m^3	WOOD m^3	CONSUMPTION OF WOOD		
						m^3 wood / m^3 concr.	m^3 wood / m^2 const.	bd ft / m^2 const.
C	Bco. BRADESCO	3,109	6,200	440	58.0	0.13	0.019	08
U	Bco. BRADESCO	5,502	12,628	950	118.1	0.13	0.022	09
R	Bco. BRADESCO	8,507	16,560	1,380	154.8	0.11	0.018	08
I	Bco. BRADESCO	2,061	3,979	309	37.2	0.12	0.018	08
B	Bco. BRADESCO	4,905	8,042	670	75.2	0.11	0.015	06
T	Messrs. BARAO	790	1,546	152	14.5	0.10	0.018	08
S. P	T. UENO	3,000	6,000	343	56.1	0.16	0.019	08
AVERAGE: MULTIFAMILY BUILDINGS						0.12	0.018	08

Source : Banco BRADESCO and building enterprises

The average consumption figures for these seven multifamily buildings would be:

$$0.12 \ \frac{m^3 \text{ wood}}{m^3 \text{ concr}} \quad \text{or } 0.018 \ \frac{m^3 \text{ wood}}{m^2 \text{ const}} \quad \text{equivalent to } 8 \ \frac{\text{bd ft}}{m^2 \text{ const}}$$

The FORMA PRONTA system of Industrias Madeirit obtains similar results with an average varying between 0.015 and 0.017 m^3 wood/m^2 construction area, depending on whether 12 or 10 uses, respectively, are estimated for the formwork. According to experience (the company provides approximately 15,000 m^2 of formwork per month), 2.5 m^2 of formwork are required for ever square metre of construction area (coinciding with the consumption rates for Argentina, Chile and Peru) and the average distribution of formwork in a structure is: 29 per cent for columns, 35 per cent for beams and 36 per cent for slabs. Editorial PNI de Brasil, which specializes in construction, takes 12 m^2 of formwork per m^3 of concrete as the average consumption.

These consumption rates coincide with the range of figures obtained in the research study *A Aplicação da Madeira e Seus Derivados Na Construção Habitacional* (The utilization of wood and wood-based products in housing construction) published in 1978 by the Brazilian Forestry Development Institute (IBDF). The study was intended to quantify the total consumption of wood by volume in the residential subsector in various cities and regions of Brazil.

The surveys of building enterprises covered a sample of 22 per cent of total construction activity in 1974 (15,571,621 m^2) and were carried out in eight cities: Manaos of the Northern Region; Recife and Salvador of the North-eastern region, Belo Horizonte, Río de Janeiro and Sao Paulo of the South-eastern region; Curitiba of the Southern region and Brasilia of the Central West region. The cities selected represented a substantial share of the total for each region.

The total consumption of wood at national level per average dwelling unit of 107 m^2 was as follows: one- or two-storey houses used 1.8 m^3 of sawn wood and 0.17 m^3 of plywood panels. Dwellings in multifamily buildings consumed 7.19 m^3 of sawn wood and 0.69 m^3 of plywood panels. In the analysis of consumption, wood used on a temporary basis was also considered, that is to say: formwork, scaffolding, provisional structures, etc. as well as the permanent use of wood in roof structures, doors, windows, built-in furniture, etc.

The consumption of sawn wood and plywood panels used in formwork and for other temporary uses represented 47 per cent of the total of wood consumed in one-family dwellings and 82 per cent of the total of wood used in multifamily buildings.

Table 5.10 presents the consumption at national level for the two types of temporary use of wood.

The consumption figures obtained by analysis of the seven buildings studied earlier was 0.018 m^3/m^2, rather lower than the consumption in multistorey buildings, namely 0.0672 m^3/m^2 presented in table 5.10, but this is within the range of 0.014 - 0.08 m^3/m^2. The lower current consumption of wood in multifamily buildings is due to the use of industrially produced plywood formwork, which came on to the market at the beginning of the 1970s. Since the study was carried out in 1974, it is most probable that formwork was predominantly made of sawn wood, with more wastage and a lower number of reuses.

TABLE 5.10

CONSUMPTION RATES: CUBIC METRE OF WOOD PER SQUARE METRE OF CONSTRUCTION AREA

TYPE OF USE	CONSUMPTION $\frac{m^3}{m^2}$	TYPE OF STRUCTURE	IMPACT OF SAMPLE	VARIATION IN RATES $\frac{m^3}{m^2}$
- Formwork for concrete	0.0168 0.0672	Houses Buildings	100% 100%	0.014 - 0.08 0.003 - 0.07
- Fences, huts, scaffolding	0.0285	----	100 %	0.003 - 0.005

Source: Brazilian Forestry Development Institute. IBDF-1978

It is interesting to present in table 5.11 the types of species of wood most used according to the region of the country, on the basis of the same study.

TABLE 5.11

SPECIES OF TIMBER UTILIZED IN FORMWORK BY REGION

NORTH	NORTH-EAST	SOUTH-EAST	SOUTH	CENTRAL WEST
Laurel *Virola* *Andiroba* *Jacarandá* Sandbox tree	Pine *Agreste* *Jequitibá* Sandbox tree *Virola*	Pine Cinnamon *Maçaranduba* *Peroba* *Virola* Northern pine Eucalyptus	Pine *Bracatinga* *Peroba*	*Virola* Pine Sandbox tree Northern pine

Source: Brazilian Forestry Development Institute. IBDF-1978

5.6 COST OF FORMWORK

Ing. Toshi Ueno, the inventor of the UENO formwork system, reported at a symposium on "The global stability of reinforced concrete structures" held in Sao Paulo in 1985 that sawn wood formwork, used on a large scale up to the 1970s, accounted for 60 per cent of the cost of the structure.
When plywood and prefabricated formwork is used it represents approximately 40 per cent of the costs of the structure and in turn the structure represents 25 per cent of the total cost of the project, which means that formwork at present represents approximately 10 per cent of the direct cost of construction. Ing. Ueno analysed the impact of three types of prefabricated formwork on the costs of one and the same building. The premisses for the analysis are given below, as follows:

STRUCTURE	:	Multifamily building
Nº OF STOREYS	:	10
CONSTRUCTION AREA	:	3,000 m²
AREA OF FORMWORK	:	6,000 m²
COST PER m²	:	US$ 126
TOTAL DIRECT COST	:	US$ 377,400

TABLE 5.12

COST OF WOODEN FORMWORK WITH 12 mm PLYWOOD PANELS

	QUANTITY (10 uses) m²	UNIT PRICE US$	TOTAL PRICE US$
Formwork: columns, beams and slabs	600	33.14	19,884.00
Base for beam (5%)	30	33.14	994.20
Total manufacture			20,878.20
Replacement (10%)			2,087.82
Labour, assembly and striking	6,000	2.44	14,640.00
T O T A L			37,606.02
Unit price/m²			12.54
% TOTAL DIRECT COST			**9.97%**

Source: Toshio Ueno Engenharia S/C Ltda.

TABLE 5.13

COST OF MIXED FORMWORK WITH 20 mm PLYWOOD (duration 4 months)

	QUANTITY (10 uses) m^2	UNIT PRICE US$	TOTAL PRICE US$
Formwork, columns, beams and slabs	600	22.32	13,992.00
Base for beam (5%)	30	22.32	669.60
Total manufacture			14,661.60
Replacement (10%)			1,466.20
Hiring of metal elements	600	2.96	1,776.00
Labour, assembly and striking	6,000	(x 4) 2.44	14,640.00
T O T A L			32,543.80
Unit price/m^2			10.85
% TOTAL DIRECT COST			**8.64%**

Source: Toshio Ueno Engenharia S/C Ltda.

TABLE 5.14

COST OF MIXED FORMWORK WITH 20 mm PLYWOOD (duration 5 months)

	QUANTITY (10 uses) m^2	UNIT PRICE US$	TOTAL PRICE US$
Formwork, columns, beams and slabs	600	22.32	13,992.00
Base for beam (5%)	30	22.32	669.60
Total manufacture			14,661.60
Replacement (10%)			1,466.20
Hiring of metal elements	600	2.96	8,880.00
Labour, assembly and striking	6,000	(x 5) 2.44	14,640.00
T O T A L			39,647.80
Unit price/m^2			13.22
% TOTAL DIRECT COST			**10.5%**

Source: Toshio Ueno Engenharia S/C Ltda.

The average impact of the cost of formwork on the total cost of the structure was 9.7%, on the basis of the three alternatives analysed.

5.6.1 Comparison of costs between a traditional wood formwork system and an industrially produced wooden formwork system

As a reference, a comparative economic study carried out by FORMAPRONTA de Brasil, which analysed the costs of formwork exported for a 10-storey structure in Uruguay, in comparison with a traditional wooden formwork system in that country

5.6.2 Traditional wooden formwork

MATERIALS

- Consumption of wood	:	180 bd ft/m³ of concrete
- 1 m² of roofed-over area	:	0.175 m³ of concrete
- 1 bd ft of pine wood	:	US$ 0.27
- In 10 ceilings	:	0.175 x 10 = 1.75 m³ concrete

giving:

- 1.75 m³ x 180 bd ft/m³ = 315 bd ft/m² floor
- 315 x US$ 0.27 = US$ 85.00 + MVA/m² of floor

An MVA of 22-50% of the value of the wood
US$ 85.00 x 0.5 x 1.22 = US$ 93.5/m² floor

Labour

- US$ 3.5 h/m²
- 1 m³ of concrete/6.5 days

Cost of labour with 75% carpentry component

- 6.5 x 0.75 = 4.875 days/m³ of concrete
- 4.875 x 0.175 = 0.853 days/m² of floor
- 0.853 x 10 ceilings = 8.53 h/m² of floor of the building
- 8.53 x 3.5 = US$ 29.86/m² of floor of the building

TOTAL COSTS

Materials + labour = US$ 93.50 + US$ 29.86 = US$ 123.26/m²

5.6.3 FORMA PRONTA system

MATERIAL S (including manufacture)

- US$ 40.0/m² of formwork (estimated, with freight, taxes, etc)

Assuming an index of 2.5 m² of formwork/m² of floor

- US$ 40.0/m² x 2.5 m² = US$ 100.00/m² of floor

Labour for assembly

Assuming an index of 1.4 h/m² of formwork

- 1.4 x 2.5 = 3.5 h/m² floor
- 3.5 h/m² x US$ 3.5/h = US$ 12.25/m² of floor

TOTAL COSTS

Material + labour = $ 100.00 + $ 12.25 = US$ 112.25/m² of floor

To sum up, the industrially produced wooden system proves to be approximately 9 per cent more economical, and it uses approximately one-quarter of the wood required in the traditional system, i.e. 6.8 bd ft/m² as compared with 31.4 bd ft/m².

5.7 CONCLUSIONS AND RECOMMENDATIONS

It can be deduced from the analysis made on the use of wood and wood-based products in formwork that Brazil is the country in which the greatest concern and efficiency has been identified, compared to the other Latin American countries studied with regard to the optimum use of wood and other materials used in concrete formwork.

This is partly due to the rapid and progressive development of the costs of wood in recent decades, causing unanimous concern among all builders so that efforts have been intensified to overcome difficulties and deficiencies in the use of wood on sites, particularly its use in formwork.

In that situation the prices of formwork become a determining element in the total costs of a structure, since builders initially delegated responsibility for the fabrication and assembly of formwork to foremen, who had no knowledge of calculation methods and prepared the formwork on the basis of the experience acquired throughout their occupational life.

This procedure normally entailed significant wastage of material and labour, since the formwork was fabricated and assembled on the site, without any major planning and later reuse of materials. Labour, in turn, became excessively expensive because of the absence of a disciplined scheme of work, entailing unnecessary effort and creating "dead time" between one stage of the work and the next.

Taking this situation into account, some professionals, plants and engineering enterprises developed formwork within an integrated scheme for the concrete structure as a whole, without severing the link between technology and a realistic working method appropriate to existing materials and labour in the market. At present it can be said that there are "formwork systems" in Brazil that are a combination of technology, through plans and designs for formwork, with a working discipline that results in rationalized use of labour.

At present, formwork of wood and wood-based products, as in the rest of the countries analysed, represents the predominant alternative in construction, both in multifamily and one-family housing. Other alternatives are used, especially metal formwork, but their use is limited to large-scale structures or special cases, particularly in shoring studs. Depending on the structure, the purchase of metal formwork may result in a high initial investment, or, in the case of hiring formwork, there is the risk that construction will proceed at an unplanned rate, which will make hiring costly.

The problem of using wood in formwork is solved better in the country's industrial zones and areas of greater urban concentration, especially in the South and South-east regions. The greatest concentration of enterprises that offer industrially produced formwork systems at the national level and for export is found in Sao Paulo. The situation is different in zones that are less industrialized and have lower levels of economic development, such as the North and North-east regions, where one-family houses predominate, in contrast to multifamily buildings. However, there is great concern at national level for increasing rationalization of the use of wood and industrially produced formwork systems. This is reflected in the concern felt among professionals, marketing enterprises and builders regarding the need to standardize activities involving the use of formwork in construction. Meanwhile there are standards that regulate the characteristics of plywood used in formwork, by the resin-coated or plastic coated for external use.

Recently the Brazilian Industrialized Construction Association (ABCI), with the support of the Brazilian Association for Technical Standards (ABNT), has set up a working group consisting of representatives of enterprises manufacturing plywood and formwork, building enterprises, research workers in the academic world and other users, which is preparing a basic text for the standardization of formwork for concrete.

The study carried out in six countries reveals that this is the first time that interest has been found in standardizing formwork for concrete. All previous standardization was based on guidelines of the American Plywood Association (APA). At present, a study is being made of calculation systems and the factors that influence lateral pressure acting on formwork, with the help of the Testing Laboratory for Building Materials of the University of Campinas (UNICAMP). This effort should serve as a guideline for a study at Latin American level related to the standardization of wooden formwork.

A number of recommendations gathered during the interviews have been identified that could be implemented for various levels of utilization of wood and wood-based products in formwork:

(a) Production of raw material

- To promote the gradual replacement of traditional broad-leaved species by newly discovered forest species, especially in regions in which there are less forestry plantations.
- To stimulate greater utilization of forest species from re-afforestation projects, particularly eucalyptus wood, in rationalised traditional formwork systems.
- To improve the quality and durability of the sawn wood used in formwork, improving finishes in the processing of wood as well as applying appropriate preservation and drying techniques.

(b) Standardization

- To support the preparation of technical specifications or practical guides for users of traditional sawn wood or plywood formwork specifying alternative formwork systems, solutions for structural joints, relation or group of apparent species, permissible loads, construction details and recommendations for good practice.
- To promote testing for resistance to lateral pressure in plywood, as well as of the water-resistant property of glue and of the finished surface of exposed concrete.

(c) Training

- To train the site staff responsible for formwork in techniques of striking with proper tools, reducing to the minimum the use of metal tools and encouraging the use of wooden wedges.
- To ensure the widespread and proper use of concrete vibrators in order to minimize wear and tear on formwork and increase reuse and the useful life of the material.

- To make site staff aware of the desirability of observing a pre-established discipline for work, following a strict sequence of assembly operations with little modification on the site.
- To optimize the architectural and structural design capacity of architects and engineers, stimulating rationalization on a modular basis, especially in the case of large-scale structures or high buildings.

(d) Technology

- To investigate and promote wide-spread adherence to the optimum cost-benefit ratio for the reutilization of formwork according to the various thicknesses of sawn wood and plywood panels.
- To analyse the possibilities for the use of new alternatives for release agents according to the type of formwork surface, the final finish of the concrete, the useful life of the wood and the resultant cost of formwork.
- To develop new analytical models that would increase technical knowledge on the magnitude and behaviour of the dynamic forces acting on the formwork during pouring of the concrete.
- To stimulate the design of new and better semi-industrialized formwork systems using sawn wood and plywood that can be used in one-family dwellings, incorporating the advantages of the UENO system or equivalent formwork.

(e) Market

- To promote the establishment of enterprises specializing in wooden formwork that offer standardized elements on a hiring basis, intended to meet the demand for the construction of one-family dwellings and multifamily buildings of medium height and high density.

(f) Institutional support

- To sponsor the work of the Brazilian Industrialized Construction Association (ABCI) and the Brazilian Technical Standards Association (ABNT) in the current development of standards on wooden formwork and disseminate the results of such work.

This latter recommendation can be implemented at Latin American level in the same manner and with the same attention that UNIDO is currently devoting to the preparation of a Latin American wood construction code among the countries of the region. Similarly, there is interest on the part of the member countries of MERCOSUR, namely, Brazil, Uruguay, Paraguay and Argentina, in taking action that would improve trade between them, as a possible first step in standardizing the use and thus the marketing of wood-based formwork.

6.0 DIAGNOSIS OF PERU

6.1 THE HOUSING SECTOR

According to the IXth Population Census carried out in 1993, the current population of Peru was 22,128,466, 70 per cent of whom were in urban areas. The rate of growth over the period 1981-1993 was 2.2 per cent at national level, the urban growth rate being 2.9 per cent and the rural 0.9 per cent per annum.

There are different figures regarding the housing deficit in Peru which , according to different sources varies from 1,500,000 to 2,500,000 dwelling units, considering population growth, the qualitative deficit and dwellings without water, drainage and electricity, of which there are stated to be more than 1,000,000 units. Recently, however, the figure considered as statistically acceptable fluctuates between 1,200,000 and 1,300,000 for the housing deficit[2].

At the date of publication of this report, the official results of the 1993 IXth National Population Census and the IVth Housing Census were not available. According to the 1991-1992 Statistical Compendium of the National Institute of Statistics and Information Sciences (INEI), the housing stock and the number of households in Peru was broken down as follows:

[2] *Revista ½ de Construcción*, No. 84 – November 1993

TABLE 6.01

HOUSING STOCK AND NUMBER OF HOUSEHOLDS IN PERU

	1972	1981	1991
Nº OF DWELLINGS	2,686,471	3,257,124	3,970,416
Nº OF HOUSEHOLDS	2,771,553	3,436,283	4,363,436

Source: Statistical Compendium 1991-1992, INEI.

The above table shows that more than 390,000 dwellings were required in 1991, if only as a result of the greater number of households as compared with the number of available dwellings (the quantitative deficit). Similarly the annual rate of building, formal and informal, was approximately 70,000 units per year over the period 1981-1991.

The final results of the 1993 Census for the Department of Lima indicate the existence of 1,399,530 dwelling units (941,427 units in 1981). Only 11.5 per cent of this total were located in multifamily apartment buildings, most being detached houses (70 per cent) and the rest dwellings on the outskirts of towns, houses in the vicinity of towns, etc. all of one or two storeys.

The number of high-rise dwellings in Lima, which represented 11.5 per cent of the total in 1993, is greater than the percentage registered in 1981 at the national level – namely, only 4.0 per cent – since Lima is the city with the greatest concentration of population (6.3 million inhabitants, representing 28.5 per cent of the country's population).

Finally, with regard to the predominant materials used in building according to the final results for the Department of Lima in the 1991 census, the typical dwelling would consist of the following materials:

Floors:	Cement	(44.1%)
Walls:	Brick or blocks	(68.8%)
Roofs:	Light-weight slabs or concrete	(47.8%)

According to the 1981 census, only 31 per cent of the dwellings at national level had brick or concrete-block walls and approximately 14 per cent had wooden or wattle-and-daub (*quincha*) walls.

6.2 THE CONSTRUCTION SECTOR

In general it is agreed that the economic crisis in Peru, especially during the 1980s, led to a crisis lasting more than 10 years in the civilian construction sector. Since 1990, the country has been going through one of the most radical processes of change in the history of the Republic, a new economic model being launched for reduction of the size of the State sector and for deregulation of the economy, leading towards an open market with free competition, as is happening in a number of countries at the regional and world level.

Since 1992, the Ministry of Housing and Construction has been merged with the Ministry of Transport and Communications, and some executive organs from the latter have been transferred to the Ministry of the Presidency, for instance, the National Housing Fund (FONAVI), the Materials Bank, the National Buildings Enterprise (ENACE) and the Lima Drinking Water and Drainage Service (SEDAPAL).

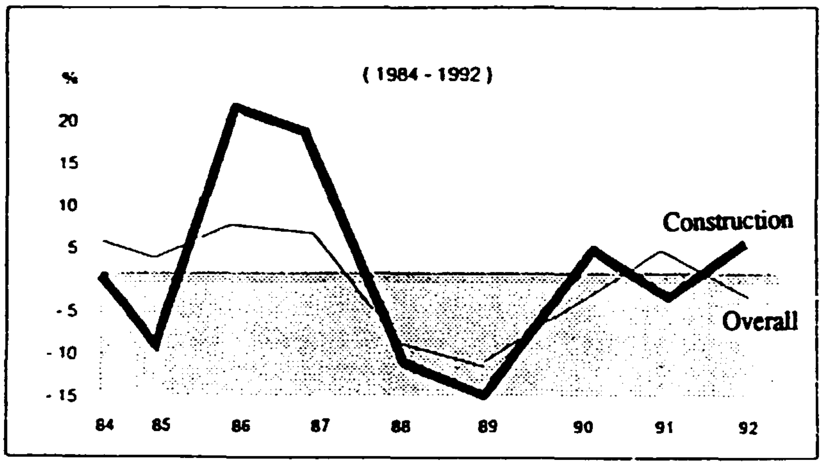
In the same period, the Housing Bank, the Central Mortgage Bank of Peru and the System of Mutual Housing Associations were dissolved. In the period 1981-1991, according to ENACE, the public sector constructed 130,489 dwellings, most of them the so-called "serviced lots".

The present Government has expressed its interest in the assumption by the private sector of a leading role in the construction of housing, limiting the public sector to a regulatory and promotional role, to meet the needs of the extremely poor sectors of the population through agencies that now belong to the Ministry of the Presidency, to which should be added the Compensation and Social Development Fund (FONCODES) and the National Institute for the Educational Infrastructure and Health (INFES).

Recently, FONAVI, which serves poor but not indigent sectors, has announced an investment of US$ 360 million for 1994 that would permit the complete financing or the co-financing of 31,000 dwelling units. Also, a new mortgage system has just been implemented in the first quarter 1994 for the construction and purchase of dwelling units, using resources from the private sector, and will be administered and supervised by the private banks.

This new mortgage system, which has had great success in Chile, is based on the utilization of mortgage bonds, which will be offered for sale through the stock exchange and will channel private money to the construction sector, using resources from the administrators of pension funds, the banks themselves and other private investors. It has also been calculated that for 1994, the new mortgage system will make it possible to raise US$500 million, which will facilitate the construction and sale of 50,000 dwellings in the medium and long term. Historically, the construction sector has had a share of between 5 and 7 per cent of the gross domestic product of Peru, although, as was mentioned earlier, its development has been very erratic in recent years. Figure 6.01 shows that construction had a 4.1 per cent growth in activity from the previous year in 1992, although national production decreased by 2.9 per cent. Construction was practically the only production sector to experience growth in that year.

FIGURE 6.01: GDP development overall and in construction



SOURCE: *Revista ½ de la Construcción* N° 84 – November 1993

It is estimated that construction grew by between 6 and 7 per cent in 1993, experiencing one of the best sectoral growth performances, together with the mining and fishery sectors. In the first six months of 1993 it grew by 10.3 per cent over the similar period in 1992. The draft general budget of the Republic estimates 8 per cent growth for construction in 1994 and assumes that construction will lead to an increase in the national GDP, which is envisaged to be not less than 4.0 per cent (in 1993, Peru had approximate GDP growth of 6.5 per cent, the highest in Latin America).

6.3 THE FORESTRY SECTOR

6.3.1 Forestry resources

After Brazil, Peru has the largest area of forests in the largest river basin in the world, the Amazon basin. The tropical forest in the country has an area of 69.8 million ha, representing 54 per cent of the national territory. Table 6.02 shows the forestry resources available to the country.

Without doubt, the dense heterogeneous forests constitute the most important and abundant forest ecosystem of the jungle and thus of the country. They represent 69 per cent of the wooded area of the regions, being followed in importance by the dense cloudy woods that cover 20 per cent of the jungle territory.

TABLE 6.02

AREA OF NATURAL FORESTS BY REGIONS (ha)

NATURAL REGIONS	TOTAL AREA IN COUNTRY	NATURAL FOREST	%
Coast	13,637,000	3,202,800	23
Mountains	39,198,000	2,761,100	07
Forest	75,687,000	69,820,230	92
TOTAL	128,521,600	75,784,130	59

Source: National Forestry Action Plan of Peru. 1991.

6.3.2 Reafforestation

This began in 1870 on the initiative of the mining companies, principally in the mountainous region and by 1990 262,997 ha had been reafforested. It is calculated optimistically that only 50 per cent prospered of which 70,000 would have potential for commercial logging, eucalyptus being the predominant species. Also, 10,000 ha is covered by trees of the pine genus.

Reafforestation in the coastal and jungle regions has been very low, being estimated at 20,500 and 9,300 ha respectively. In general it is estimated that only 2.5 per cent of the land potentially available for reafforestation in the country has been used up to the present.

At the same time it is estimated that about 250,000 ha is deforested annually, principally for agriculture or cattle-rearing, although a very high percentage (up to 75 per cent) of the standing timber of the trees used for industrial purposes is wasted in sawing, logging and processing.

6.3.3 Industrial processing of wood

In 1990, logging for the forestry industry reached 917,000 m^3, 88 per cent of which was intended for the production of sawn wood, 6 per cent for laminated wood and plywood panels, 4 per cent for parquet, 0.5 per cent for sleepers and 0.3 per cent for decorative veneer. In the jungle, there are 540 enterprises for the mechanical processing of wood, divided up into sawmills and plants for plywood panels, decorative veneer, parquet and floor-boards. Table 6.03 shows the production and apparent consumption of forestry products in 1990.

Approximately 40 per cent of the wood processed is used in the construction industry and a similar percentage in the handicraft and industrial production of furniture. In turn, the mining sector consumes approximately 12 per cent of the national output of wood from small eucalyptus plantations in the mountains.

TABLE 6.03

APPARENT CONSUMPTION OF TIMBER RESOURCES - 1990
('000 m^3)

ITEM	PRODUCTION	IMPORT	EXPORT	APPARENT CONSUMPTION
Sawn wood	489.3	0.2	1.3	488.2
Plywood	23.7	---	---	23.7
Laminated wood	1.7	---	---	1.7
Parquet	12.6	---	0.5	12.1
Decorative veneers	1.6	---	0.1	1.5
Sleepers	2.4	0.2	---	2.6
T O T A L	531.3	0.4	1.9	529.8

Source: DGFF. Peruvian forestry in figures, 1990

6.4 THE USE OF WOOD IN FORMWORK

6.4.1 Introduction

In Peru, wood is the predominant formwork material, whether merely sawn or planed, used as boards and studs for formwork for walls, columns, beams and, normally, light-weight slabs. The other material commonly used is plywood board, especially for formwork for arches, carcasses and fair-faced concrete. To a lesser extent plastic elements are used to produce ribbed slabs and metal formwork for lightweight and solid slabs.

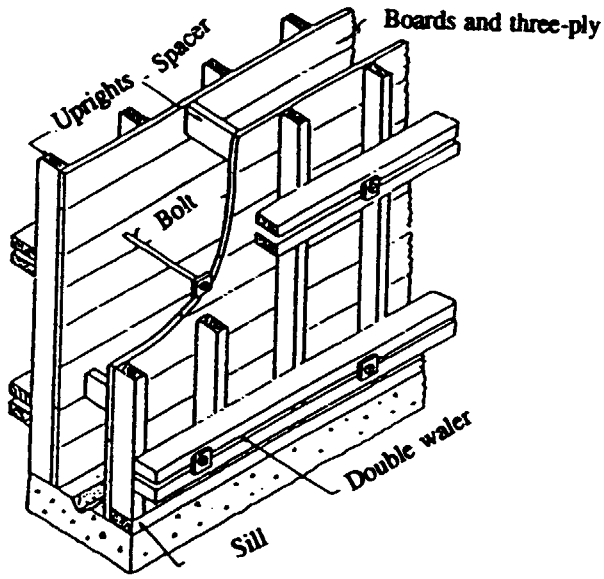
6.4.2 Traditional wooden formwork

Oregon pine (Douglas fir) was used formerly, but owing to its cost and to the fact that it is imported, its use has been discontinued. At present, the timber species most commonly utilized is *tornillo* (*Cedrelinga catenaeformis*), which has obvious physical and mechanical properties although it is not marketed in the lengths that used to be supplied in Oregon pine.
For sawn wood formwork, boards of the following thicknesses are used: 1", 1 ½" and 2", in widths of 4", 6", 8", 10" and 12", and studs or stanchions, generally of 2 x 3", 3 x 3", 3 x 4" and 6 x 4" cross-section.

6.4.2.1 Formwork for walls

The material principally used is 1½ x 8" boards, stiffened with 2 x 4" uprights or battens and braced by single or double 2 x 4" longitudinal members (*longarinas*). The other principal elements are the spacers or separators which control the thickness of the walls, and the stanchions or braces, which have different dimensions according to their position. The consumption of wood for a wall with formwork on both surfaces is 4.07 bd ft/m^2, on the basis of 8.64 uses of the elements on the average and wastage of 10 per cent.

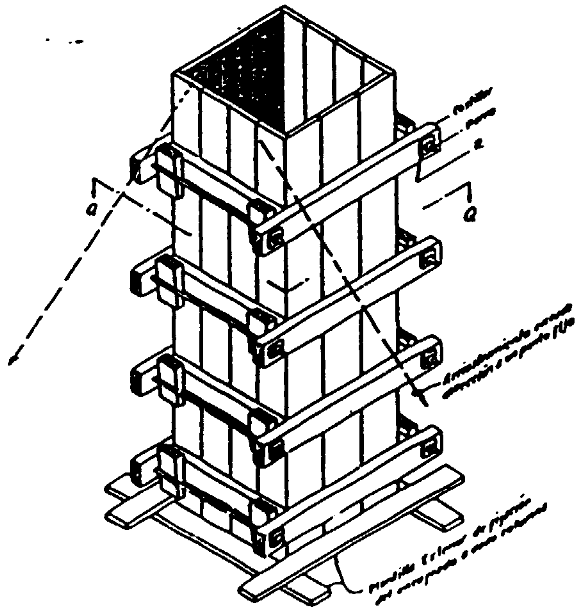
FIGURE 6.02: Sketch of formwork for walls



6.4.2.2 Formwork for columns

The typical formwork consists of 1½ x 6" and 1½ x 8" vertical boards or planks, stiffened by means of a framework of 2 x 4" battens fixed together with bolts or nails, and spaced at intervals of approximately 50 cm. Also, 2 x 3" studs fixed to the floor are used to brace the formwork in both directions. The boards are replaced by 19 mm plywood panels in the case of fair-faced concrete columns.

FIGURE 6.03: Sketch of formwork for columns



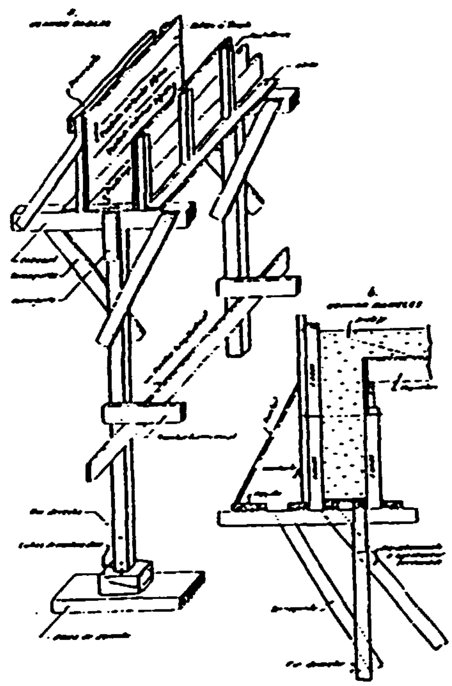
The consumption of wood and plywood panels is 4.24 bd ft/m² in the case of formwork for fair-faced columns. Normal columns use 5.16 bd ft/m² of sawn wood and the average number of used is considered to be 7.07 for wood, with 10 per cent wastage.

6.4.2.3 Formwork for beams

The beam consists of the sides and the base. Depending upon whether the beam is in fair-faced concrete or not, 19 mm plywood or 1½ x 8" wooden boards are used. The sides and the base of the beam are stiffened by a framework of 2 x 3" wooden elements.

A system consisting principally of studs, struts and bolsters is needed to support the beam formwork. The studs stand on wedges resting on the floor and are interconnected by means of lateral braces.
The consumption of wood and plywood for formwork for fair-faced concrete beams is 2.93 bd ft/m². In the case of normal formwork of wooden boards, consumption is 6.71 bd ft/m². An average of 6.37 uses for the various elements of the entire formwork and 10 per cent wastage are assumed.

FIGURE 6.04: Sketch of formwork for beams



6.4.3 Other wooden formwork.

There is only one enterprise that manufactures a semi-industrial wooden formwork system based on the use of PACCO boards which is a solution equivalent to the that used with DONATH boards and with the *galletas* (literally, "biscuits") of the prefabricated modular system in Chile (sections 4.4.2 and 4.4.3).
The dimensions of the PACCO boards are 0.60 x 1.2 m and their thickness is 30 mm. They are manufactured from 15 mm thick boards nailed at right angles to each other to give greater structural strength. The wood is kiln-dried until a moisture content of 10 to 16 per cent is reached. The boards have an average weight of 10 kg and are joined together with 1½" nails bent to increase resistance to ill-treatment. The use of this type of board offers the following advantages:

- Competitive price as compared with formwork made of 19 mm plywood;
- Not less than 40 reuses are possible, since it is used on both faces, which are of planed wood;
- The thickness of 30 mm eliminates the necessity for reinforcement frames and reduces the time for assembly and striking by half;
- Manipulation transport and storage are easy to carry out owing to the weight and the modular dimensions;
- It can be used either for beams, columns, slabs and horizontal slabs.

6.5 CONSUMPTION OF WOOD IN FORMWORK

Table 6.04 presents the unit consumption rates in 12 one- or two-storey one-family houses, which represent almost 90 per cent of the housing stock in Peru. The average consumption is 0.080 m³ of wood/m³ concrete and 0.034 m³ wood/m² construction area, equivalent to 14 bd ft/m² of construction area. The construction system used in the houses is the so-called traditional system, i.e. columns of concrete, walls of brick and light-weight roof or ceiling slabs. In houses of this type, sawn wood or planed wood is used as traditional formwork.

It is interesting to note that the total consumption of wood in one-family dwellings constructed by the traditional method in Peru is 20.6 bd ft/m² of construction[3], which means that the average figure of 14 bd ft/m² quoted in table 6.04 represents 70 per cent of the total wood consumed in housing. The remainder of the wood is used for joinery (doors, windows, cupboards, etc.) and for structural purposes.

Table 6.05 gives details of the consumption rate for 10 multifamily buildings of up to 16 floors in height and 13.500 m² construction area. The construction system used in Peru for multifamily buildings consists of concrete columns and plates, walls of brick and light-weight slab ceilings or in some cases solid concrete slabs. The information comes from three building enterprises and three institutions related to construction.

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[3] Arbaiza M., Christian: *Madera, Vivienda y Economía en Latinoamérica* (Wood, housing and economics in Latin America)

TABLE 6.04

CONSUMPTION OF WOOD IN ONE-FAMILY DWELLINGS

TYPE OF HOUSING		CONST. m^2	FORM-WORK m^2	CON-CRETE m^3	WOOD m^3	CONSUMPTION OF WOOD			DIRECT COST	
						$\frac{m^3 \text{ wood}}{m^3 \text{ conc}}$	$\frac{m^3 \text{ wood}}{m^2 \text{ const}}$	$\frac{\text{bd ft}}{m^2 \text{ const}}$	$\frac{\text{US\$}}{m^2 \text{ const}}$	$\frac{\%}{\text{d. c.}}$
Ventanilla	1 floor	48.0	101.2	27.6	1.6	0.058	0.033	14	15.6	9.1
Tallanes	1 floor	75.7	162.8	42.5	2.7	0.064	0.036	15	16.3	8.6
Santa Cruz	1 floor	80.2	192.4	36.5	3.7	0.101	0.046	20	22.6	12.0
Esmeraldas	1 floor	55.7	112.1	28.4	2.2	0.078	0.040	17	15.1	7.9
Ayacucho	1 floor	125.5	240.8	53.9	4.3	0.080	0.034	14	15.2	9.3
C. Cueto	2 floors	85.1	174.6	38.2	3.1	0.081	0.036	16	16.5	9.1
San Borja	2 floors	91.7	201.5	32.7	3.5	0.107	0.038	16	18.5	10.1
La Paz	2 floors	86.6	119.5	29.4	3.6	0.122	0.042	18	11.9	6.8
Próceres	2 floors	92.2	160.0	35.0	2.7	0.077	0.029	12	13.0	9.7
Capullana	2 floors	169.4	284.0	53.5	5.7	0.107	0.034	14	14.5	9.4
G.M.L. 1	1 floor	136.0	328.5	57.6	2.0	0.034	0.014	06	na	na
G.M.L. 2	1 floor	1,100.0	2,662.0	505.0	23.7	0.047	0.022	09	na	na
AVERAGE						0.080	0.034	14	15.9	9.2

na: Information not available.

TABLE 6.05

CONSUMPTION OF WOOD IN MULTIFAMILY BUILDINGS

TYPE OF HOUSING			CONST. m^2	FORM-WORK m^2	CON-CRETE m^3	WOOD m^3	CONSUMPTION OF WOOD			DIRECT COST	
							m^3 wood / m^3 conc	m^3 wood / m^2 const	bd ft / m^2 const	US$ / m^2 const	% / d. c.
G.M.L.	1 basemt.	8 floors	2,663	7,454	1,094	44.3	0.041	0.017	07	na	na
G.M.L.	2 basemt.	16 floors	9,500	24,415	3,705	145.1	0.039	0.015	07	22.5	6.7
G.M.L.	2 basemt.	13 floors	11,400	24,248	3,876	144.1	0.037	0.013	05	na	na
G.M.L.	1 basemt.	12 floors	13,500	32,309	4,803	192.0	0.040	0.014	06	na	na
H.V.S.A.	1 basemt.	12 floors	4,607	11,499	2,061	52.9	0.026	0.012	05	17.1	3.8
B.C.H.P.		4 floors	608	1,149	187	8.3	0.045	0.014	06	na	na
B.C.H.P.		10 floors	7,200	26,123	5,001	217.7	0.044	0.030	13	18.7	9.2
CAPECO		4 floors	1,400	2,874	371	35.5	0.096	0.025	11	22.1	11.7
M.E.S.		5 floors	2,200	7,232	827	99.0	0.120	0.045	19	33.7	12.7
ENACE		4 floors	1,152	2,885	289	11.5	0.040	0.010	04	18.0	15.2
AVERAGE							0.053	0.020	08	22.0	9.9

na: Information not available.

The average consumption rates obtained were 0.053 m^3 wood/m^3 concrete and 0.020 m^3 wood/m^2 of construction area, equivalent to 8 bd ft/m^2. As can be observed, the consumption of wood in multifamily buildings is 35 per cent less than in one-family dwellings, although much more concrete is used in high-rise buildings and a greater area of formwork is therefore required than in one- or two-storey houses.
The explanation is that traditional sawn wood formwork is used in one-family dwellings and plywood panels in multifamily buildings, especially in the case of fair-faced concrete. Though the investment is greater, the finish is better and both the consumption of wood and working times are lower.

6.6 THE COSTS OF FORMWORK

Tables 6.04 and 6.05 mentioned earlier also show that, in the case of one-family dwellings, wooden formwork represents on the average 9.2 per cent of the direct costs of the project, costing US$ 15.90/m^2 of construction area. In multifamily buildings, the costs of formwork represents 9.9 per cent of the total for the structure and the unit cost is US$ 22.0/m^2 of roofed-over area.
As can be seen, the unit cost of formwork in multifamily buildings is higher but the impact on the direct cost of the structure is less, compared with one-family dwellings, where the formwork costs less but has a greater impact on the project budget. The explanation might be the higher productivity obtained in the construction of high-rise buildings, which are characterized by the repetitiveness of the architectural design; this does not happen in one-family dwellings, which require separate formwork in each case.

6.6.1 Comparative cost of wooden and metal formwork for light-weight ceiling slabs

Table 6.06 shows the breakdown of two analyses of unit costs for lightweight slab formwork, the traditional wooden system and metal formwork belonging to the H.V.S.A. building enterprise. As can be seen, the cost of the traditional formwork US$ 7.41/m^2, i.e. more than double the cost of the metal formwork, namely US$ 3.58, while the useful life of the latter was considered to be 1,000 uses.
There is no doubt that with regard to reutilization, metal formwork can be a more economical option than wood, although it involves a very high initial investment, which becomes profitable only for large-scale structures or in the case of great repetitiveness of design.
If we assume that the cost for hiring metal equipment for 1 m^2 of lightweight slab is 3.30 soles (US$ 1.51)/m^2 and this is prorated to 1,000 uses, it would mean that the initial investment is US$ 1,510/m^2 of slab (including the profit from the hiring of the equipment).
On a conservative estimate, a building enterprise could not have less than 1,000 m^2, which means an investment of more than US$ 1 million, discounting the possible profit from rent. This initial investment limits the use of metal formwork for certain volumes of work or certain building enterprises, which must be isolated cases in relation with the total building activity in the country, where more than 30-50 per cent of the houses are built by self-help methods.

TABLE 6.06

COMPARATIVE COSTS OF FORMWORK FOR LIGHT-WEIGHT SLABS

		WOODEN FORMWORK			METAL FORMWORK		
MATERIALS	Unit	QUANTITY	PRICE	ITEM	QUANTITY	PRICE	ITEM
Black wire # 18	kg	0.1000	1.42	0.142	0.0115	1.42	0.02
Builder's nails	kg	0.1000	1.42	0.142	0.0444	1.42	0.06
Tornillo wood	bd ft	3.7255	1.90	7.079	0.0711	1.90	0.14
Diesel oil # 2	gl.	0.05	2.86	0.143	0.05	2.86	0.14
SUBTOTAL				7.506			0.36
LABOUR							
Foreman	h	0.0571	6.08	0.347	------	----	----
Operative	h	0.5714	5.53	3.160	0.5333	5.53	2.95
Semi-skilled	h	0.5714	4.50	2.571	0.2667	4.50	1.20
Unskilled	h	0.5714	4.04	2.308	------	----	----
SUBTOTAL				8.386			4.15
EQUIPMENT							
3% labour	%	0.03	8.386	0.252			
Extensible joist	Set						
(7 days' hire)	(24)				0.800	2.31	1.85
Metal stanchions	Set						
(7 days' hire)	(27)				0.900	1.61	1.45
SUBTOTAL				0.252			3.30
TOTALS	Soles			16.144			7.81
	US$			7.41			3.58

Source: H.V.S.A. building enterprise

6.7 CONCLUSIONS AND RECOMMENDATIONS

The consumption of wood in formwork in Peru can be considered as relatively efficient owing to the high cost of wood, about US$ 430/m³. The species most used is *tornillo*, although *Moena amarilla* and several varieties of oak are also used. The physical and mechanical properties of *tornillo* make it possible to use the wood 6-10 times on the average. All the wood used comes from natural tropical forests. In the case of the Lima market it comes from the central jungle and Ucayali. Finally, logs from eucalyptus plantations from the mountains are being used.

The other reason that would explain the moderately good use of wood in formwork is the fact that the most common practice in one-family dwellings is to sub-contract to a maker of formwork who comes with his wood to the site and, when the formwork operation is concluded, takes it back to be used at the following site. In this way, the sub-contractor takes care of the wood, because it represents his working capital, so that he obtains a high rate of reutilization.

This form of sub-contracting for formwork has limited the presence of large enterprises, specializing in the hiring or sale of formwork, and it can be noted that not more than five enterprises offer this type of service in the construction sector.

From the point of view of the *production of raw material*, many deficiencies have been noted regarding the standardization of dimensions and the quality of wood. The system of intermediaries in the marketing of wood leads to an increase in price, but not to an improvement in quality nor to the value-added component of wood. To some extent, the marketer has been obliged to buy wood of run-of-mill quality, that is to say, mixed lots of good and bad quality. On the other hand, the consumer has been accustomed to buying wood without its being grouped or classified in the warehouses or re-sawing plants.

Another problem in heterogeneous tropical forests, as is the case in Peru, is the selective logging of certain species, such as *tornillo*, which are used for formwork and wooden structure and are becoming exhausted day by day without reafforestation or are simply becoming more and more expensive owing to the distances between the wood processing and consumption centres.

Some progress has been made with regard to standardization, as a consequence of the interest shown by the board of the Cartagena Agreement over 15 years, to incorporate wood in the economy of the five Andean Pact countries, through its use as building material. However, those benefits do not include the use of wood in formwork, although there is a standard for the grouping of species for structural purposes, based on a visual classification rule and mechanical tests carried out during the projects of the Board, which could be used to group wood for formwork on a structural basis.

Finally, a Code for Design and Construction with Wood has been approved but does not cover the use of wood in formwork either. However, owing to the progress made, standards for wood as a structural material can be applied to formwork since it also has a structural function. This could be done on the initiative of the National Institute for Research and Standardization in Housing – ININVI.

Training for professionals on the subject of wooden formwork is provided in the Faculties of Civil Engineering of the country's universities, which do not offer courses for civilian construction. In addition, the subject of formwork in general is studied in courses and seminars sponsored by the Peruvian Chapter of the American Concrete Institute – ACI, the Association of Cement Producers – ASOCEM and the College of Engineers of Peru – CIP.

The training of workers and carpenters is the responsibility of the National Service for Training in the Construction Industry (SENCICO), which offers four special subjects, one of which is precisely that of wooden formwork, in courses intended for different levels of skills. Recently SENCICO has been authorized to train construction technicians in intermediate courses lasting two to three years, in which it will also have an opportunity to teach the use of wood in formwork.

From the *technological* point of view, some serious problems can be noted that militate against better use of wood. One of them is the low or almost non-existent level of industrial production of wooden formwork. There are no specialized enterprises that offer industrially based systems for sawn wood or plywood formwork. This lack represents an obstacle that will probably be solved by the effect of supply and demand in the market.

The two other problems are the high costs of release agents, which have to be replaced by less efficient alternatives, such as ordinary petroleum, and the absence of water-resistant plywood panels with phenolic adhesives. Only boards for internal use are manufactured with formaldehyde adhesives but without any type of surface treatment that would increase their useful life. In recent months, and in view of the expectation of reactivation of the construction sector, panels and formwork systems have begun to be imported from Chile and Argentina.

Accordingly, the market aspects of supply and demand for wooden formwork have been affected by the general recession in the country over the last ten years and by the crisis in the construction sector in particular. At present, timber warehouses sell only 30 per cent of the wood intended for building, whereas this sector formerly accounted for 80-90 per cent of sales. The most recent measures adopted by the Government in favour of construction and the economic reactivation of the country itself give expectation of an early reversal of the situation.

In the context of the situation described above, it is possible to suggest a number of recommendations that could make the use of wood in formwork more efficient:

(a) Production of raw material

- To promote the creation of collection centres for raw material in the production zones, with the availability of preservation services and above all facilities for drying wood.
- To implement integrated programmes for sawing logs in order to reduce the percentage of waste, stimulating the pre-dimensioning of boards for formwork, taking into consideration the preferred dimensions that are most commonly used, i.e. 1½ x 8", 1½ x 10" and 1½ x 12" in lengths of 8, 10 and 12 feet.
- Identification of new forest species to replace *tornillo* with more abundant species that have similar physical and mechanical properties, e.g. *cachimbo*, *utucuro* or *lagarto* from the Pucallpa zone and *nogal amarillo*, *palo hueso*, *manzano*, etc. from the central jungle.
- To improve the quality of plywood panels by introducing more resistant wood species, water-resistant phenolic adhesives and appropriate coating of surfaces in order to increase the useful life of panels in contact with concrete.

(b) Standardization

- To develop a visual classification rule for defects, with relevant tolerances for formwork wood that is intended to withstand stresses that are not permanent but for which a process of analysis and structural design is necessary.
- To establish a structural group of wood for formwork taking as a basis construction technical standard E.101 "Grouping of wood for structural use", which establishes values for density, modules of elasticity and permissible stresses for groups A, B and C.

(c) Training

- The preparation of teaching material and reference works with regards to the use of wood in formwork, intended for different levels of teaching, e.g. technical manuals, practical manuals and elementary technical textbooks.
- To implement courses and training for "Wood Classifiers" specializing in studies for middle managers.
- To stimulate the development of university theses on wooden formwork systems, especially for students of civil engineering, with the support of building enterprises and research centres.

(d) Technology

- To promote the creation of industrially based solutions for formwork and the establishment of specialized enterprises that would give technical assistance and offer hire-purchase services for prefabricated sawn wood formwork systems.
- To introduce new types of release agents whose quality and price would stimulate their utilization in the construction of one-family dwellings and medium-sized buildings.

(e) Market

- To carry out a market study to identify present and potential opportunities for the commercial promotion of building elements in general and wooden formwork in particular.
- To promote a "Competition of ideas" among students and professionals in construction with the aim of finding new solutions and industrially-based systems for wooden formwork.

(f) Institutional support

- To support the work of the *Instituto Superior Enrich Magis de la Construcción*, under the auspices of SENCICO, which would for the first time in Peru train intermediate-level building technicians who could specialize in the use of wood in concrete formwork.
- To promote coordinated action on the better use of wood in formwork and the preparation of a plan of action on wooden formwork by institutions such as the Association of Cement Producers, the Peruvian Chapter of the American Concrete Institute, SENCICO, the National Timber Confederation, the National Forestry Chamber and the Peruvian Construction Chamber.

Finally, it is necessary to take into account and utilize the advantages of commercial integration existing within the Andean Pact, whose technical organ is the Board of the Cartagena Agreement, with headquarters in Lima. Thus, the member countries, Bolivia, Colombia, Ecuador, Peru and Venezuela are part of the Amazonian Cooperation Treaty, jointly with other Latin American countries; as from 1994, the Temporary Secretariat will also have its institutional headquarters in Lima, Peru.

Also, in Peru and in other countries with tropical forest resources, national forestry action plans have been implemented for a number of years under the auspices of FAO and various agencies for international technical cooperation. In the case of Peru, there are various projects for the industrial use of wood as a building material, which could include activities related to the use of wood in formwork.

7.0 THE MULTIPLIER EFFECT OF THE USE OF WOOD AS BUILDING MATERIAL.

In a recent research project entitled *Madera, Vivienda y Economía en Latinoamérica* (Wood, housing and economics in Latin America)[4], it was demonstrated that construction using wood was a better alternative than "traditional" construction using cement, iron and brick, owing to its multiplier effect on the economy of the Latin American countries, from the point of view of the generation of employment, the consumption of energy and the capital goods requirements for the manufacture of building materials.

After studying the process of production of each of the building materials in the light of these three variables, a simulation model was run for solution of the existing housing deficit in Peru, with four different construction systems, proving that construction using wood was not only more economical than "traditional" methods, but

[4] Arbaiza, M. Christian. (1993)

also offered the advantage of a 77 per cent higher generation of employment, 58 per cent lower consumption of energy and 23 per cent lower investment in capital goods for the country.
These conclusions were based on the use of wood as a structural material but the results are not the same when wooden formwork is compared with its competitor, namely, metal formwork. In other words, it is a question of finding out the multiplier effect of the three above-mentioned variables if all structures used metal formwork as compared with the present alternative of wooden formwork.
While it would hypothetically be possible to solve outright the problem of constructing the housing necessary to make good the housing deficit in Latin America, which is calculated at 24 million units, the only advantage of using wooden formwork would be related to the creation of new jobs, since its use would generate 2.8 times more jobs than metal formwork. However, the latter type of formwork has in turn the advantage of consuming 65 per cent less energy and 63 per cent the manufacture of steel requires less machinery and other tangible fixed assets than the processing of wood.
A first reason that explains this unexpected result would be that in the research study mentioned, a wooden house was compared with a traditional brick, cement and iron house, in which the latter input had a minor impact on construction and in which, by contrast, concrete and brickwork fundamentally predominated. Comparing formwork, steel has a major impact on the system and thus its multiplier effect is felt in another way.
A second explanation is related to processing the raw material in each case to obtain the building material itself. It is possible to talk of the industrial processing of steel but it is difficult to state that in Latin America there is genuine industrial processing of wood, especially if it is merely sawn.
The result of the heterogeneity of the forest, the processes for extraction of the raw material, climatic aspects, wastage during processing and in the marketing chain is that "the industrialization" of wood in fact generates many jobs but is at the same time proportionally a greater consumer of energy (especially if one takes into account the process of kiln-drying) and requires more capital goods, owing to low productivity through all stages of the so-called "wood chain".
This conclusion would reaffirm the necessity of optimizing the use of wood in formwork, which is furthermore used temporarily, and of increasing efficiency in its use. The alternative might be to increase the present value-added component of wood, for example, by a greater use of wood as a permanent structural element in the construction of buildings.

8.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Table 8.01 shows the principal characteristics of the housing and construction sector in the six countries analysed. The housing deficit in those countries affects approximately one-third of the population, the deficit being lower than one-third in Peru and above the average in Mexico, Ecuador and Argentina. The total housing deficit in the six countries is 19 million units for a population of 291 million, it being estimated that the Latin American deficit is approximately 24 million dwelling units.
The annual rate of construction in Ecuador, Chile and Peru is equivalent to an average of 60,000-70,000 dwellings, and the countries with the highest figures are Mexico with more than 600,000 units and Brazil with more than 800,000 units. The construction sector has an average share of about 5 per cent of total GDP, being most dynamic in Brazil with 7.4 per cent and least dynamic in Ecuador, namely, 2.8 per cent in the period 1986-1992.
The most commonly used construction system is based on cement and reinforced concrete and is considered as the "traditional" construction system. In the case of floors, the predominant material is cement, except in Ecuador, which uses wood more (laid on cement). In walls, ceramic brick or concrete blocks are most commonly used in all cases. In roofs, concrete or light-weight slabs are used, with different types of roofing material.

TABLE 8.01

CHARACTERISTICS OF THE HOUSING SECTOR AND CONSTRUCTION

	MEXICO	ECUADOR	ARGENTINA	CHILE	BRAZIL	PERU
POPULATION	65,200,000	10,782,000	32,608,687	13,417,900	146,900,000	22,128,466
No. OF HOUSES	17,700,000	2,339,281	8,515,441	3,260,674	35,578,857	4,363,436
HOUSING SHORTAGE	6,400,000	630,000	2,700,000	700,000	6,655,000	1,300,000
ANNUAL CONSTRUCTION	625,000	60,000	128,326	70,000	880,000	70,000
GDP/CONSTRUCTION	5.0%	2.8%	4.8%	5.4%	7.4%	6.0%
PREDOMINANT MATERIAL						
- Floors	Cement	Boarding	Mosaic	Cement	Cement	Cement
- Walls	Masonry	Masonry	Masonry	Masonry	Masonry	Masonry
- Roofs	Concr. slabs, arch	Tiles, concr. slabs	Concr. slabs, mosaic	Asbestos cement	Clay tiles	Light-weight slabs, Concrete slabs
UTILIZATION OF WOOD						
- Walls	8.0%	9.2%	6.7%	20.0%	20.2%	14.8%
- Roofs	55.0%	81.0%	52.1%	80.0%	93.6%	69.0%
TYPES OF HOUSING						
- One-family	84.2%	92.2%	81.8%	n.a.	90.0%	95.0%
- Multifamily	15.8%	7.8%	18.2%	n.a.	10.0%	5.0%

Source : Taken from the report

n.a. : Information not available

As was said earlier, the use of wooden formwork is intimately linked to the use of concrete and, as can be observed there is a predominant culture for the use of concrete in Latin America although the use of wood has recently tended to increase in walls (13 per cent on the average) and especially in roofs (72 per cent on the average).

Finally, statistics indicate that the commonest type of housing in cities in the six countries studied is the one- or two-storey one-family dwelling, which represents on the average more than 88 per cent of the total housing stock. This aspect is very important for the purposes of the present study, since, although metal formwork has recently replaced wooden formwork in the construction of multifamily buildings to some extent, that does not apply to the construction of one-family dwellings, where wooden formwork is the commonest system.

This trend in construction confirms the hypothesis that wood was, is and will continue to be the predominant material for use in formwork, for which reason action should be taken to rationalize and optimize its use in the shortest possible time. This is particularly important if we bear in mind that in some countries self-help construction of low density housing is still the formula most commonly applied to solve the problem of the housing deficit.

Table 8.02 describes the most important characteristics of the forestry sector in the six countries studied. As can be seen, the forestry reserves available in the countries analysed are immense, Brazil being outstanding as it possesses 63 per cent of the Amazon basin, followed by Peru, with an 11 per cent share of that forest area, which in turn is the largest tropical forest reserve in the world.

Forestry resources occupy on the average 32 per cent of the total territory, Ecuador, Brazil and Peru being the countries with the greatest percentage of forestry resources, which occupy 42, 48 and 59 per cent of the territory, respectively. The lowest percentage of forests in relation to the total territory is in Chile, with 7.5 per cent, followed by Argentina with 13 per cent and Mexico with 20 per cent.

The largest areas of reafforestation are in Brazil with 6,200,000 ha and Chile, Mexican and Argentina with figure fluctuating between one million and 1,400,000 ha. The reafforestation effort in Peru and Ecuador is even lower, above all in terms of the potential of land available for that purpose. To be precise, in the four countries with the largest forestry plantations, it is wood from reafforestation projects that is most used in construction formwork, the most striking process being that under way in Chile with *Pinus radiata*.

Table 8.03 shows the per capita consumption of sawn wood and plywood panels in the six countries studied. As mentioned before, the production of sawn wood and plywood panels is highly dynamic in Chile, particularly in the light of the volume of forestry resources available. Similarly, attention must be drawn to the case of Ecuador, both with regard to the per capita consumption of plywood panels and the production of sawn wood, although in the latter case 55 per cent of production is carried out by using power saws. And "mountain timber" produced by power-saw operators is principally intended for the construction market and for use in concrete formwork.

It is calculated that the principal market for sawn wood is the construction sector, which takes about 40-60 per cent, followed by the furniture market which absorbs between 20 and 40 per cent of production, while the rest goes to other industries, generating different levels of value added.

There is a great diversity in the measurement units used in marketing wood in the six countries studied. The board foot, which is a nominal dimension of 1" thickness, 12" width and 12" length is used in Mexico and Peru. In Ecuador lengths are measured in feet and rods (*varas*), thicknesses in inches and widths in centimetres. In Brazil and Argentina wood is marketed in cubic metres and finally in Chile the board inch (*pulgada maderera*) is used, i.e. 1" thickness, 10" width and 3.2 m length for pine wood and 3.6 m for native timber.

TABLE 8.02

PRINCIPAL CHARACTERISTICS OF THE FORESTRY SECTOR

	MEXICO	ECUADOR	ARGENTINA	CHILE	BRAZIL	PERU
RESERVES : - Forests (ha) - Conifers (ha) - Broad-leaved (ha)	 38,890,000 18,660,000 8,000	 11,500,000 78,000 11,422,000	 36,000,000 1,000,000 35,000,000	 5,500,000 1,400,000 4,100,000	 406,200,000 6,200,000 400,000,000	 75,784,000 263,000 75,521,000
TERRITORIAL COVERAGE	20%	42%	13%	7.5%	48%	59%
TOTAL REAFFORESTATION	1,300,000	78,000	1,100,000	1,400,000	6,200,000	263,000
No. of sawmills	1,543	566	1,300	1,618	14,000	540
Timber production (m^3)	5,509,000	1,450,000	1,100,000	3,060,000	10,400,000	489,300
No. of plywood plants	35	06	22	n.a.	n.a.	10
Production of panels (m^3)	184,000	78,000	56,800	272,000	1,251,000	23,700

Source : Taken from the report
n.a. : Information not available

TABLE 8.03

PER CAPITA CONSUMPTION OF SAWN WOOD AND PLYWOOD PANELS 1985-1990
(m^3/1000 inhabitants)

	YEAR	MEXICO	ECUADOR	ARGENTINA	CHILE	BRAZIL	PERU
Sawn wood	1985 1990	32 35	127 132	39 54	122 173	130 117	28 43
Plywood panels	1985 1990	3.5 1.8	4.9 5.4	1.4 1.8	1.4 2.5	4.4 6.2	1.0 2.4

Source : Project PD 137/91 *Estrategias para la Industria Sostenida de la Madera en Ecuador* (Strategies for a sustained timber industry in Ecuador). 1993

Table 8.04 shows the consumption rates for wood in formwork and the number of uses or reuses depending on the type of product used.

It can be seen that various species of the pine family from reafforestation projects represent the types of timber most used in concrete formwork. To a lesser extent logs are used in Ecuador, Brazil and Peru, especially eucalyptus stanchions or studs. In Ecuador and in Columbia, bamboo is much used for various purposes, specially in the coastal zones. The broad-leaved species are used in Brazil and especially in Ecuador and Peru. With regard to the number of uses of sawn wood in formwork, better reutilization values are observed in Mexico, Brazil and Peru, moderate values in Argentina and Chile, and very low values in Ecuador. The explanation of the low level of utilization in the latter country is the low cost of "mountain timber" used in formwork whose price fluctuates at around US$ 40-60/m^3 in comparison with *Pinus radiata* in Chile, whose cost is US$ 150/m^3 or *tornillo* in Peru, whose approximate cost is US$ 430.

In relation with the rates of consumption of wood in formwork it is necessary to differentiate between consumption in one-family dwellings and in multifamily buildings, since the latter require a larger quantity of reinforced concrete and thus a larger area of formwork, either sawn wood or plywood panels.

In the case of one-family dwellings, the average consumption was 0.13 m^3 of wood per m^3 of concrete. The average consumption in terms of roofed-over area was 0.027 m^3 of wood per m^2 of construction area or, which is the same, 12 bd ft per m^2 of roofed-over area. Consumption was lowest in Argentina and Brazil (0.014 and 0.017 m^3 wood/m^2 const) followed by Chile and Mexico (both 0.023 m^3 wood/m^2 const), that of Peru with 0.034 m^3 wood/m^2 const and the highest consumption figure, Ecuador with 0.052 m^3 wood/m^2 const.

The lower consumption of wood for formwork in dwellings in Argentina, Brazil and Mexico, is the result of the type of constructional system employed in floor structures and roofs, since prefabricated concrete joists and bricks for arches have recently been used, which notably reduce requirements for formwork. In Chile, wood is much used above all in roofs. In the case of Peru, the higher level of consumption is explained by the use of cast *in situ* light-weight slabs, which require formwork; in Ecuador, it is explained by the low level of reutilization of "mountain timber".

TABLE 8.04

RATES OF WOOD CONSUMPTION IN FORMWORK

		MEXICO	ECUADOR	ARGENTINA	CHILE	BRAZIL	PERU
- TYPE, SPECIES		Pine	Broad-leaved, Eucalyptus, Bamboo	Pine	Pine	Pine, Broad-leaved	Broad-leaved
- No. OF USES OF WOOD		04-12	01-03	03-06	02-06	04-10	04-14
- No. OF USES OF THREE-PLY		07-50	08-10	15-25	08-20	10-20	03-05
- CONSUMPTION OF WOOD							
$\frac{m^3}{m^3 \text{ conc}}$	HOUSES	0.080	0.29	0.08	0.12	n.a.	0.080
	BUILDINGS	n.a.	0.13	0.10	0.11	0.12	0.053
$\frac{m^3}{m^2 \text{ const}}$	HOUSES	0.023	0.052	0.014	0.023	0.017	0.034
	BUILDINGS	n.a.	0.059	0.030	0.037	0.043	0.020
$\frac{\text{bd ft}}{m^2 \text{ const}}$	HOUSES	10	22	06	10	07	14
	BUILDINGS	n.a.	25	13	16	18	08

Source : Taken from the report. Building enterprises
n.a. : Information not available.

In multifamily buildings, the consumption of formwork is greater than in one-family dwellings owing to the greater requirement for reinforced concrete in the structure. The average consumption was 0.10 m^3 wood/m^3 concrete or 0.038 m^3 wood/m^2 construction area, i.e. 16 bd ft/m^2 of roofed-over area. That would mean that on the average, large buildings consume almost 40 per cent more wood per unit of construction area than single family houses or dwellings.

In the case of large buildings, in which plywood panels are predominantly used instead of sawn wood as in the case of dwellings, the highest consumption levels were observed in Ecuador (0.059 m^3 wood/m^2 const) but moderate figures in Argentina, Chile and Brazil with 0.030, 0.037 and 0.043 m^3 wood/m^2 const, respectively, the lowest figure being found in Peru with 0.020 m^3 wood/m^2 const or, which is the same, 8 bd ft/m^2 roofed-over area.

If we take into account the consumption rates for wood products in formwork and multiply them by the number of one-family dwellings and multifamily houses constructed annually per country, wooden formwork would be responsible on the average for consumption of 16.9 per cent of the total production of sawn wood and plywood panels. The figures obtained are: 16.4 per cent in Mexico, 14 per cent in Ecuador, 27.6 per cent in Argentina, 6.0 per cent in Chile (considering only apparent consumption at national level), 10 per cent in Brazil and 27.6 per cent in Peru.

As was mentioned earlier, it is considered that the construction sector generally consumes between 40 and 60 per cent of the output of sawn wood and plywood panels. If wooden formwork accounts for less than 20 per cent, that means that there are other uses for wood in construction such as: structural elements, carpentry, finishing and above all wooden roofs, which consume the rest of production. However, wooden formwork probably represents the most important product consumed in the construction sector.

Finally, table 8.05 shows the impact of the costs of formwork on the direct costs of the projects.

In the case of housing, the average cost of formwork was US$ 15 per m^2 of roofed-over area and US$ 24.6 in the case of multifamily buildings. On the average, these costs account for 5.7 and 8.4 per cent of the direct cost of the project and constitute the only variable cost component of a project, especially in the case of structures. It often depends on the costs of formwork and the efficiency of its use whether a public tender is awarded or a price competition is won, especially in large building projects.

A final comment that can be deduced from the above table is the high costs per m^2 of formwork in Argentina, owing to the cost of labour. The contrary applies in Ecuador, where, as a result of the relative cost of labour and wood for formwork, the figures for both types of housing are lower and their impact on the total direct costs of the project is less important.

It is interesting to mention the existence of a series of standards which building companies use when they calculate the volumes of consumption of wood and concrete. For example, in almost all countries it is considered that it is necessary to multiply the roofed-over area by a factor of 2 to 2.5 to calculate the area of the formwork or what is also called the "moistened area".

Similarly, in Brazil, Editorial PINI, which specializes in building, considers that on the average 12 m^2 of formwork area is needed per m^3 of concrete used in the structure. In Argentina it is assumed that 0.18 - 0.20 m^3 of concrete is consumed per m^2 of roofed-over area if the foundation is not included and 0.22 - 0.24 m^2 of concrete per m^2 of construction area if the foundations are included. In Peru, this figure rises to 0.39 m^3 of concrete per m^2 of roofed-over area, perhaps because of the earthquake resistance requirements of buildings.

Some recommendations of a subregional or Latin American character are proposed below and could be implemented for the purpose of optimizing the use of sawn wood and plywood panels in formwork for concrete.

(a) Production of raw material

- To identify new forest species that would replace in quality and durability those that are at present being marketed, making logging and reafforestation of the woods more profitable.
- To improve the logging and processing of wood in general (not only that for formwork), identifying an optimization programme starting with the primary process, so as to eliminate waste and improve quality control in sawmills. That could facilitate the reduction of costs, using off-cuts from boards and planks for the prefabrication of formwork.
- To increase the value-added component of wood for formwork, establishing quality grades, using kiln-drying and offering planed wood and not simply sawn wood.
- To improve the quality of plywood panels, introducing more resistant species of wood, water-resistant phenolic adhesives and suitably coated surfaces in order to improve the useful life of panels in contact with concrete.

TABLE 8.05

IMPACT OF THE COSTS OF FORMWORK ON THE DIRECT COST OF STRUCTURES

		MEXICO	ECUADOR	ARGENTINA	CHILE	BRAZIL	PERU
- COST OF FORMWORK							
US$ / m^2 const	HOUSES	12.03	2.70	$ 26.26	$ 18.01	n.a.	$ 15.9
	BUILDINGS	n.a.	13.13	$ 56.10	$ 19.73	$ 12.20	$ 22.0
% / direct cost	HOUSES	6.0 %	2.4 %	3.6 %	7.3 %	n.a.	9.2 %
	BUILDINGS	n.a.	4.6	9.4 %	8.5 %	9.7 %	9.9 %

Source : Taken from the report. Building enterprises.
n.a. : Information not available.

(b) Standardization

- To promote the establishment of structural groups of timber species for formwork that would be offered on the market in different qualities and with different value-added components so as to permit various options for finish and durability at prices corresponding to the quality of the product.
- To support the preparation of technical specifications or practical guides for users of traditional formwork incorporating sawn wood or plywood panels, specifying alternative formwork systems, solutions for structural joints, groups of related species, permissible loads, structural details and recommendations for good building practice.
- To develop a visual classification rule with regard to defects with relevant tolerances for wood to be used in formwork that would be intended to withstand non-permanent stresses that would, however, require a process of structural design and analysis.

(c) Training

- To prepare technical and audio-visual material on wooden formwork that would be a compilation of good practice by skilled labour intended for technical staff, university students and building professionals. Technical manuals, practical manuals and elementary technical guides can be developed.
- To coordinate action between Latin American organizations for the training of site carpenters and workmen, intended for the exchange of experience and for harmonizing levels of training with regard to the use of wood in formwork.
- To evaluate the content and scope of courses for basic subjects taught at universities with regard to the use of wooden formwork, with the aim not only of optimizing use of the resource but also of reducing construction costs. In addition, specialized courses or periodic extension seminars should be held with emphasis on construction practice and new techniques for wooden formwork and striking.
- To promote the development of university theses on wooden formwork systems, especially for civil engineering students, with the support of building enterprises and research centres.

(d) Technology

- To promote the design of new and better systems of industrially or semi-industrially produced formwork using sawn wood and plywood panels that can be used in multifamily buildings and in one-family dwellings.
- To analyse the possibility of using new alternative release agents according to the type of formwork surface, the finish of the concrete, the useful life of the wood and the resultant cost of formwork.
- To promote the utilization of new accessories and materials for wood-based formwork such as: double-head nails, stronger and rigid plywood panels with finished surfaces, or new products such as wood cement particle boards (of the Bison type) or MDF (Medium Density Board).

(e) Market

- To carry out a market study to identify the present and potential opportunities for the commercial promotion of construction elements in general and wooden formwork in particular.
- To promote the establishment of enterprises specializing in wooden formwork that would offer standardized elements on a rental basis in order to meet demand for the construction of one-family dwellings and multifamily buildings of medium height and high density.
- To promote a "competition of ideas" at Latin American level among students and professionals in construction with the purpose of highlighting the importance of wooden formwork and finding new industrially based solutions and systems.

(f) Institutional support

- To implement a Latin American regional programme with the support of UNDP, associating the timber dealers' association with the institutions that are members of the Inter-American Cement Federation or the Inter-American Federation of Chambers of Construction. The use of wood in formwork is a subject of mutual interest to lumber dealers and producers or consumers of cement and concrete.

(g) Financing sources

- For the financing of the external component of the initiatives proposed, assistance could be requested from bilateral cooperation agencies, such as JICA (Japan), GTZ (Germany), FINNIDA (Finland), CIDA (Canada), SIDA (Switzerland), USAID (United States) as well as from international organizations such as ILO, ITTO, FAO, UNDP, ITC/UNCTAD/GATT, the Treaty for Amazonian Cooperation, etc. Similarly the assistance of financial agencies such as the World Bank could be sought, particularly through the GEF (Global Environmental Facility) or the Inter-American Development Bank (IDB). Internal resources can in general be made available as counterpart contributions of national agencies out of their budgets.

Projects could be implemented in the framework of the ongoing integration processes such as the North American Free Trade Agreement (NAFTA), the Permanent Secretariat of the General Treaty on Central American Economic Integration (SIECA), the Andean Group (AG) or MERCOSUR.
It is necessary to act immediately in optimizing the use of wood in formwork, and any effort made will be supported and welcomed both by the forestry industry and the construction industry, particularly on the part of the producers and/or consumers of cement and concrete. There is a favourable scenario for the implementation of a plan of action that would act as a catalyst for the concurrent interest of various sectors of the economy in the Latin American countries.

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