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# LABOR-REQUIREMENT AND -COST COMPARISON OF CONSTRUCTION METHODS FOR LOWER-COST HOUSING

by  
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## INTRODUCTION

One of the most serious problems facing the building industry in many countries is the shortage of labor with the attendant escalation of wages. The inability to keep pace with the steadily growing demand for construction work of all kinds (especially housing) is forcing both state and industry to promote the search for new construction methods and improvement of existing ones, with a view to increased building capacity. As a result, there is an urgent need for reliable quantitative data on the comparative labor requirements of the different methods.

Earlier attempts to this end, based on contractors' records or on unrated observation on the site, proved unsatisfactory, in view of the large number of factors involved (design, topography, organization, wage incentives, individual skill, interchangeability of labor, material and capital, etc.), as a result of which the time requirement of apparently identical operations varies widely. In order to eliminate these distorting influences, in comparing four of the main construction methods used at present in Israel for lower-cost housing (1)(2)(3)(4), data on direct labor-requirement were compiled in time studies with all measured times normalized. (For a brief description, see Table 1) These latter studies formed, in turn, the basis of a cost comparison undertaken with the aid of a model embodying the interrelationships of all time- and quantity-dependent cost components of the production process. (5)(6)

## DIRECT LABOR REQUIREMENT

Direct labor comprises the man-hours (site and plant) directly proportional to the production output. The requirement was determined by a group-study technique (7), based on systematic sampling with a fixed interval of one minute, permitting simultaneous observation of all gang members at work. Although these studies were conducted on identical four-storey terrace buildings, prevalent in lower-cost housing in this country (Figure 1), small differences in design details, floor-area or finishing standards were inevitable. Results for a prototype dwelling of 57 sq. m. floor-area, are presented in Tables 2, 3, 4 and 5, and the proportion of skilled and unskilled labor for the various methods, in Table 6.

## DIRECT- AND INDIRECT-LABOR COSTS

A comparison of the labor costs, with the conventional method as 100%, is given in Table 7. Indirect labor comprises the wages of those engaged in supervision, direct administration, inspection, operation of equipment and maintenance in the plant and on the site. Being time-dependent, its requirement was calculated for a four-block project (128 dwelling units), assuming an annual plant output of 750 units.

The relative weights of the direct- and indirect-labor in total cost of each method, subject to local conditions, are listed in Table 8.

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## SENSITIVITY ANALYSIS

Table 9 shows the influence of a change in labor cost on the percentage pattern of the total construction cost for the different methods, with the conventional method as 100%.

Finally, Table 10 shows the influence of dwelling-unit size on the direct-labor requirement, illustrated for the 75 sq. m. unit with the same floor-plan as given in Figure 1.

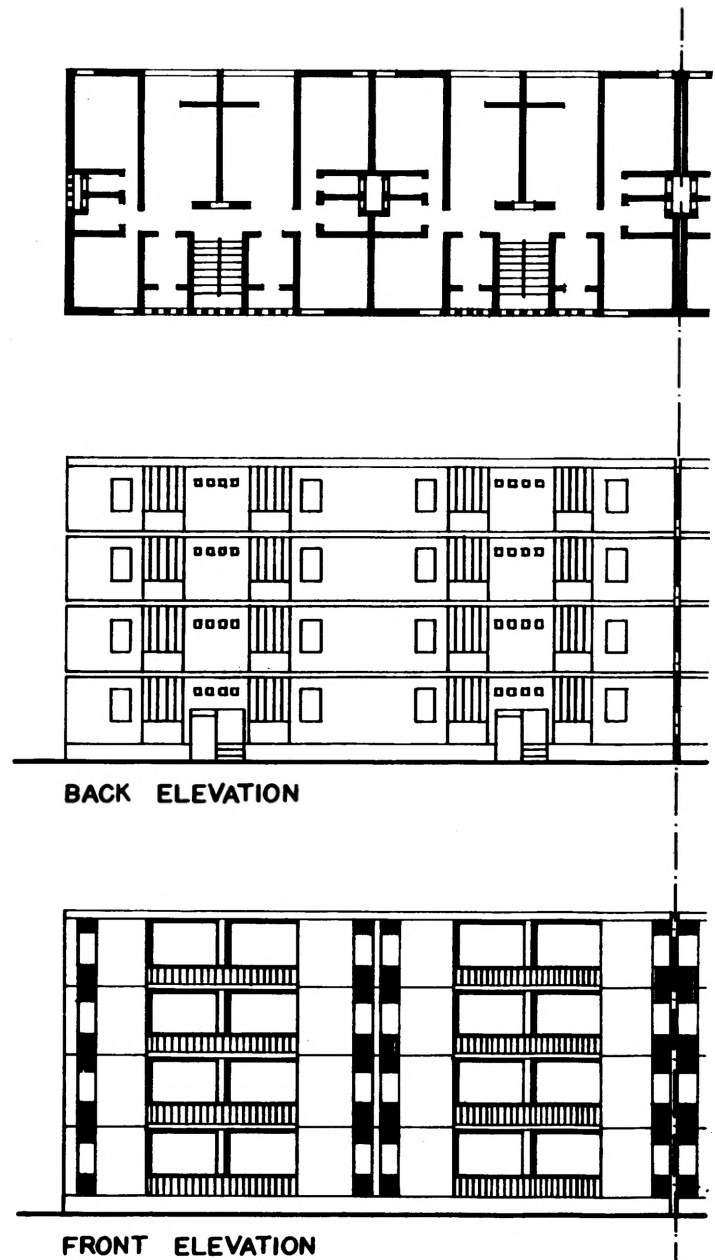


Fig. 1. Basic Project - Floor Plan and Elevations

Table 1:

Main Features of Analyzed Construction Methods

Method	Skeleton	External Walls	Stairs	Partitions	Plaster
Convntl.	Reinf. concr. columns, beams, floors cast in situ	Hollow concr. blocks with ext. rendering in three coats	Prefab. flights; landings cast in situ	Hollow concr. blocks	Two coats
Cross-walls*	Load-bearing reinf. concr. cross-walls; floors cast in situ	-Do.-	-Do.-	-Do.-	Two coats on masonry, single coat on concr. walls
Partial prefab.	Load-bearing walls cast in situ. Floors prefab. on site	Prefab. in field plant w/ finish, incl. carpentry; no rendering	Flights prefab. in plant; landings prefab. on site	-Do.-	-Do.-
Comprehensive prefab. (field plant)	Bearing walls and floors prefab. in plant	-Do.-	Flights and landings prefab. in plant	Reinf. concr. prefab. in plant	Single coat

\*A system of parallel reinforced concrete walls (cast in crane-transported steel forms) supporting a continuous reinforced concrete floor slab.

Table 2: Direct Site-Labor Requirement in Erection of Carcase

Work Item	Man-hours per sq.m. net floor area			
	Conven. Method	Cross Walls Method	Partial Prefab. Method	Comprehensive Prefab. Method
Substructure:	2.50	2.61	2.62	2.75
<b>Concrete in Storey:</b>				
Columns - Formwork	0.60	--	--	--
- Reinfmt.	0.09	--	--	--
- Casting	0.11	--	--	--
Walls - Formwork	--	0.96	0.86	--
- Reinfmt.	--	0.18	0.13	--
- Casting	--	0.24	0.17	--
Slabs - Formwork	1.35	1.02	--	--
- Reinfmt.	0.62	0.13	--	--
- Casting	0.23	0.18	--	--
Lintels - Formwork	0.38	0.32	0.06	--
- Reinfmt.	0.05	0.03	0.01	--
- Casting	0.15	0.11	0.02	--
Concrete work, total	3.58	3.17	1.25	--
<b>Prefabricated Elements:</b>				
Prod. of slabs and landings	--	--	0.62	--
Erection - Walls	--	--	0.19	0.51
- Partitions	--	--	--	0.08
- Slabs	--	--	0.36	0.29
- Stairs and other elements	0.12	0.12	0.09	0.09
Prefab. elements, total	0.12	0.12	1.26	0.97
<b>Masonry:</b> - External walls	0.51	0.22	--	--
- Partitions	0.97	0.45	0.45	--
Masonry, total	1.48	0.67	0.45	--
Total site - labor	7.68	6.57	5.58	3.72
Total excluding substructure	5.18	3.96	2.96	0.97

Table 3: Direct Site-Labor Requirement, Finishing Operations

Work item	Man-hours per sq.m. net floor area			
	Conven. Method	Cross Walls Method	Partial Prefab. Method	Comprehensive Prefab. Method
<b>Walls:</b>				
Plaster - interior	2.33	1.67	1.62	1.34
- exterior	0.73	0.71	--	--
Whitewash	0.23	0.23	0.23	0.23
External joints	--	--	0.11	0.11
Walls, total	3.29	2.61	1.96	1.68
<b>Other operations:</b>				
Floor tiling (terrazzo)	1.06	1.06	1.01	0.96
Floor skirtings	0.21	0.21	0.21	0.21
Wall tiling	0.15	0.15	0.15	0.15
In-situ terrazzo	0.11	0.11	0.08	0.08
Sanitary installation	0.88	0.79	0.78	0.50
Electrical installation	0.49	0.46	0.42	0.32
Carpentry	0.68	0.68	0.63	0.62
Glazing	0.04	0.04	0.04	0.04
Paint	0.71	0.71	0.71	0.71
Ironwork	0.13	0.13	0.13	0.13
Roof insulation	0.29	0.29	0.29	0.29
Cleaning and miscellaneous	0.44	0.44	0.41	0.37
Other operations, total	5.19	5.07	4.86	4.38
<b>Grand total, Site Finishing Operations</b>	<b>8.48</b>	<b>7.68</b>	<b>6.82</b>	<b>6.06</b>

Table 4: Direct Off-Site Labor Requirement, Plant Prefabrication

Item	Man-hours per sq.m. net floor area	
	Partial Prefab. Method	Comprehensive Prefab. Method
<b>Production in plant:</b>		
- External walls	0.52	0.52
- Internal loadbearing walls	--	0.57
- Partitions	--	0.34
- Lintels	0.03	--
- Slabs and landings	--	0.62
- Stair flights	0.08	0.08
<b>Carcase, total</b>	<b>0.63</b>	<b>2.13</b>
- Finishing operations in plant	0.05	0.27
<b>Grand total, plant</b>	<b>0.68</b>	<b>2.40</b>

Table 6: Breakdown of Direct Labor Requirement (in percent)

Construction Method	Proportions		Percent compared with conventional	
	Skilled	Unskilled	Skilled	Unskilled
Conventional	73.2	26.8	100.0	100.0
Cross-walls	69.6	30.4	83.7	100.2
Partial Prefabrication	63.8	36.2	70.4	109.7
Comprehensive Prefabrication	62.2	37.8	64.2	105.7

Table 7: Comparison of Labor Costs\* (in percent)

Labor	Construction Method			
	Conven. Method	Cross Walls Method	Partial Prefab Method	Comprehensive Prefab Method
Direct	100.0	87.6	79.2	73.1
Indirect	100.0	97.8	125.2	144.0
In total	100.0	88.8	84.7	81.5

\*In calculating this cost, wages were taken as 5% lower at the plant than at the site.

Table 5: Summary - Direct Labor Requirement for Dwelling Unit of 57 sq.m. Floor Area

Description	Man-hours per sq.m. net floor area			
	Conven. Method	Cross Walls Method	Partial Prefab. Method	Comprehensive Prefab. Method
Substructure (Table 2)	2.50	2.61	2.62	2.75
Carcase in storey on site (Table 2)	5.18	3.96	2.96	0.97
Plant excluding finishing ops. (Table 4)	--	--	0.63	2.13
Wall finishing ops. on site (Table 3)	3.29	2.61	1.96	1.68
Carcase plus wall finishing ops.	8.47	6.57	5.55	4.78
Other site-finishing ops. (Table 3)	5.19	5.07	4.86	4.38
Finishing ops. in plant (Table 4)	--	--	0.05	0.27
Other finishing ops., total	5.19	5.07	4.91	4.65
<b>Site total</b>	<b>16.16</b>	<b>14.25</b>	<b>12.40</b>	<b>9.78</b>
<b>Off-site total</b>	<b>--</b>	<b>--</b>	<b>0.68</b>	<b>2.40</b>
<b>Grand total per sq.m. net area</b>	<b>16.16</b>	<b>14.25</b>	<b>13.08</b>	<b>12.18</b>
Percent, compared with conv	100.00	88.2	80.9	75.5
As above, site only	100.00	88.2	76.7	60.5
<b>Total per sq.m. net area excluding substructure</b>	<b>13.66</b>	<b>11.64</b>	<b>10.46</b>	<b>9.43</b>
Percent, compared with conv	100.00	85.2	76.6	69.0
As above, site only	100.00	85.2	71.6	51.5

Table 8: Relative Weight of Labor Cost (in percent)

Cost Component	Construction Method			
	Conven. Method	Cross Walls Method	Partial Prefab Method	Comprehensive Prefab Method
Direct labor: site	28.1	25.7	22.6	17.7
plant	--	--	1.0	3.8
Indirect labor: site	3.8	3.8	3.6	3.3
plant	--	--	1.4	2.4
<b>Total labor</b>	<b>31.9</b>	<b>29.5</b>	<b>28.6</b>	<b>27.2</b>
Materials	56.0	57.5	57.1	56.8
Investment	4.4	5.1	5.6	6.3
Transportation	--	--	0.4	1.7
General site expenses	1.9	1.8	2.1	1.9
Overhead	5.8	6.1	6.2	6.1
<b>Grand total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Table 9: The Influence of a Change in Labor Cost (in percent)

Change in Labor Cost	Construction Method			
	Conven. Method	Cross Walls Method	Partial Prefab Method	Comprehensive Prefab Method
-10	100.0	96.1	94.8	96.1
0	100.0	95.9	94.4	95.6
+10	100.0	95.7	94.2	95.2
+20	100.0	95.5	93.9	94.7

Table 10: Direct Labor Requirement for Dwelling-Unit  
of 75 sq. m.

Description	Man-hours per sq. m. net floor area			
	Conven. Method	Cross Walls Method	Partial Prefab. Method	Comprehensive Prefab. Method
Substructure	2.50	2.61	2.62	2.75
Storey carcass, site	4.71	3.47	2.37	0.72
Plant production (finishing ops. excluded)	--	--	0.48	1.72
Wall finishing	2.87	2.32	1.78	1.46
Total for carcass with wall finishing	7.58	5.79	4.63	3.90
Other finishing ops.	4.24	4.14	4.02	3.66
Finishing ops., plant	--	--	0.04	0.19
Other finishing ops., total	4.24	4.14	4.06	3.85
Grand total per sq.m. net area	14.32	12.54	11.31	10.50
Percent compared with conventional	100.0	87.6	79.0	73.3
Percent compared with 57 sq.m. unit (Table 5)	88.6	88.0	86.5	86.2

#### SUMMARY

The paper reports results obtained on the labor requirement and its relative weight in the total cost for different lower-cost housing construction methods: the conventional, cross-walls, partial prefabrication and comprehensive prefabrication methods.

Data on the direct labor requirement were compiled with the aid of time studies, all results being referred to normal time.

The indirect labor cost was analyzed on a project consisting of 128 dwelling units (57 sq. m.) in four-storey terrace buildings with an annual plant output of 750 dwellings.

Compared with the conventional method, the total saving in direct labor ranges up to 24.5% in the comprehensive construction method and up to 39.5% for the work on site. Excluding the substructure, it is up to 31% and 48.5% respectively. The total saving in skilled labor is up to 36%, and for unskilled labor the requirement is up to 5.7% higher.

The total construction cost, with the conventional method as 100%, was 95.9% for the cross-wall method, 94.4% for the partial prefabrication and 95.9% for the comprehensive prefabrication method. The relative weight ranges between 31.9% and 27.2% of the construction cost, with 3.8% and 5.7% for the indirect labor respectively.

An increase in labor cost favors the more mechanized methods. Its increase by 10% reduces the percentage for the comprehensive prefabrication vs. the conventional method from 95.6% to 95.2%.

Enlargement of the floor-area to 75 sq. m. (by 31%) reduces the direct labor requirement per sq. m. by 11.4% in the conventional method up to 13.8% in the comprehensive prefabrication method.

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