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CONSTRUCTION EMPLOYMENT, SKILLS, AND FACTOR SUBSTITUTION

General Principles and an Application to Core Housing

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Introduction

As long as unemployment is widespread, whatever creates more jobs at no cost is good, and what creates jobs with a net gain besides the employment is better.[1] Such opportunities exist in construction, as elsewhere, and often they seem to contradict common sense and experience. After all, economic development is about higher productivity, meaning less employment for any given volume of output.

Employment policy for any sector should not be made without considering productivity in all sectors. Productivity in a sector can rise or fall while it expands with more output and employment, but nothing is worthwhile if offset by contractions elsewhere. These contractions, together with possible distributional effects and externalities, are the ultimate cost of more employment. One seeks more employment, but not at any cost.

One also seeks more productivity, but not at any cost. If construction sites are organized better and if workers learn to be more skilled, those changes can raise productivity without cost or reduced output elsewhere. But, on the other hand, if workers build more per hour because of spending on better equipment and more easily installed materials, that change may lower productivity and output elsewhere. The capital and foreign exchange needed could have been used by workers in other sectors. Without it they might have been unemployed. The extra building productivity is worthwhile only if greater in value than what is lost is agriculture, manufacturing, mining and services.

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[1]The author is indebted to Michael Farbman of the Agency for International Development for helpful suggestions during all stages of this project. Surveys were organized with great diligence by Ehsan Ahmed, Pakistan; Norma Botero, Colombia; Abel Centurión and Jorge Bernedo, Peru; Ridha Ferchiou, Tunisia; Nimal Gunatilleke, Sri Lanka; Davinder Lamba, Tara Chana, and Suresh Amlani, Kenya; and Manenga Ndulo, Zambia. I am grateful to Ting-ing Ho, Ehsan Ahmed, and Nimal Gunatilleke for computations.

Labor, capital, and foreign exchange in market economies are never simply ordered about and shifted from one sector to another in gross quantitative terms. No one dictates that construction will get exactly 15 percent, agriculture 35 percent, etc. Instead the decisions are made in terms of equipment prices, interest rates on loans, foreign exchange rates, taxes, insurance, utility rates, wages, and salaries. Contractors bid for a proposed project in accordance with the least-cost combination of all these factors plus a margin of profit. If all bids are too high from the point of view of the buyer, the project is not built, and the resources are available for other projects or other economic sectors.

According to neoclassical assumptions of perfect economic competition, output and welfare will be optimized if prices and wages are allowed to vary freely, shifting resources about until no further improvement in productivity is possible. The assumptions (perfect knowledge, no externalities, etc.) never hold fully, and that justifies some interference with prices and wages but not all that occurs in practice. For example, some years ago Gordon Hughes estimated that monopolistic high prices of cement in Kenya had led to an overuse of timber in construction.[2]

In this paper we are concerned with the potential for using onsite labor in construction. How does the level of wages of skilled and unskilled workers affect the proportions in which these two are used compared with one another and compared with other factors of production? These other factors in construction are not just various types of mechanizing equipment like

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[2]Gordon Hughes, "Low-Income Housing: A Kenyan Case Study," in I.M.F. Little and M.F.G. Scott, eds., Using Shadow Prices (London, 1975), pp. 51-52.

lifting and mixing devices. Capital consists primarily of work-in-progress and inventories or materials. If onsite labor is expensive, then work can be accelerated through more processed, hence more expensive, materials and components.

We can simplify the analysis by dividing inputs simply into labor (skilled, unskilled) and non-labor. The objective is to determine the extent to which more or less onsite labor can be incorporated in structures without economic loss as wages rise or lag behind changes in non-labor costs. That changing extent of factor use is called "the elasticity of substitution." It relates the percentage decline in labor as an input for a given structure to the percentage rise of wages compared with non-labor prices. If no decline in labor takes place, the elasticity is zero: Substitution is impossible. If all labor is displaced, the elasticity is infinite. If the percentage decline in labor is equal to the percentage rise in relative wages, the elasticity is unity. In that case, the receipts of onsite labor as a whole are unchanged. For example, 10 percent fewer workers receive 10 percent more pay per hour. The same approach can be used with respect to the number of skilled and unskilled workers employed.

The rest of this paper is thus an empirical account of employment and substitution possibilities as related to the level of wages and fringe benefits of construction workers in developing countries. Any casual survey of experience will suggest that substitution possibilities are strong. Attempts to be more than casual run into problems of finding accurate data. The paper concludes with a comparison of costs and employment in building an identical core house in six developing countries.

Rates of Labor Substitution According to a Variety of Sources

The most casual observer can tell that the labor-intensity of construction falls with economic development. One sees fewer workers on the

construction sites of more developed countries, and one hears that work is finished faster. The problem is to identify and to quantify the causes. Specifically, to what extent are changes in building design and working methods due to rising wages and skill levels? If technological change is not influenced by the quality and cost of workers, then labor policies will not change employment levels.

My own interest in this question began in 1968 when I tried to determine the extent to which a set of 11 innovations was spreading in Peru, where building wages and fringe benefits were much higher than in Colombia, Mexico, and India. It turned out that all eleven were labor-saving. Eight also raised material costs, while three lowered them.[3]

Later John McConnaughey and I surveyed the technical literature in English since 1950 and analyzed the economic characteristics of the 65 innovations in developing countries that were sufficiently well documented. Two-thirds of innovations reduced labor costs with the effect about equally distributed among skilled and unskilled workers. Less than 10 percent raised labor costs, usually for the sake of better quality. Equipment cost rose for 37 percent of innovations, primarily those that were mere "off-shelf" imports from abroad or those that adapted advanced technology to local conditions. Innovations that attempted to improve traditional building techniques but without thorough scientific research appeared to be least successful. Like science-dependent innovations, they were least oriented toward reducing costs and viewed as risky. Users perceive as risky any

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[3] W. Paul Strassmann, "Innovation and Employment in Building: The Experience of Peru," Oxford Economic Papers, July 1970, pp. 243-259.

complex need to change design, materials, and sitework simultaneously.[4]

Almost no case studies or descriptions of novel techniques include a systematic economic comparison of alternatives at different wage levels. Of course, most technological change consists, not of innovations, but of a choice among known options. For some of these, Gerard Boon has estimated the labor-capital elasticity of substitution with Mexican data:[5]

Process	Elasticity of Substitution
Excavation: Shovels vs. mobile crane	1.09
Concrete mixing: Shovels vs. portable mixer	1.03
Vertical transport for bricks and concrete:	
a. Manual winch vs. power winch	1.20
b. Power winch vs. tower crane	1.15
c. Manual winch vs. tower crane	.97

These elasticities for specific processes are somewhat higher than that for Mexican construction as a whole during 1950-1967: 0.88. During that period wages rose at an annual 8.1 percent and other inputs at an annual 6.0 percent. The displacement of workers through mechanization and better materials was somewhat less than might have been expected with an elasticity of 1.0.[6] The Mexican elasticity was less than that of the United States, 1.12[7],

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[4]John S. McConnaughey and W. Paul Strassmann, "The Economic Characteristics and Origins of Building Innovations in Developing Countries," Journal of Developing Areas, January 1979, pp. 143-159.

[5]Gerard Boon, unpublished estimates based on data used in "Employment Creation by Technology and Output Variation in Mexico," in Christian Araud, et. al., Studies on Employment in the Mexican Housing Industry, Development Center Studies, Employment Series No. 10 (Paris: OECD, 1973) pp. 109-210.

[6]W. Paul Strassmann, Housing and Building Technology in Developing Countries (East Lansing: MSU International Business and Economic Studies, 1978), p. 39.

[7]Peter J. Cassimatis, Economics of the Construction Industry, Studies in Business Economics, No. 111 (New York: National Industrial Conference Board, 1969), p. 72.

but very close to the 0.86 for a sample of 15 countries during 1960-1970.[8]

A problem with elasticities for entire countries or sets of countries is that apparent labor-nonlabor substitution may not be due to differences in wage levels at all but show instead that at different times and places different sorts of buildings were constructed. Even if wages remain the same, a shift toward highrise apartments will reduce employment per dollar invested. On the other hand, Boon's process-specific substitution elasticities cannot be aggregated easily into an assessment of general trends. Too much would have to be known about too many additional options. Actual technological change consists mainly of a myriad of small variations in procedures that cannot be specified in advance because builders and foremen do not think of them until confronted by higher costs of some component. After introduction, they take the change for granted and cease to be aware of it.

Another problem is that employment and wage data are notoriously inaccurate. Much construction work is subcontracted and sub-subcontracted, and the general contractor often has no idea about the number of workers actually needed on the site. His bids are based on the cost of components. Where labor legislation puts wages and fringe benefits up to unrealistic

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[8] Strassmann, Housing and Building Technology in Developing Countries, p. 40. Ranked according to per capita income, the countries were Kenya, Syria, El Salvador, Turkey, Cyprus, Argentina, Spain, Israel, Puerto Rico, United Kingdom, Belgium, France, Austria, Sweden, and the United States. For the technique of estimation, see Kenneth Arrow, Hollis Chenery, Bagicha Minhas, and Robert Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economic and Statistics 43, (August 1961): 225-50; Jan Kmenta, "On Estimation of the CES Production Function," International Economic Review 8, (June 1967): 180-89, and Elements of Econometrics (New York: Macmillan, 1971), pp. 463-65. For a thorough review see Jacques Guade, "Capital Labour Substitution Possibilities: A Review of Empirical Research." chapter 2 in Bhalla, ed., Technology and Employment in Industry (Geneva: International Labour Office, 1975), pp. 35-58.

levels, strict enforcement is impossible even if incorruptible inspectors check payrolls weekly. If unemployment is high, workers will share the job with a brother or cousin or they will agree to deliver five days of work for four days of pay. In Peru under the recently replaced military government, we found that contractors said that they never paid unskilled workers less than the daily minimum of US$7.21 in wages and fringe benefits. The average unskilled worker whom we interviewed said he only received the equivalent of US$4.35. Skilled workers said they received 35.6 percent more, while builders said the skill premium was only 7.0 percent, incredibly low, but specified by law. Peruvian census figures show that construction employment in the formal sector is much higher than could be deduced by adding up all reported on payrolls. Other countries with such pressures show the same pattern.

Substitution in Expandable Core Housing

For a more accurate estimate of the employment effects of rising wages, we therefore undertook a project of interviewing both builders and workers in six countries, using detailed specifications of one floorplan translated into English and Spanish. The original is in French and refers to a 24.9 m^2 expandable core dwelling made with concrete blocks and reinforced concrete posts and a collar beam. It was designed by the Société Nationale Immobilière de la Tunisie (SNIT).[9] With the support of a $5 million loan from the U.S. Agency for International Development, about 1,400 such units were completed during 1980 at Tunis, Monastir, Mahdia, Gabes, and other locations. For 500 units at Sousse, the Tunisian sponsors had

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[9] Tunisie, Cinquieme Plan de Developpement: Le Secteur Habitat - Examen et Commentaires. Washington, D.C.: IBRD, Working Paper, 1977.

already provided a 9 m^2 second room, but this may not have been necessary since virtually every owner-occupant had added his own elsewhere. In April 1981 I saw as many as three rooms added, including two on the second story, at Ouardia and Sidi Fatallah near Tunis. A few had changed the position of doors, windows, and plumbing.

During 1979-1980 we obtained detailed breakdowns of the cost and employment needed to build such core houses in six countries, including Tunisia. We interviewed 74 contractors of different sizes about building them at various volumes -- 1 - 10, 100, and 1,000. Information was also obtained on locally preferred variations on the standard plan. Since some responses were incomplete, statistical analysis often had to be confined to subsets. Before going into that, we should say more about the basic floor plan and make some preliminary comparisons.

The dwelling, as may be seen in Figures 1 and 2, is rectangular, has a flat roof, a 12 m^2 room, a 5.5 m^2 kitchen, a 1 m^2 entrance, and a 1.5 m^2 Turkish toilet connected to a septic tank. Occupants are supposed to add a shower above the toilet (but actually prefer to continue using public baths). Each room has one window, and the kitchen has running water at a sink. Additional rooms can be built on the upper right (Figure 2) or on the roof. Specifications are summarized in Table 1. The dwelling is intended for a 77 m^2 lot, but site cost and related infrastructure are not included in the estimates. In Tunisia the actual lot size ranged as high as 96 m^2 and averaged 80 m^2. The wall around the property was assumed to have concrete blocks and not the four posts shown on the plan although these help stabilize additions.

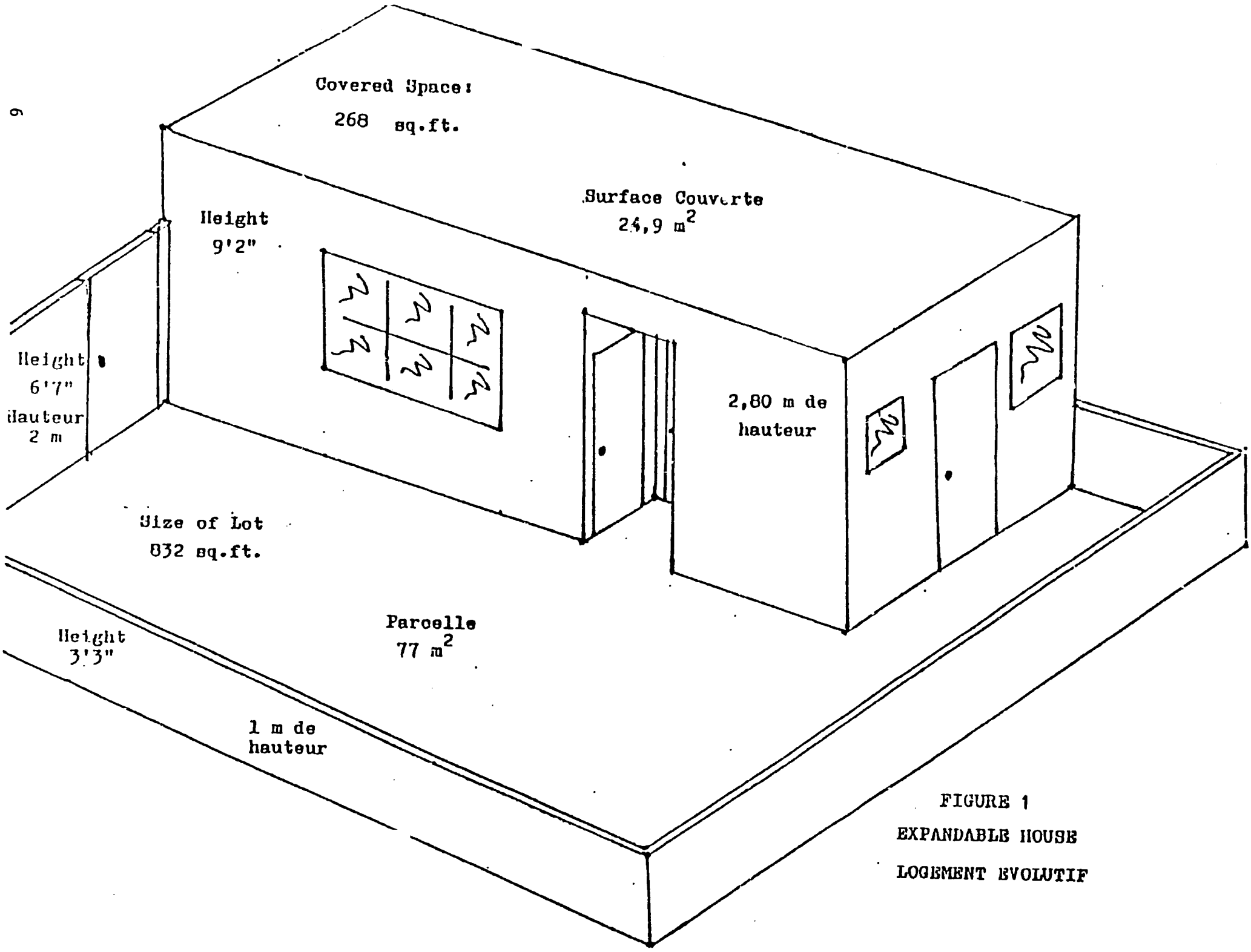
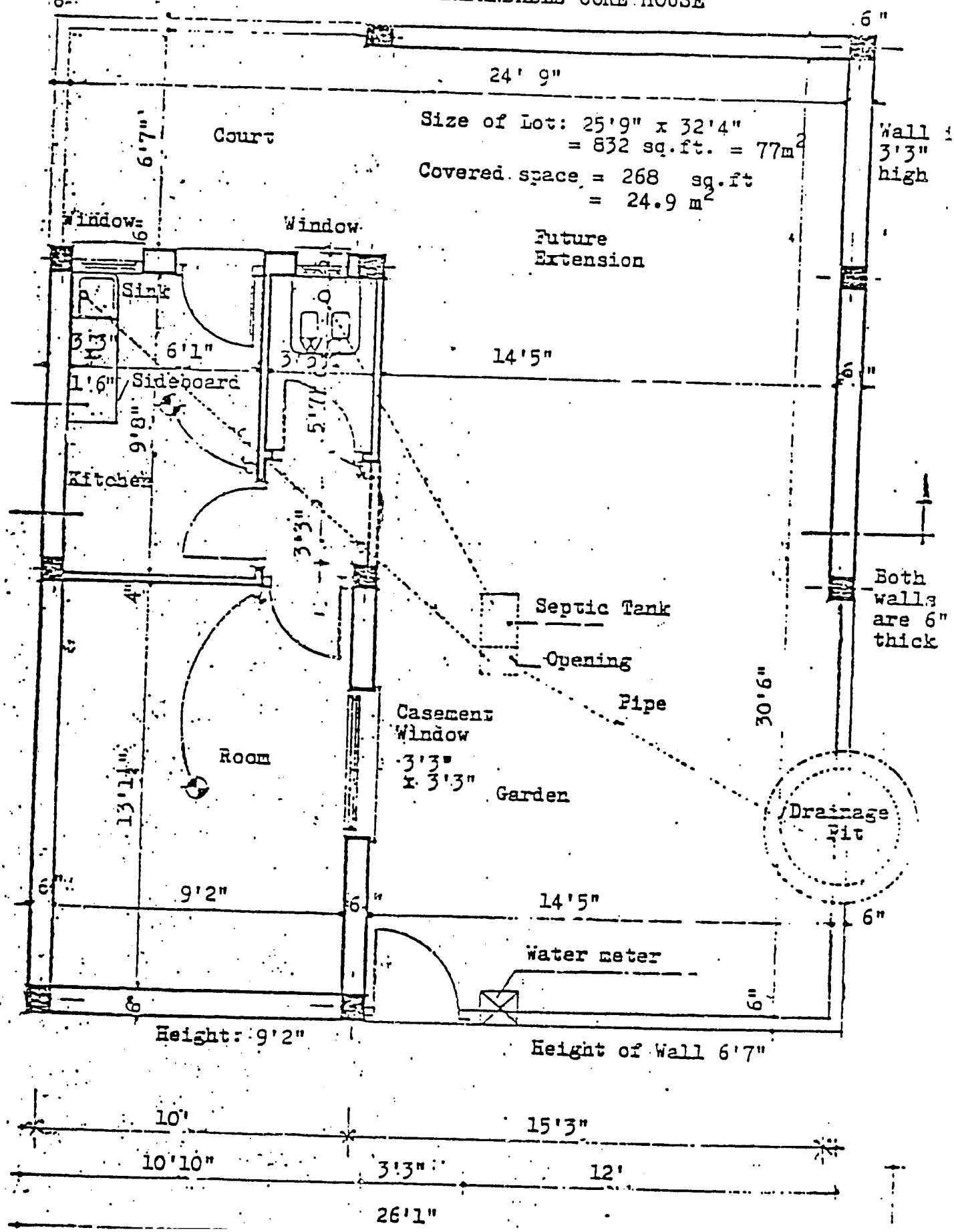


FIGURE 1
EXPANDABLE HOUSE
LOGEMENT EVOLUTIF

FIGURE 2. EXPANDABLE CORE HOUSE



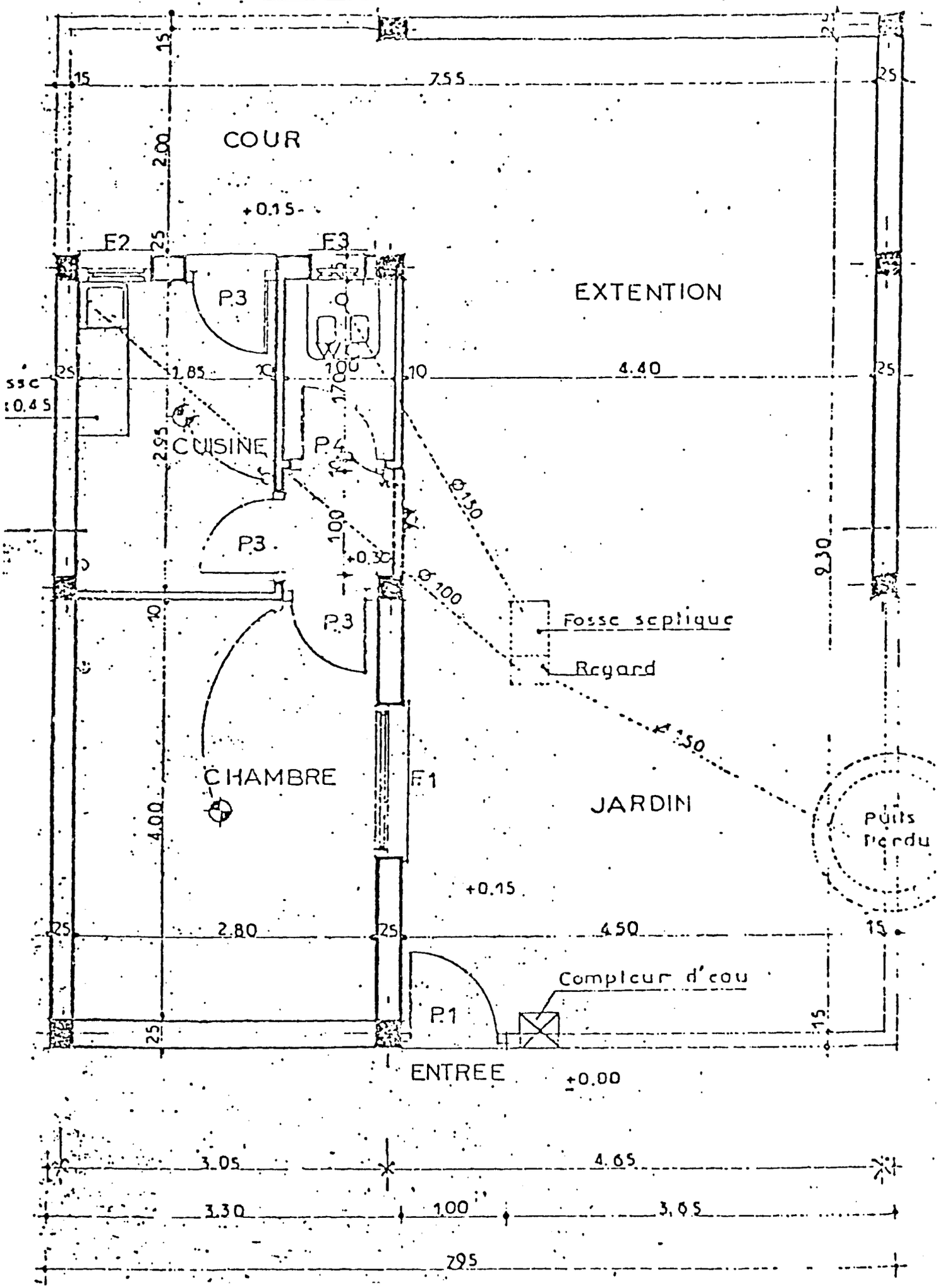

COUR
+0.15
F2
F3
P3
EXTENTION
ssc
+0.45
1.85
1.00
4.40
CUISINE
P4
Ø150
P3
+0.30
Ø100
P3
Fosse septique
Regard
CHAMBRE
F1
JARDIN
Puits Perdu
+0.15
2.80
4.50
Compteur d'eau
P1
ENTREE
±0.00
3.05
4.65
3.30
1.00
3.05
7.95

TABLE 1. EXPANDABLE HOUSE: SPECIFICATIONS

COMPONENT	UNIT	QUANTITY
1. Site Preparation		
2. Excavation, Trenching		
a. Holes 5' deep for six posts 20"x20" = 83.3 cubic feet.	cu.ft.	83.3
b. Trenches for the walls of fence and house = 78.0 cubic feet.	cu.ft.	78.0
3. The Shell: Walls, Ceiling, Floors		
a. Reinforced concrete collar beams and posts 6"x6".	cu.ft.	70.6
b. Roof panels	sq.ft.	226.0
c. Standard concrete, 15 pounds per cubic foot	cu.ft.	88.3
d. Lightweight concrete, 10 pounds pounds per cubic foot	cu.ft.	144.8
e. Bricks or blocks with holes for the housewalls, 9'2" high 50'4" long	sq.ft.	462.9
f. Concrete block fence 6"x 3'3" front 6"x 6'7"	sq.ft.	193.8
g. Partitions, hollow blocks	sq.ft.	215.3
h. Cement floor 4½", base 2"	sq.ft.	226.0
i. Plastering: Ceilings 205 sq.ft; walls --all interior and only the facade outside, 915 sq.ft. Bathroom excluded.	sq.ft.	1,120
4. Carpentry		
a. Formwork, shuttering, frames, window sills.		
b. Frames for windows, openings, and doors.		8
c. Casement window 3'3" high 3'3" wide		1
d. Window panes	sq.ft.	16.1
e. Garden door, 35½"x 79"	sq.ft.	19.5
f. 4 interior doors	sq.ft.	75.5
5. Painting		
a. Oil paint on doors, windows	sq.ft.	237
b. Whitewash	sq.ft.	1119.5
6. Plumbing		
a. Sink, sideboard, faucet and drain		1
b. Turkish toilet, tank, and drain 20 liters		1
c. Galvanized pipes	ft.	34.5
d. Two appropriate valves		
e. Cement pipes for sewage (to septic tank)	ft.	12
f. Recess for water meter.		1
7. Electrical		
a. Lights, wiring, switches,		

Cost of building this house in the summer of 1979 ranged from $3,117 in Colombo, Sri Lanka, to $5,107 in Lusaka, Zambia. The average was $3,650 (see Table 2, line 1). Currency conversion was made with official exchange rates.

For each city we have details on hours of employment of skilled and unskilled workers by component. In our notation N is onsite employment in workdays, C is the total cost given above, w_u is the daily pay of unskilled labor, p is the ratio of skilled to unskilled wages, q is the ratio of unskilled to skilled workers employed, and r is the ratio of on-site labor costs to the total. The components, p and q, can come either from a survey of builders or from one of workers. Since much construction work is subcontracted to labor on a piece rate basis, as mentioned above, builders are often uncertain about the relative pay and numbers of skilled and unskilled workers. Their estimate of p and q averaged 6 and 9 percent higher than that of workers, but these two overestimates tend to offset one another. If builders claimed to employ 18 percent fewer workers, it is mainly because they claimed to pay 29 percent higher wages (lines 2a and 2b).

The average number of workdays needed for this building was 224 according to workers and 183 according to builders. In Colombo 73 percent more than the average were used and in Medellin 37 percent less or 137 workdays. (Table 2, line 7a.)

Why does employment generation vary this much for building a very simple structure with well-known technology? The first clue can be found in Table 2, line 2, the level of unskilled workers' wages. It ranges from US$0.94 daily in Colombo to $4.35 in Lima (average: $2.96). If builders are good at substituting labor and non-labor inputs for one another, and if

Table 2. Cost of Construction and Employment Generation for a Standard 24.9 M^2 Dwelling Built with Reinforced Concrete Posts in Six Countries, Summer 1979 (Lima = Summer 1980)

Volume: 1-10 Units

	Colombo, Sri Lanka	Rawalpindi, Pakistan	Lusaka, Zambia	Medellín, Colombia	Tunis, Tunisia	Lima, Peru	Average Six Countri
1. Cost of construction, C	$3,117	$3,482	$5,107	$3,794	$3,550	$2,852	$3,650
2. Daily pay, w_u, of unskilled workers, According to:							
a. Workers	$ .94	$ 1.92	$ 3.05	$ 3.30	$ 4.17	$ 4.35	$ 2.96
b. Builders	1.02	$ 2.00	3.80	4.24	4.70	7.21	3.83
3. Ratio of skilled to unskilled wages, p, According to:							
a. Workers	1.713	1.818	1.898	2.786	1.808	1.356	1.897
b. Builders	2.125	2.300	2.000	2.975	1.654	1.070	2.021
4. Unskilled workers employed per skilled worker, q, According to:							
a. Workers	1.50	1.73	1.50	1.46	.48	1.70	1.40
b. Builders	1.31	1.53	1.62	2.11	1.80	.74	1.52
5. Ratio of labor costs to total cost, r,	.150	.185	.198	.205	.297	.265	.217
6. Employment generator, $\phi = \frac{r(1+q)}{(p+q)}$							
a. Worker-based	.117	.142	.146	.119	.192	.234	.158
b. Builder-based	.101	.121	.143	.125	.241	.255	.163
7. Workdays for the dwelling. According to:							
a. Workers	388	258	244	137	164	154	224
b. Builders	309	210	192	112	182	101	183

these inputs are readily available, employment generation will fall as wages rise. If substitution is difficult, then a rise in wages (relative to other costs) means a rising share of labor costs in the total (line 5) and a higher total cost as well.

The wage level in Rawalpindi is 104 percent above that of Colombo, but the share of labor in total costs is only somewhat higher, 18.5 compared with 15.0 percent. About 130 onsite workdays have been replaced by better tools, management, etc., and the total cost is only 12 percent higher.

The wage level in Tunis is substantially (117 percent) above that of Rawalpindi; hence, only 63 percent as many workdays are used, but the share of labor rises to 29.7 percent of total costs, which are 2 percent above those of Rawalpindi. The unskilled wage levels in Lusaka and Medellín are both somewhat above $3.00 daily, and the share of labor in total costs is close to 20 percent in both. Yet the house can be built for 26 percent less in Medellín, using 44 percent less labor. The skill premium in Medellín of 179 percent is double that of Lusaka's 90 percent, but that does not account for most of the difference in workdays. Medellín, an old industrial center with a renowned work ethic, seems to have a better organized construction industry and higher productivity than fast-growing Lusaka where 90 percent of adults grew up in villages. Thus, even for this simple dwelling, employment and costs per unit are influenced by factors more complex than the relative prices and substitutability of different inputs.

Not only can labor and non-labor construction inputs be substituted for one another as their relative price and quality varies: The same is

true of different types of labor.[10] As the skill premium rises, one expects builders to supplement skilled workers with unskilled helpers to a greater extent. One expects p and q (Table 2, lines 3 and 4) to rise and fall together. This tendency is not, however, pronounced. According to builders, Medellín is the only city where more than two unskilled workers are used with each skilled one; and Medellín does pay the highest skill premium, nearly 200 percent. Qualitative differences are involved in the relative meaning and worth of skills. Each city has its own pattern.

The Relative Importance of Components

Over half of employment generated in building is usually in the structure of the dwelling, the walls and the roof; and this basic shell also accounts for a comparable share of costs. If carpentry and plumbing are added, 90 percent of construction costs and 80 percent of employment are accounted for. The remaining activities -- site preparation, excavation, painting, and electrical installation are relatively labor-intensive, but they each account for only a very small proportion of total cost and employment. Table 3 shows the share in total costs of the seven major components of a dwelling, as estimated in detail by construction firms of different sizes in six cities. The shares are averages for those firms that gave complete and internally consistent cost estimates.

Perhaps the most striking deviations from averages in Table 3 are the high shares in cost of carpentry and plumbing in Sri Lanka, over 50 percent,

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[10] Researchers in this field have commonly assumed separability, that is, the assumption that changing the proportion of skilled and unskilled workers to one another will not change the proportion of labor costs in total costs. See the survey of the literature by Daniel S. Hamermesh and James Grant, "Econometric Studies of Labor-Labor Substitution and Their Implications for Policy," Journal of Human Resources, Fall 1979, pp. 518-42. Our findings partly contradict the assumption.

about double that in the other cities. In the case of Sri Lankan carpentry, the high cost is due to the lack of prefabricated doors, window frames, and the like, which may be employment generating on the site but are otherwise inefficient. Plumbing installation in Colombo, by contrast, does not take more workdays than are needed in Rawalpindi or Lusaka; but the components, often imported, are relatively expensive. The share of labor costs in plumbing installation are 8.9 percent in Colombo and average 20.4 percent in the other five cities, more than twice as much. (See Table 4.)

In general, labor costs average 21.7 percent of total onsite costs, and their share is 21.5 percent in costs of the shell. Labor costs in plumbing and carpentry are lower; but painting, site preparation, and excavation have substantially higher labor cost shares. Table 4 shows variations from this general pattern. Especially striking is the variation in the share of labor in the shell, from 14 to 32 percent. In all cases whether or not total employment varies in proportion to that in the shell depends on the number of unskilled workers and their relative wages in the total share of labor, as we shall see.

An interesting phenomenon is the lack of variation in the skill premium. In the different cities with their divergent general wage levels and in the various specialties, skilled workers get about twice as much as unskilled laborers and helpers. Apparently the extra effort needed to learn one trade is comparable to that for others, and the gain in productivity is in proportion. The major exception was Medellín, Colombia, where the skill premium ranges from 140 to 200 percent. The premium was highest for masons and lowest for electricians and plumbers.

Table 3. Percentage Distribution of Costs by Component for a Standard 24.9 M^2 Dwelling Built with Reinforced Concrete Posts in Six Countries, Summer 1979 (Lima, Summer 1980)

Volume: 1-10 Units

Component	Colombo, Sri Lanka	Rawalpindi, Pakistan	Lusaka, Zambia	Medellín, Colombia	Tunis, Tunisia[1]	Lima, Peru	Average, Six Countries
1. Site preparation	0.7	1.3	--	2.9	--	0.7	0.9
2. Excavation and trenching	0.1	0.2	0.4	2.8	.7	1.2	0.9
3. The shell: reinforced posts and non-load-bearing blocks	40.9	68.6	58.7	62.9	67.4	39.7	56.0
4. Carpentry	26.8	17.8	14.3	15.0	18.6	42.3	22.5
5. Painting	2.3	1.6	6.6	3.4	2.3	2.6	3.1
6. Plumbing	25.9	6.7	17.6	9.0	8.7	8.7	12.8
7. Electrical	3.3	3.8	2.5	4.0	--	7.4	4.2
8. Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]For Tunisia, carpentry includes electrical work.

The comparatively small variation in the relative skill premium does not necessarily mean little variation in the number of unskilled laborers and helpers used with each skilled worker. On the contrary, Table 5, line 8, shows a rising trend, except for Lima. Apparently one learns to use the unskilled to better advantage and to replace more of the skilled with non-labor inputs. The low skill premium of Lima discourages use of the unskilled.

For the principal component of the dwelling, its shell, 2 unskilled helpers are used with each skilled worker, primarily masons. In carpentry, plumbing, and the other late phases of construction, about two unskilled workers are used with every three skilled craftsmen. Skills are least needed in site preparation, excavation, and trenching, where 8 to 15 unskilled workers can work under the guidance of one trained man. In Lima, high wages have led to mechanization, and the ratio was only 1:1. These early stages generate only about 10 percent of total employment and show great variability in data. In general, it appears that in the higher-income countries unskilled workers need less supervision and are therefore used in greater proportion. (See Table 5).

The Labor-Non-Labor Elasticity of Substitution for the Standard Core House

There are a number of ways of estimating the elasticity of substitution.[11] The most feasible method for our case is to regress the logarithm of gross output per worker on the logarithm of the average wage including fringe benefits. For the complete sample of 74 firms, we found the labor-non-labor elasticity of substitution to be 0.95, very close to unity. (Standard errors are in parentheses.)

$$(1)\quad \text{Log}\,(Y/N) = \underset{(.21)}{1.04} + \underset{(.17)}{.95}\ \log w \qquad \bar{R}^2 = .300 \qquad F = 31.79$$

[11]See footnote 8.

Table 4. Ratio of Labor Cost to Total Cost, r
by Component for the Standard Floor Plan (Posts)

Volume: 1-10 Units

Component	Colombo, Sri Lanka	Rawalpindi, Pakistan	Lusaka, Zambia	Medellín, Colombia	Tunis, Tunisia	Lima, Peru	Average
1. Site preparation	0.738	0.769	--[3]	0.708	--	.940	.789
2. Excavation and Trenching	0.632	0.769	0.849	0.419[2]	0.270	.942	.647
3. The Shell	0.139	0.173	0.144	0.221[2]	.301	.315	.215
4. Carpentry	0.195	0.180	0.183	0.078	.307	.103	.174
5. Painting	0.393	0.235	0.510	0.415	.301	.450	.384
6. Plumbing	0.089	0.160	0.247	0.103	.280	.229	.185
7. Electrical	0.176	0.215	0.280	0.244	.300	.288	.251
8. Total	0.150	0.185	0.198	0.205	.297	.265	.217

Note: 1. For Tunisia Component 2 included 1.
2. For Colombia the Components 2 and 3 have been modified to suit specific local requirements.
3. For Zambia Component 1 data was unavailable.

Table 5. Ratio of Unskilled to Skilled Workers, q, and the ratio of Skilled to Unskilled Wages, p, by Component for the Standard Floor Plan (Posts)

Volume: 1-10 Units

Component	Colombo, Sri Lanka	Rawalpindi, Pakistan	Lusaka, Zambia	Medellín, Colombia	Tunis, Tunisia[1]	Lima, Peru	Average
1. Site preparation	9.490	—	--	15.000	--	1.000	8.500
2. Excavation and Trenching	—	—	8.000	10.500[2]	2.270	5.375	6.536
3. The Shell	2.775	2.202	2.000	1.923[2]	2.063	.623	1.931
4. Carpentry	.475	.276	1.000	1.000	0.810	.895	.743
5. Painting	.570	.604	1.000	.600	--	.263	.607
6. Plumbing	.660	.604	1.000	.657	0.840	.533	.716
7. Electrical	1.000	1.139	1.000	.833	0.500	1.083	.926
8. Total	1.307	1.528	1.616	2.107	1.803	.738	1.517
9. Ratio of Skilled to Unskilled Wages, p.							
a. Workers	2.13	2.30	2.00	2.98	1.65	1.07	2.02
b. Builders	1.71	1.81	1.90	2.79	1.81	1.36	1.90

Note: 1. For Tunisia, Component 2 included 1 and Component 4 included 5.
2. For Colombia, Components 2 and 3 were modified to suit specific local structural requirements.

Table 6. The Employment Generator Ø by Component for the Standard Floor Plan 2.

Volume: 1-10 Units

Component	Colombo, Sri Lanka	Rawalpindi, Pakistan	Lusaka, Zambia	Medellín, Colombia	Tunis, Tunisia	Lima, Peru	Average
1. Site preparation	.659	--	--	.655	--	.912	.742
2. Excavation and Trenching	--	--	.695	.371	.225	.932	.556
3. The Shell	.107	.121	.108	.131	.248	.302	.170
4. Carpentry	.110	.088	.122	.040	.226	.099	.114
5. Painting	.226	.130	.340	.173	--	.424	.259
6. Plumbing	.051	.088	.165	.074	.207	.219	.134
7. Electrical	.114	.128	.187	.189	.209	.279	.184
8. Total	.101	0.121	.143	.125	.241	.255	.164

Note: 1. For Tunisia, 4 includes 5.

2. The three ratios that have been discussed are r, the labor cost ratio, p, the wage ratio, and, q, the skill ratio. Together they make up the employment generator, $Ø = \frac{r(1 + q)}{(p + q)}$, the multiplier that will give the workdays created for any expenditure that has been divided by the unskilled wage rate.

That elasticity of substitution of 0.95 may be regarded as the longrun potential. In the shortrun a number of customs and constraints may limit one's options. Hence the elasticity of substitution within a country at a given time is likely to be lower than the elasticity among countries with widely different wage levels. Thus we find that for the subsample of 20 firms in Rawalpindi, Pakistan, the elasticity of substitution was 0.80 and only 13 percent of the variation in labor intensity could be explained by differences in labor costs.[12]

$$(2) \quad \text{Log } (Y/N) = \underset{(.43)}{2.22} + \underset{(.41)}{.80} \text{ Log } w \qquad \bar{R}^2 = .130 \quad F = 3.72$$

A different way of measuring the employment effects of variations in labor costs is to relate the two directly to one another, omitting reference to non-labor inputs and holding output constant.[13] In that case one regresses the logarithm of employment on both the logarithms of the average wage and fringe benefits and that of output. The result for the 42 firms with the most reliable data was -0.91. This means that a 10 percent rise in wages leads to a 9.1 percent fall in employment. On the other hand a 10 percent rise in output would lead to a 7.7 percent rise in employment.

$$(3) \quad \text{Log } N = \underset{(1.26)}{.39} - \underset{(.13)}{.91} \text{ Log } w + \underset{(.11)}{.77} \text{ Log } y \qquad \bar{R}^2 = .750 \quad F = 63.96$$

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[12] Ehsan Ahmed, "Employment Generation in the Construction of Low Cost Housing: A Comparison of Building Firms in Pakistan with Firms in Five Other Countries," Michigan State University Housing-in-Development Paper A-1 and Pakistan Development Review, forthcoming.

[13] Jora Minasian, "Elasticities of Substitution and Constant Output Demand Curves for Labor," Journal of Political Economy, June 1961, pp. 260-270.

Again we find that for a single country the elasticities are lower. In the case of the 20 Pakistani firms, the wage elasticity of employment if -0.72.

$$(4) \quad \text{Log } N = \underset{(3.66)}{1.71} - \underset{(.42)}{.72} \text{ Log } w + \underset{(.34)}{.69} \text{ Log } y \qquad \bar{R}^2 = .17 \quad F = 2.97$$

Size of Firm, Volume, and Employment Generation

Size of building firm affects employment generation because of differences in wage rates paid, economies of scale, and general experience and efficiency. Table 7 shows the effect of these elements in the case of three Tunisian firms with contracts to build the 24.9 m^2 core dwelling that we have been analyzing. Patterns are comparable in other countries.

The best option shown is that of a medium-sized firm building 100 units. At its price of $3,283 some 305 units could be built with $1 million and 61,900 workdays would be created. If such firms had contracts for only 10 units each, 3,500 fewer workdays would result because of a fall in the employment generator $\emptyset$ from .305 to .288. This fall is due to a fall in r, the share of labor in total costs, that is in turn due to a rising share of overhead and profits. With a smaller volume, overhead can be spread over fewer units. Moreover, for $1 million, only 282 units could be built if they are built 10 at a time instead of in sets of 100.

The small firm had a substantial employment generator and the advantage of a lower level of wages, but its lack of experience and bargaining power made its costs much higher (65 percent) than that of the medium sized firm. It generated almost as much employment but much less housing. It was least efficient at digging the foundation and raising walls. Such firms need assistance if they are to be used at all. In Tunisia they did get such assist-

Table 7

Employment Effects of Size of Firm and Volume For Building a 24.9 M^2 Dwelling in 1979, Tunisia

Size of Firm	Units in Contract (1)	Cost per Unit (2)	Number of Units per $1,000,000 (3)	Daily Unskilled Wage (4)	Employment Generator Ø (5)	Workdays per $1,000,000 (6)
Small	1	5,407	184.9	$4.70	.284	60,425
Medium	10	3,550	281.7	4.93	.288	58,425
Medium	100	3,283	304.6	4.93	.305	61,875
Large	100	4,450	224.7	5.50	.249	45,275
Large	1,000	3,650	274.0	5.50	.275	50,000

NOTE: Managers of the three firms were asked to make detailed cost and employment estimates for an identical unit. Its 24.9 m^2 are divided among a kitchen, room, and water closet with a connection to a septic tank. Interviews with other firms suggest that the results are typical though not necessarily the arithmetic mean. The employment generator is explained in the footnote to Table 6.

Altogether nine firms were surveyed in Tunisia. Small firms averaged 16 employees, none offsite, and could build 23 small dwellings per year. Medium-sized firms averaged 101 workers onsite and 14 offsite and could build 200 units annually. Large firms averaged 775 workers onsite, 89 offsite, and could build 750 small units annually. The survey was carried out by Dr. Ridha Ferchiou, University of Tunis, in collaboration with Michigan State University.

ance and were used on the core house projects with excellent results.

Large firms that can build thousands of units are least employment generating, in part because they pay the highest wage rates. Note, however, that if such firms are to be used, they will generate more employment per dollar with a large than with a small volume. Table 7 also shows that they will only then bring their costs down to a competitive range. Per $1 million they can build 50 more units (22 percent) and employ 189 (10 percent) more workers at the large volume. Nevertheless, the medium-sized firm performed better on both counts, regardless of volume.

The main point of this section is that employment estimates must be made with extra care if unusually large or small firms are to be employed for the task. If maximizing the number of units to be built with given funds is the objective of highest priority, low cost clearly remains more important than high employment. This priority need not limit the role of small firms in large programs if they are given guidance and bargaining support.

Conclusion

In the course of economic development the productivity of construction workers rises steadily though perhaps not as much as productivity in other sectors. Since the demand for buildings and infrastructure rises at least as much as national product, lagging productivity means that employment in construction must rise faster than that in other sectors. Not counting informal employment and temporary fluctuations, construction employment typically rises from about 4 to 8 percent of the economically active population.

The level of daily pay is both cause and effect of changes in productivity and employment. In early development construction workers are usually, though not always, in less militant unions or none and subject to less vigilant social legislation than are manufacturing workers. Wages and productivity inevitably lag as a result, but employment grows faster. In the middle-income phase, the need to build reaches a peak with accelerating population growth, migration, urbanization, and industrialization. Construction wages begin to rise faster than manufacturing wages and eventually surpass them on an hourly basis. The sector becomes unionized and socially regulated. In advanced economies construction wages rise at about the same rate as other wages, and employment growth depends on the composition of output and, as always, on the elasticity of substitution.[14]

No matter how the elasticity of substitution between labor and non-labor inputs was measured, as reported here, the results tended to be between 0.80 and 1.20. The best estimate, using the standard core house, was 0.95 for the 74-firm multi-country comparison. That figure may fit a long period of adjustment, while something like 0.80 applies to the shortrun within a country, as found in Pakistan. If labor costs rise 10 percent compared with other inputs, a firm with 100 workers will lay off 8.

That lay-off is good if the eight workers are needed elsewhere in an economy and if wages have risen because workers are being bid away. It forces contractors to reorganize with better equipment and different materials to raise productivity. They have to invest more, yet it is economically justified and, indeed, the essence of development. But if labor costs have risen only

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[14] W. Paul Strassmann, "The Construction Sector in Economic Development," Scottish Journal of Political Economy, Nov. 1970, pp. 391-409.

because trade union action and social legislation have affected the construction sector out of proportion to general trends, then the related lay-offs and investments will not be economically optimal. They are likely to lower output, increase unemployment, worsen income distribution, and promote evasion. They can only be justified on a possibly dubious social or political basis.

We cannot be as definite about the subset of skilled workers. Their share in employment differs in accordance with the various building operations and components but in general seems to remain around 40 percent for building at the $200 to $1,000 per capita income level, which is also the range of the $1 to $5 daily unskilled wage level. The ratio, q, stays around 1.5. The skill premium seems to remain around 100 percent, meaning skilled workers get twice as much. The ratio p hovers around 2.0. In highly developed countries, the skill premium can fall as low as 25 percent ($p = 1.25$) and the proportion of skilled workers in employment then rises to as much as 75 percent ($q = .33$). For the U.S., $p = 1.27$, $q = 0.35$, $r = 0.24$, and $\emptyset = 0.201$.

The controversy is about deviations from this pattern. Can persistent and acute shortages of skilled labor prevail in a city and sharply raise costs and inhibit building? The evidence is mixed. The oil-exporting countries have had no problem raising wages and importing workers from all over the world but especially from neighboring countries. The migration of skilled workers to Venezuela partly explains the 200 percent skill premium in Medellín and the use of perhaps 25 percent more unskilled workers than might otherwise be expected.

Nairobi, Kenya, may be a different case. For the early 1970's, Gordon Hughes found the skill premium to be a high 419 percent ($p = 5.19$) and a corresponding high but not high enough ratio of unskilled to skilled workers in building core housing, $q = 3.23$. (The data are only partially comparable to ours since offsite and indirect labor are counted.) Hughes concluded that, "housing projects cannot be considered a particularly good way of generating employment for unskilled workers unless there is a plentiful supply of the complementary skilled labor."[15] The implication is that this is not a simple matter, and several writers share that view.

My own tentative impression is that the skill problem can easily be exaggerated, especially by builders who are frustrated during a boom. The thousands of construction workers who migrated from Egypt and the Maghreb have not left a permanent void. As a group of experts concluded,

> ... it is generally agreed that it is relatively easy to train skilled labor through, for example 9 to 12 month training programs at a government training center. The main difficulties are found in training middle level, or project level supervisors and technicians. There is also a need for the training of small contractors.[16]

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[15] Hughes, op. cit., pp. 62, 73. In a survey of 5 Kenyan building firms in 1979 we could partially confirm Hughes' report. We found a high $q = 3.00$ according to workers and 2.86 according to builders. On the other hand, the onsite skill premium was only 57.4 percent according to workers and 100 percent according to builders. The share of labor in total costs, r, was said to be a high 35.2 percent; unskilled wages were $2.65 according to workers and $2.79 according to builders. The cost of the standard core dwelling was reported as $6,276, or 71.9 percent above the average of Table 2 and 22.9 percent above the next highest estimate, Lusaka, Zambia.

[16] Ad-hoc Expert Group Meeting on Criteria for the Selection of Appropriate Building Technologies, Amman, Jordan, 10-14 December, 1977, "Draft Final Report," (Nairobi United Nations Commission for Human Settlements, 1978), p. 28.

For a sample of 15 firms in 5 countries we found a skilled-unskilled elasticity of substitution of 0.66 (standard error 0.27; adjusted $r^2 = .270$).

If labor is made more productive because of training and better organization, unemployment is not likely to follow because these increases in productivity can lead to lower costs and an expanded volume of building. By contrast, making labor more productive by inducing excessive spending on capital equipment and more elaborate materials reduces employment and raises costs. The higher earnings help some workers at the expense of others.