METHODOLOGY FOR FORECASTING COST ESTIMATES

OF

CIVIL ENGINEERING PROJECT

A PROJECT REPORT

BY

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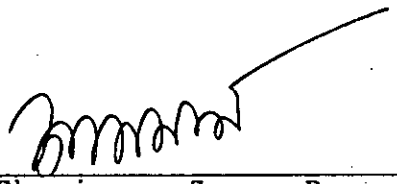

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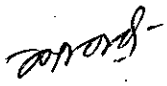

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ABSTRACT

The study was undertaken with a view to develop a method for cost estimate of Civil Engineering projects before the detail plans and specifications are available. From past information of projects of similar type, correlation of work to floor area has been developed and it is found that there is a reasonable consistency between quantities of works and floor area of different buildings. Also from past information of cost of a project, the effect of price escalation during the construction stage has been evaluated. Load bearing wall and normal reinforced concrete slab type residential buildings are studied and the works of the projects are grouped into 7 major work items. The average values of ratios of works to floor area of 7 major work items are listed for use in estimating the cost of a proposed building. These values are then applied to new projects and the results seem to reasonably forecast the proposed costs of such projects.

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DEFINITION AND NOTATIONS

Floor Area : The gross floor area of the building

C : The total project estimated cost

Rqi: ratio's of work of item i to floor area

pi : unit price of work item i

At : Total floor area of the building

Ag : Ground floor area of the building

Y : Expected period of completion of project

Q_i : Estimated quantities of work item i

Qij: Quantities fo work in work item i in project j

CHAPTER 1

INTRODUCTION

1.1 General Remarks

The final estimate of a construction project must be close to the actual cost of the job when completed, because it is generally used as a basis for submitting a bid. Making a firm estimate requires considerable amount of design work as well as detailed and time-consuming quantity estimates, materials pricing, and labour estimates.

Therefore, preliminary, or predesign estimate is frequently justified. Initial appropriations are often based on this estimate and it is also useful in appraising the economic feasibility of alternate projects.

1.2 Statement of Problem

There are numerous methods of estimating the construction costs. These are classified in accordance with the stages of designs and cost of executing the methods.

The classifications are:

i) End product unit methods: Preliminary, short-cut estimates in terms of end product unit are useful tools in appraising the feasibility of new projects, in determining the order of magnitude of proposed construction, and in providing a rough check on estimates obtained through more refined methods. This method requires the analysis of numerous completed projects, so that general relationships between unit costs and project size or plant capacity can be identified. The cost of proposed new projects of any given magnitude can then, by comparison, be estimated with accuracy, that is satisfactory for many specific purposes.

ii) Physical size method: This method also requires information of completed projects. From the past information the costs can be designed as a function of physical size, i.e length, floor area or volumes of the structures. The costs of new projects are then estimated by multiplying the size of new projects by the cost per unit.

iii) Work unit method: In this method costs per unit of works are calculated based on the current market prices. The cost of the new project may be estimated by determining the quantities of works required for the project and then multiplying them by the corresponding unit prices of works.

End product unit method is used for predesign estimating in many types of Civil Engineering projects and can be applied quite easily. However, the estimates must be made with great care and used with caution, fully recognizing their limitations.

This method cannot provide cost adjustments in case there are price escalations of construction materials, labour, and equipment, nor they can provide cost differences in case there are alternatives of design or specifications of work.

Physical size method is used when the size of the project is known. This method can also be applied quite easily and conveniently. However, similar to the end product unit method, they can not provide cost adjustments in case of price escalations, nor cost differences in case of alternative design or specifications of works.

Work unit method provides most accurate idea about costs and can provide cost adjustments in case of price escalation and alternative specifications of works. However, this method can only be used when detailed drawing, design and plan of the projects are available.

The above discussion reflects the shallowness of the present methods of predesign cost estimate. Hence it is necessary to develop a method of estimation in the predesign stage which can

provide accuracy, similar to the physical size methods and at the same time can provide cost adjustments in case there are price escalations of construction materials, labours etc.

1.3 Objective and Scope of Study

Forecasting cost estimates are generally made before the plan and specifications of a project are available. This type of estimate is used by all key people involved in the building process by the owner or his consultant during the feasibility study, by the designers to evaluate possible design alternatives and by the contractors for bidding and budgetting.

An estimate at the concept or preliminary design stage cannot be precise as it is based on the owner's space requirements and rough design sketches. However a method is needed for a reasonably accurate easily completed and inexpensive prediction of the cost of a project from the preliminary drawings.

The cost of new construction is made up of various components such as materials, labour, equipments, financing cost and general or overhead expenditures. When one estimates the future price of a given building, industrial plant, or other cosntruction, he knows only the past and present costs of the aforementioned components. But he does not know, how these prices will vary in the future. In many cases, when it was impossible to make

reasonable predictions of how prices would change the owner was asked to take the risk of under writing all possible price escalations.

Thus for the prediction of a reasonably accurate cost estimate in the predesign stage, the influence of price escalation should be considered carefully.

The objective of this study is to demonstrate how to use past information of cost of projects to make a reasonable accurate estimate in the predesign stage and at the same time to provide the effects of price escalations and change of specifications of works.

1.4 Outline of the Study

The project work has been divided into the following activities:

i) All the available methods for forecasting construction cost estimate i.e the methods for the preparation of cost estimate will be critically reviewed.

ii) It is believed that there exists relationships between quantities of works and the physical sizes of buildings i.e. there is a reasonable consistency in the ratios of works to one square meter of floor area which can be expressed as cubic meter

of concrete, killogram of reinforcing steel, square meter of wall etc. per one square meter of floor area.

To find the reasonable consistency between quantities of work and one square meter of floor area, the necessary data and information of some completed buildings will be collected from government and private agencies.

Knowing the relationship of each item of work with the square meter of floor area, the total quantity of each item of work for a building of given size can be estimated. Then by multiplying the total quantity with unit price, the cost can be calculated.

iii) In order to provide the effect of price escalation of construction materials, labour etc. on the cost estimate during construction process, it is necessary to establish a statistical relationship between cost and time i.e, the variation of cost with time.

For this purpose the construction cost of a single ideal building will be estimated with past and current schedule of rate. Schedule of rates, and plan drawings and design of such an ideal building will be collected from Local Govt. Engineering Bureau (LGEB) or Public Works Department (PWD). With the help of statistical relationship between cost and time, the rate of variation of cost, i.e, the effect of price escalation during construction process can be predicted.

iv) The results of this study will be examined with some new projects, i.e. the applicability of this result will be verified.

CHAPTER 2

REVIEW OF LITERATURE

William R. Park [1] in 1963 developed preliminary cost estimating data for four different types of Civil Engineering projects: (1) Sewage treatment plants, (2) Steam-electric generating plants, (3) School construction and (4) Public housing.

1) Sewage treatment plants: These data identify direct construction costs for more than 500 sewage treatment plants. These data were converted to an ENR (Engineering News Records) construction cost index of 100 and relationships between unit costs and plant capacities (expressed as population equivalents) were developed. These relationships were tabulated for both primary and complete sewage treatment plants.

In the same procedure, unit construction costs of primary treatment plants have been converted to a unit cost per mgd, using 100 gallons per capita per day as the conversion factor. These calculation are presented in Table 2.1 and the corrosponding curves are shown in Fig. 2.1

2) Steam-Electric Generating Plants: A sample of 44 steam-electric plant was used in this analysis, drawn from the Federal Power Commission's annual publication. Plant capacities ranged

from 12 mw to 625 mw. The costs are summarised in Table 2.2 and are plotted in Fig. 2.2.

3) School Construction: Cost relationships have been developed based on a sample of 33 public elementry schools built during 1960 and 1961. Table 2.3 summarizes pertinent data, which are plotted in Fig. 2.3.. But it is seen from the data provided that there is no correlation between either the number of pupils and the square feet per pupil, or the number of pupils and the cost per pupil.

4) Public Housing: This study was concerned only with public housing developments involving multi-story apartment unit of fire proof construction. A total of 34 such buildings were included in this analysis. All of them were built during the period from 1956 to 1961. They ranged in size from 4 stories to 32 stories high, and contained 350 to 6000 rental rooms each. In general a single apartment unit will include an average of from 4 to 5 rooms. The result are shown in Fig. 2.4 and the data are summarized in Table 2.4.

Nowadays the shape and size of room has been changed largely from project to project. Also the requirements of building have changed and become more complicated. So this method is not reasonably accurate.

Table 2.1 Primary Treatment Plant Construction Costs

Population Equivalent	Waste flow, in mgd	Per capita cost			Cost per gpd capacity		
		Lower limit, in dollars	Estimate, in dollars	Upper limit, in dollars	Lower limit, in dollars	Estimate, in dollars	Upper limit in, dollars
100	0.01	10.49	15.58	23.20	0.1049	0.1558	0.2320
1,000	0.1	4.99	7.42	11.05	0.0499	0.0742	0.1105
10,000	1.0	2.38	3.53	5.26	0.0238	0.0353	0.0526
100,000	10.0	1.13	1.68	2.50	0.0113	0.0168	0.0250

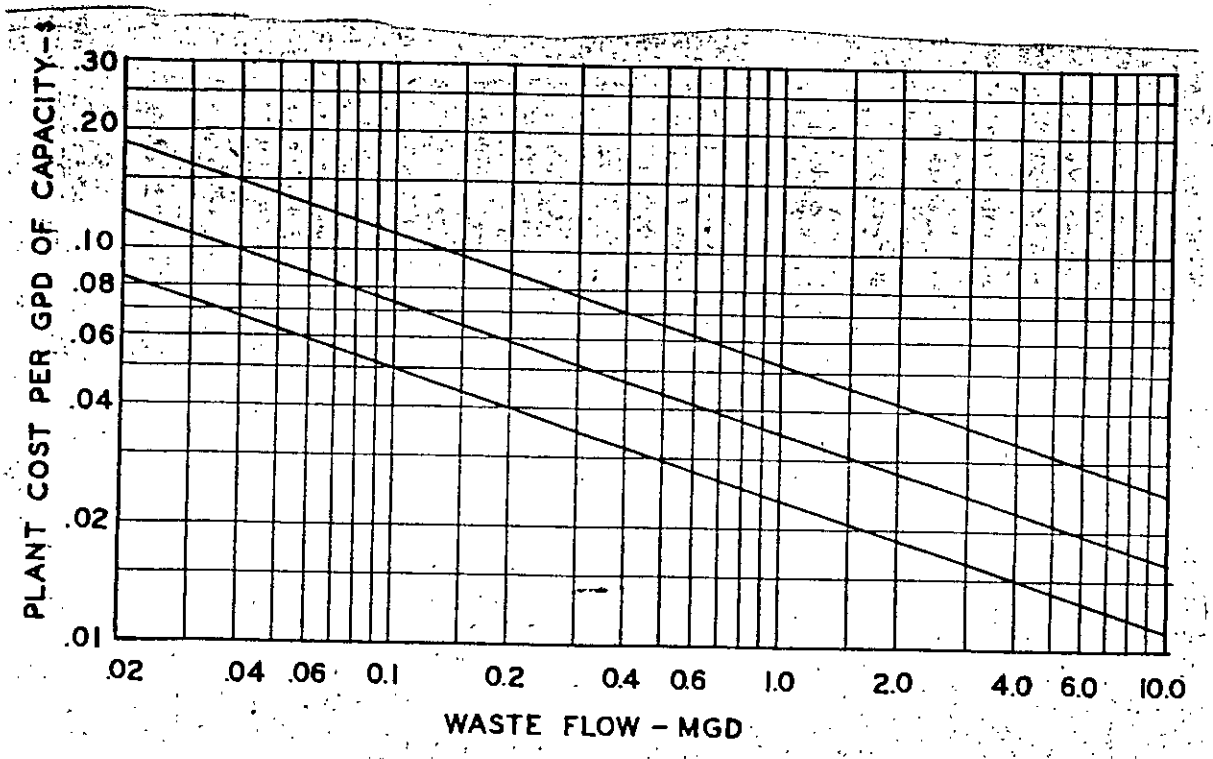

FIG. 2.1 —COST OF PRIMARY WASTE TREATMENT PLANT

Table 2.2 Steam-Electric Plant Construction Costs

Plant capacity, in megawatts	Cost per kilowatt of Plant Capacity		
	Lower limit, in dollars	Median, in dollars	Upper limit, in dollars
20	29	45	68
50	24	37	56
100	21	32	48
200	18	27	41
500	15	22	34

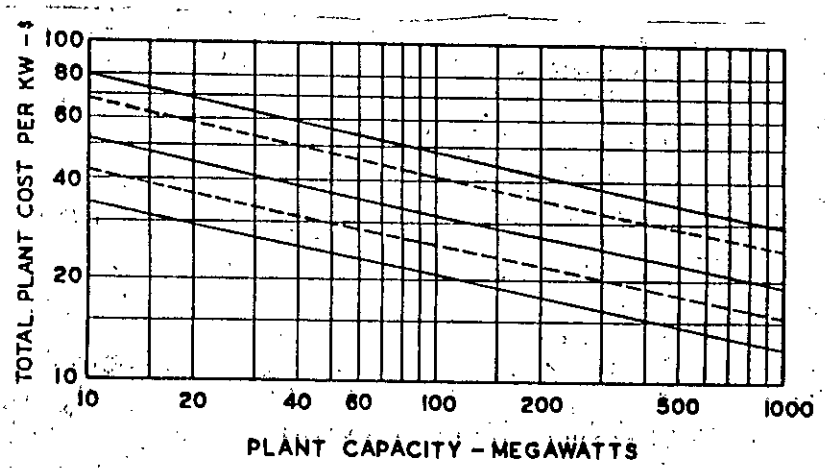

FIG.2.2 COST OF STEAM-ELECTRIC GENERATING PLANT

Table 2.3 School Construction Costs

Area per pupil, in sq. ft.	Cost per Pupil		
	Lower limit, in dollars	Median, in dollars	Upper limit, in dollars
50	105	130	165
60	135	170	215
70	170	210	265
80	205	255	320
90	240	300	380
100	275	350	440
110	320	400	505

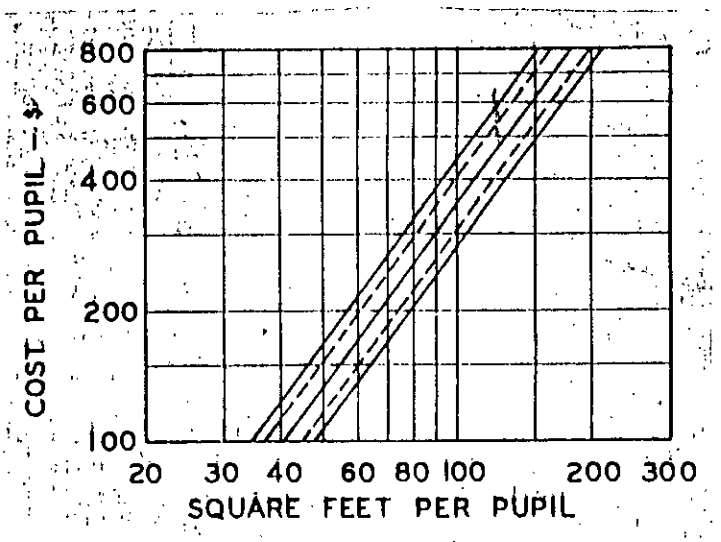

FIG. 2.3 —COST OF SCHOOL CONSTRUCTION

Table 2.4 Public Housing Construction Costs

No. of rooms	Cost per Room		
	Lower limit, in dollars	Median, in dollars	Upper limit, in dollars
300	810	700	880
500	550	640	800
1,000	490	560	700
1,500	450	520	650
2,000	430	490	620
3,000	400	460	570
4,000	380	430	540
5,000	360	410	520
6,000	350	400	500

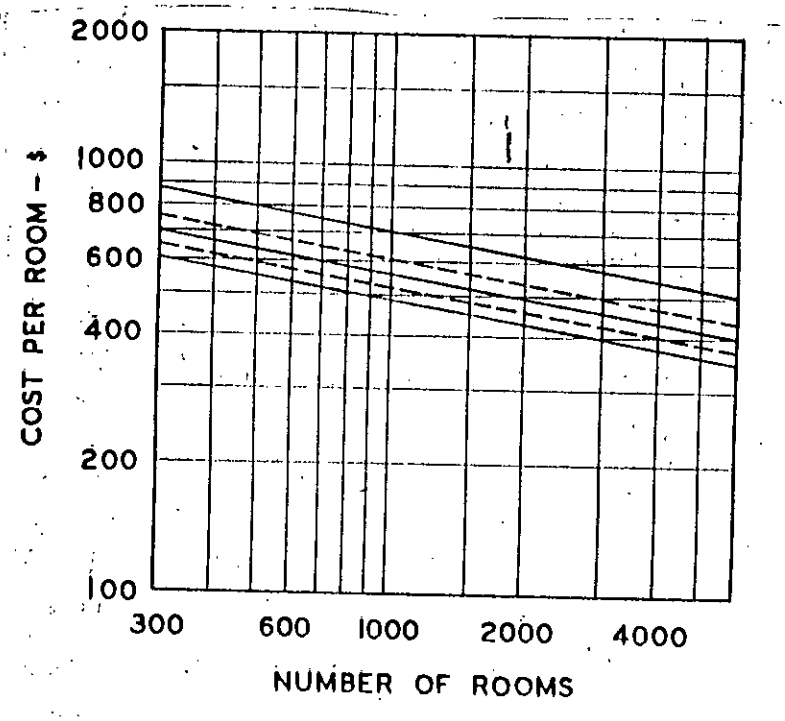

FIG. 2.4 —COST OF PUBLIC HOUSING PROJECTS

A cost equation was developed by Kouskoula and Kochn [2] that expresses the square foot cost of the building in terms of several variable, including the building height. By using historical building costs, they developed a linear equation that defines the square-foot cost of a building in terms of six variables: height, type, location, construction year, quality and the building technology.

The equation that they had derived is

$$C = -81.49+23.93L+10.97P+6.23F+0.167H+5.26Q+30.9T$$

where L = location index; F= type index; P=Price index; H=height of stories; Q= quality index; and T=technology index.

In 1984, Saeed Karshenas [3] presented a cost estimating equation for multistory buildings which was derived from historical building cost data. He developed the equation that defines the cost of a building in terms of two variables: height and typical floor area. This equation is of the form:

$$\ln \hat{C} = -0.0235+1.1045 \ln A + 1.1268 \ln H$$

$$\text{or } \hat{C} = A^{1.1045} \cdot H^{1.1268} \cdot e^{-0.0235}$$

in which $\hat{C}$ = the predicted cost of a building with the typical floor area of A sq-ft, and height of H ft.

The predicted cost $\hat{C}$ for a building will never be exactly equal to the actual cost of the building C. The ratio $C/\hat{C}$ = , is a random variable whose value for a given building depends on the value of variables that influence the building cost, but are not included in the model. The actual cost of a building, therefore, would be

$$\ln C = -0.0235+1.1045 \ln A+1.1268 \ln H+\ln \epsilon$$

or $C = A^{1.1045} . H^{1.1268} . e^{-0.0235} . \epsilon$

The above two methematical relationship were derived by using historical cost data and least square method. The accuracy of cost estimation of a building had been improved by considering such influencing parameter as building height, type, quality, price index etc. The above mentioned methods have not considered the breakdown of individual work item.

Therefore, when the market price of some work items are changed then the effect of change of price on the cost cannot be revealed by using these methods.

CHAPTER 3

THEORETICAL CONSIDERATIONS

3.1 Theoretical Aspect

Work unit method for estimating construction cost is the most accurate method. With the help of this method the cost can be calculated by adopting the following procedure:

i) Careful study of the ready plans, drawings, specifications and site conditions.

ii) List the items of works.

iii) Calculate the quantities of work itemwise.

iv) Determine the unit prices of works, considering all the factors such as construction methods, equipments needed, type of labour, market price of material, availability of materials etc.

v) By multiplying the quanities of work with the respective unit price, itemwise cost of the project can be calculated. Then by adding all the itemwise cost the total project cost can be estimated, which can be expressed in the following general form:

$$C = \sum_{i=1}^{n} (Q_i * P_i) \qquad (3.1)$$

where C = the project cost

Q_i = the quantity of work item i

P_i = the unit price of work item i.

It is seen from the above expression that this method can provide cost adjustment in case of price escallation of construction materials, labour etc. as well as can provide cost differences in case of alternative specification of works by re-evaluating the unit price of work.

But this method can only be adopted when detailed drawing and design are clearly defined and available. This is not applicable in the predesign stage.

The other two groups, End product unit method and physical size method are normally applied in the predesign stage. Predesign estimate can be prepared quickly and sometimes they can provide reasonably accurate results. However, when there are price escalations of construction materials or labour cost or when the owner wants to know the magnitude of effect in the project cost in case alternative specifications, these methods will not be able to adjust the estimate.

Incase of predesign estimate the same expression for project cost estimation must be used as work item methods, because by using this relation (eqn. 3.1), the magnitude of change in costs from the changes in the specifications of work or the price escalations of construction materials or labour costs can be evaluated. The unit prices of work items can also be determined in the same way as work item method.

But the problem is to determine the quantities of each work item and to introduce the effect of money inflation which occurs during the period of construction process.

It is believed that there is a close correlation of the quantities of the works to the floor area. From the past information of similar projects, this correlation can be defined statistically. The purpose of defining this correlation is to help one in estimating the quantities of the works for the proposed project in the predesign stage, provided that the floor area of the proposed project is known. Again the effect of money inflation during construction period can be investigated by estimating the total overall cost of a single ideal building with past and present information regarding unit prices of each work items.

3.2 Evaluation of Items of Work

On account of the time limit and unavailability of required information, only the "Load bearing wall and normal reinforced concrete slab" type building construction will be studied. After careful study of informations collected from different Govt. organizations and private construction companies, the items of work can be grouped as follows:

i) Earth work in foundation excavations.

ii) Structural works which includes reinforced cement concrete (R.C.C), Reinforcing steel, load bearing brick work.

iii) Wall and partitions which includes 5" brick wall partitions, Doors and Windows.

iv) Finishing works which include ceiling, wall and floor finishes.

v) Plumbing works which include water supply, sanitary, drainage system.

vi) Electrical works which include lighting system, power outlet, electric fan, etc.

vii) Other works which include brick soling, sand filling, lime terracing (L.C.C), cement concrete (c.c).

3.3 Data Collection

All the datas and information were collected by direct contact with Govt. and Private Agencies. Questionnaires as shown in the Appendix are sent to them.

CHAPTER 4

RESULTS AND ESTIMATING PROCEDURES

4.1 General Remark

The study is carried out only for "Load bearing wall and normal reinforced concrete slab" type residential buildings. Data and informations of 11 such buildings are collected from Public Works Department, Consulting firm and Local Government Engineering Bureau. All the buildings were built during the period from 1984 to 1988. These buildings ranged in size from 1 to 5 story high, contained 1 to 10 apartment unit and 116.17 m^2 to 1115.20 m^2 floor area. Schedule of rates from the financial year 1984-85 to 1988-89 was obtained from the office of Executive Engineer Local Govt. Engineering Bureau, Jessore.

A building construction project consists of a few hundreds of work items as classified for inclusion in the bill of quantities and contract doccuments. But for the purpose of analysis, all work items may be conveniently grouped together into a small number of work items as mentioned in section 3.2. Some minor work items are not included in the above grouping, which should be adjusted by the estimator with careful consideration to the quality of the building required.

Construction costs including sanitation and electrification of upazila chairman's quarter were estimated on the basis of past and present (FY) 1984-85 to 1988-89) schedule of rates and a statistical correlation was established which is shown in Table 4.1.

In Table 4.2 bills of quantities of major works of 9 "Load bearing wall and normal reinforced concrete slab" type residential buildings are shown.

4.2 Results

In Bangladesh bidding of all building projects are done on the basis of unit price of work items. Hence cost estimation includes two main steps. They are (i) take off quantities and (ii) pricing.

For estimation of quantity of work requires for a particular project, average values of the ratios of each item of work to floor area (R_{qi}) were computed from the available dates of past projects, which is shown in Table 4.3. This can be expressed by the following equations:

$$R_{qi} = \sum_{j=1}^{n} (Q_{ij}/A_{qj}) \ /n \qquad (4.1)$$

where R_{qi} = ratios of works of item i to floor area.

Q_{ij} = quantities of work in work item i in project j.

A_{qj} = floor area in project j.

For q = 1,2.

where q = 1: for total floor area basis; $A_{1j} = A_t$, $R_{1i} = R_{ti}$

q = 2: for ground floor area basis: $A_{2j} = A_g$, $R_{2i} = R_{gi}$

n = total number of projects (sources).

Except "other works", the other six major class of works as classified previously [Art. 3.2] are related to the total floor area (At). "Other works" which includes brick soling, sand filling, lime terracing and cement concrete (c.c), on account of their distinctive difference in materials requirement, purpose etc. they are correlated with the ground floor area (Ag).

The average value Rqi, range of variation, standard variation and coefficient of variation are given in Table 4.3 and 4.4.

The cost estimation equation of a proposed project can be expressed as:

$$Q_i = A_g * R_{gi} \qquad (4.2)$$

$$C = \left[A_t \sum_{i=1}^{n} (R_{mi} * P_i) + A_g \sum_{i=1}^{n} (R_{gi} * P_i) \right] * (1+M) \qquad (4.3)$$

where Q_i = estimated quantities of work item i.

A_t = Total floor area

A_g = Ground floor area

P_i = unit price of work item i

M = the mark up

It is seen from Table 4.1 that the average rate of increase in cost of building construction project is about 12% per year. It is also assumed that the expenditure for construction of a project is uniformly distributed throughout its expected construction period.

Then M = K Y

= 1/2 x Rate of increase in cost x Expected period of completion of the project (Y) in year.

= 1/2x0.12xY

= 0.06Y

Thus the equation 4.3 becomes

$$C = \left[A_t \sum_{i=1}^{n} (R_{mi} * P_i) + A_g \sum_{i=1}^{n} (R_{gi} * P_i) \right] * (1+0.06Y) \qquad (4.4)$$

4.3 Accuracy of the Results

The results in Table 4.4 shows the coefficient of variation which is the measurement of accuracy of the result. Some of the values of co-efficient of variation are larger than 20% whereas most of the values are less than 20%. The results which have the coefficient of variation larger than 20% are not suggest to use because of their larger variation from project to project.

4.4 Estimating Procedure at Predesign Stage

The proposed estimating procedure at predesign stage are as follows:

i) Survey the land on which the proposed project is to be built.

ii) Measure the area of the land.

iii) Calculate the maximum floor area of the building which can be built by considering the clear space requirement of municipality, the constraints in the building code.

iv) Determine the areas for carpark, and space requirements for other purposes.

v) List the work items and average value of the ratios of work from Table 4.4.

vi) Determine the unit price of each work item.

vii) Multiply the ratios of work by the floor area.

viii) Then multiply the result in (vii) by the unit prices of each item and sum them for the project cost.

Table : 4.1 Estimated cost of a residential building calculated with the help of scheduled of rates (from Fy 1984-85 to 1988-89) and variation of cost

Financial Year (FY)	Cost at the beginning of the FY (Tk)	Cost relative or link relative	Increased % with respect to the previous FY	Price relative $P_{1984-85/1988-89}$	% increase in 4 years	Average increase per year
1984-85	4,35,417.00					
1985-86	4,83,125.00	110.95%	10.95%			
1986-87	5,38,591.62	111.48%	11.48%			
1987-88	5, 90,172.37	109.57%	9.57%			
1988-89	6,45,797.67	109.42%	9.42%	148%	48%	12%

Table : 4.2 Bills of quantities of major works of Residential Buildings

GENERAL INFORMATION : PROJECT NO.	1	2	3	4	5	6	7	8	9
Number of appartment Unit	1	4	4	4	1	8	8	10	8
Year Built	1984	1984	1984	1984	1988	1988	1988	1987	1987
Total floor area (M^2)	116.17	334.56	278.80	204.48	297.40	866.80	952.00	465.00	1115.20
Number of stories	1	2	2	2	2	4	4	5	4
Floor area of 1 story (M^2)	153.35	167.28	139.40	102.24	148.70	216.70	238.00	93.00	278.80
Typical floor height (M)	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
Floor area of one apartment unit (M^2)	116.17	83.64	69.70	51.12	148.70	108.35	119.00	46.50	139.40
1.Earth work in foundation excavation (M^3)	46.73	207	156	85	115	191	230	328	697
2. STRUCTURAL WORKS:									
Reinforced cement concrete(M^3)	26	74	67	35	49	148	156	123	223
Reinforcing steel (Kg)	2160	8130	6011	4795	6700	19800	22320	11453	20158
Load bearing brick work(M^3)	60	179	146	109	152	488	495	249	584
3. WALL AND PARTITIONS :									
5" brick wall (M^2)	31	83	75	56	52	-	-	147	143
Doors (M^2)	24	65	63	37	39	155	156	114	201
Windows (M^2)	25	71	58	45	37	154	184	94	141
Total doors & Windows area(M^2)	49	136	121	82	76	309	340	208	342

Contd....

	1	2	3	4	5	6	7	8	9
4.FINISHING WORKS :									
a. Ceiling finishes: Total finishes area(M^2)	112	330	268	198	288	860	948	458	1098
b.Wall finishes: Total finishes area (M^2)	432	1638	1310	1078	1360	2588	3550	2415	4751
Skirting (M^2)	57	123	102	75	125	264	272	188	354
c. Floor finishing : Total floor finishes area (M^2)	103	260	250	170	280	808	812	455	917
5. PLUMBING WORKS :									
Total Number of toilets(Unit)	3	8	8	4	5	16	16	10	24
Total No. of Kitchen(Unit)	1	4	4	4	1	8	8	10	8
Total No. of Bath shower(Unit)	3	8	8	4	5	16	16	10	24
6. ELECTRICAL WORKS :									
Lighting (Points)	18	60	60	48	38	112	120	90	160
Power outlet (Points)	6	20	20	20	9	40	40	40	64
Electric Fan(Points)	5	16	16	12	10	32	32	20	48
7. OTHER WORKS :									
Brick soling:Total Area(M^2)	167	307	269	188	245	370	406	170	551
Sand filling:Total Vol.(m^3)	39	70	53	33	62	99	113	40	148
Lime Terracing :Total Vol(m^3)	13	20	16	12	16	22	26	11	31
Cement concrete:Total vol.(m^3)	13	24	21	14	29	41	55	17	62

Table : 4.3 Correlation of works with floor area, Figures from item 1-6 are expressed in terms of rations of quantities of works to the floor area.and figures in item 7 are expressed as the ratio of quantities of works to the ground floor area.

GENERAL INFORMATION : PROJECT NO.	1	2	3	4	5	6	7	8	9
Floor area (M^2)	116.17	334.56	278.80	204.48	297.40	866.80	952.00	465.00	1115.20
1. EARTH WORK : (Earth work / Floor area (m^3/m^2)	0.4022	0.6187	0.5595	0.4156	0.3866	0.2203	0.2415	0.7053	0.6250
2. STRUCTURAL WORKS:									
R.C.C./Floor area (m^3/m^2)	0.2238	0.2212	0.2403	0.1712	0.1832	0.1707	0.1638	0.2645	0.1999
Reinforcing steel/Floor area (Kg/m2)	18.5934	24.3005	21.5602	23.4497	22.5285	22.8426	23.4453	24.6301	18.0756
Load bearing brick work/ floor area (m^3/m^2)	0.5165	0.5352	0.5243	0.5330	0.5099	0.5629	0.5197	0.5349	0.5238
3. WALL AND PARTITIONS :									
5. Brick wall/floor area(m2/m2)	0.2668	0.2480	0.2690	0.2738	0.1748	-	-	0.3161	0.1282
Doors /floor area(m2/m2)	0.266	0.1943	0.2259	0.1809	0.1311	0.1788	0.1638	0.2451	0.1802
Window /floor area(m2/m2)	0.2152	0.2122	0.2080	0.2200	0.1244	0.1776	0.1932	0.2021	0.1264
Door & windows/floor area (m2/m2)	0.4213	0.4065	0.4339	0.4009	0.2555	0.3564	0.3570	0.4472	0.3066
4. FINISHING WORKS:									
a.Ceiling finishes area/ floor area (m2/m2)	0.9641	0.9863	0.9612	0.9683	0.9683	0.9921	0.9958	0.9849	0.9845
b.Wall finishes area/ floor area (m2/m2)	3.7186	4.8959	4.6987	5.2719	4.5729	2.9856	3.7289	5.1935	4.2602
Skirting /floor area(m2/m2)	0.4906	0.3676	0.3658	0.3667	0.4203	0.3045	0.2957	0.4043	0.3174
c.Floor finishes area / floor area (m2/m2)	0.8866	0.771	0.8967	0.8313	0.9415	0.9322	0.8529	0.9785	0.8222

Contd....

Project No.	1	2	3	4	5	6	7	8	9
5. PLUMBING WORKS :									
No. of toilet/Floor area (Units /m2)	0.0258	0.0239	0.0287	0.0195	0.0168	0.0184	0.0215	0.0215	0.0215
No. of kitchen/floor area (Units / m2)	0.0086	0.0119	0.0143	0.0195	-	0.0092	0.0215	0.0072	0.0107
No. of showers/floor area (Units/ m2)	0.0258	0.0239	0.0287	0.0195	0.0168	0.0184	0.0215	0.0215	0.0215
6. ELECTRICAL WORKS :									
Lighting points /floor area (points /m2)	0.1549	0.1793	0.2152	0.2347	0.1277	0.1292	0.1935	0.1435	0.1720
Power outlet /floor area (Points /m2)	0.0516	0.0597	0.0717	0.0978	0.0302	0.0461	0.0860	0.0574	0.0645
Electric fan/ Floor area (points/m2)	0.0430	0.0478	0.0573	0.0586	0.0336	0.0369	0.0430	0.0430	0.0537
7. OTHER WORKS :									
a. Bricks soling area / ground floor area(m2/m2)	1.4375	1.8352	1.9296	1.8388	1.6476	1.7074	1.7058	1.8279	1.9763
b. Sand filling: Vol./ ground floor area(m3/m2)	0.3357	0.4184	0.3802	0.3227	0.4169	0.5214	0.4747	0.4301	0.5308
c. L.C.C.:Vol./G.floor area (m3/m2)	0.1119	0.1195	0.1147	0.1173	0.1075	0.1199	0.1092	0.1182	0.1112
d. Cement concrete Vol./ G. Floor area(m3/m2)	0.1119	0.1434	0.1560	0.1369	0.1950	0.1892	0.2310	0.1827	0.2223

Table : 4.4 Statistical Correlation of works to Floor area .

Item	Average value	Range	Standard deviation	Coefficient of variation
1. EARTH WORK IN FOUNDATION:				
Earth work /floor area (m^3/m^2)	0.4638	0.2203-0.7053	0.162	35%
2. STRUCTURAL WORKS :				
R.C.C./Floor area (m^3/m^2)	0.2043	0.1638-0.2645	0.0235	11.5%
Reinforcing steel / floor area(Kg/m2)	22.1584	18.0756-24.6301	2.22	10%
Brick work/floor area (m3/m2)	0.5289	0.5099-0.5929	0.002	4%
3. WALL AND PARTITIONS:				
5" brick wall/ floor area (m2/m2)	0.2395	0.1282-0.3161	0.0601	25%
Doors/floor area(m2/m2)	0.1996	0.1311-0.2451	0.0317	16%
Window/floor area(m2/m2)	0.1865	0.1244-0.2200	0.0348	18%
Doors & Windows/ floor area(m2/m2)	0.3762	0.2555-0.4339	0.0321	8.5%
4. FINISHING WORKS :				
a. Ceiling finishes area/ floor area(m2/m2)	0.9783	0.9612-0.9958	0.0121	1%
b. Wall finishes area/ floor area (m2/m2)	4.3695	2.9856-5.2719	0.7212	16%
Skirting/floor area (m2/m2)	0.3692	0.2857-0.4906	0.0324	8%
c. Floor finishes area/ floor area(m2/m2)	0.8798	0.7771-0.9785	0.0610	7%

Contd.....

ITEM	Average value	Range	Standard deviation	Coefficient of variation
5. PLUMBING WORKS :				
a.No. of Toilet / floor area (Units/m2)	0.0219	0.0168-0.0287	0.0034	15.5%
b. No. of kitchen / floor area(unit/m2)	0.0128	0.0072-0.0215	0.0048	37%
c. No. of shower/ floor area(Units/m2)	0.0219	0.0168-0.0287	0.0034	15.5%
6. ELECTRICAL WORKS :				
Lighting point/ floor area (points /m2)	0.1722	0.1277-0.2347	0.0352	20%
Power outlet / floor area(points /m2)	0.0627	0.0302-0.0978	0.0088	14%
Electric fan/floor area (points./m2)	0.0463	0.0336-0.0586	0.0082	17%
7. OTHER WORKS :				
a. Brick soling area / ground floor area (m2/m2)	1.7373	1.4375-1.9763	0.1576	9%
b. Sand filling/ Ground floor area(m3/m2)	0.4256	0.3227-0.5308	0.0695	16%
c. L.C.C./ Ground floor area (m2/m2)	0.1143	0.1075-0.1199	0.0037	3%
d. Cement concrete / Ground floor area (m3/m2)	0.1736	0.1119-0.2310	0.0130	7.5%

4.5 Testing Model

The main objective of this study is to formulate a method requiring minimum estimating time, workable with the actual availability and sufficient accuracy. The results of this study is examined with a new project and it is observed that the result is reasonably accurate. It is shown in Table 4.5 to Table 4.7.

The description of the new project is givewn below:

Project Name: D-Type Govt. Staff Quarter.
Construction Authority: Public Works Department
Total floor Area: 743.52 m^2
No. of story : 4
No. of Apartment unit: 8
Floor Area of each unit: 92.94 m^2
Ground floor Area: 185.88 m^2
Type of building: Load bearing wall and normal reinforced Concrete Slab.

The cost of the building as estimated by this newly developed methods is Tk. 2648339.40. Whereas the estimated cost at post design stage is Tk. 2691537.90. Thus the total project cost has error of only - 1.6%. Hence the results of this study is reasonably accurate and acceptable.

Table : 4.5 Estimation of Project cost (8x92.94 m^2 = 743.52m^2 4-Storied Government Staff Quarter)

Item	Ratio	Estimated quantities	Unit price (Taka)	Itemwise estimated cost (Taka)
1. EARTH WORK IN FOUNDATION:				
Earth work (m^3)	0.4638	344.84	18.54	6393.33
2. STRUCTURAL WORKS:				
R.C.C. (M3)	0.2043	151.90	3354.45	509540.96
Reinforcing steel (kg)	22.1584	16475.21	25.00	411880.25
Brick work (m3)	0.5289	393.25	1588.95	624854.59
3. WALL AND PARTITION				
5" Brick wall (m^2)	0.2395	178.07	269.00	47900.83
Doors (M^2)	0.1896	140.97	1614.00	227525.58
Windows (M^2)	0.1865	138.67	1291.20	179050.70
4. FINISHING WORKS :				
a.Ceiling finishes (m^2)	0.9783	727.38	28.00	20366.64
b. Wall finishes (M^2)	4.3695	3248.81	36.00	116957.16
Skirting (M^2)	0.3692	274.50	42.00	11529. 00
c. Floor finishes (m^2)	0.8798	654.15	233.50	152744.03
5. PLUMBING WORKS :				
a.No. of Toileta(Unit)	0.0219	16.28	1803.56	29361.96
b. No. of Shower (Unit)	0.0219	16.28	600.00	9768.00
c. No of Hand wash basin (Kitchen Unit)	0.0128	19.51	1200.00	11412.00

Contd.....

Item	Ratio	Estimated Quantities	Unit price (Taka)	Itemwise estimated cost (Tk)
6. ELECTRICAL WORKS :				
No. of lighting points	0.1722	128.03	250.00	32007.50
No. of Power outlet	0.0627	46.61	200.00	9322.00
No. of Electric fan	0.0463	34.42	2500.00	86050.00
7. OTHER WORKS :				
a. Brick soling (M^2)	1.7373	322.93	118.36	38221.99
b. Sand filling (M^3)	0.4256	79.11	70.62	5586.75
c. L.C.C. (M^3)	0.1143	21.24	2330.46	49498.97
d. Cement concrete (M^3)	0.1736	32.27	2118.60	68367.22

Table : 4.6 Comparison between the estimated quantities of works at predesign stage and post design stage.

Item	Estimated Quantities at pre design stage	Estimated quantities at post design stage
1. EARTH WORK IN FOUNDATION: Earth work (m^3)	344.84	315.62
2. STRUCTURAL WORKS :		
Concrete (m^3)	151.90	154.76
Reinforcing steel (Kg)	16475.21	17868.00
Brick work (M^3)	393.25	403. 82
3. WALL AND PARTITIONS :		
5" brick wall (m^2)	178.07	171.37
Doors (m^2)	140.97	148.12
Windows (m^2)	138.67	124.04
4. FINISHING WORK :		
a. Ceiling finishes area (m^2)	727.38	679.28
b. Wall finishes area (m^2)	3248.81	2934. 56
Skirting (m^2)	274.50	228.28
c. Floor finishes area (m^2)	654.15	704.69
5. PLUMBING WORKS:		
a.No. of toilest(units)	16.28	16
b.No. of Bath(units)	16.28	16
c. No. of Handwash Basin(Units)	9.51	8
6. ELECTRICAL WORKS :		
Lighting points	128.03	128
Power outlet points	46.61	48
Fan points	34.42	40
7. OTHER WORKS :		
a. Brick soling (m^2)	322.93	333.02
b. Sand filling (m^3)	79.11	81.23
c. L.C.C. (M^3)	21.24	19.73
d. Cement concrete (m^3)	32.27	25.37

Table : 4.7 Comparison of percentage Error of cost at predesign stage and post design stage.

Item	estimated cost at predesign stage (Tk)	Estimated cost at post design stage (Tk.)	% error
1. EARTH WORK IN FOUNDATION	6393.33	5851.59	+9.25%
2. STRUCTRUAL WROKS:			
Reinforced cement concrete	509540.96	519134.68	-1.84%
Reinforcing steel	411880.25	446700.00	-7.8%
Brick work	624854.59	641649.79	-2.6%
3. WALL AND PERTITIONS :			
5" brick wall.	47900.83	46098.53	+ 3.90%
Door	227525.58	239065.68	-4.82%
Window	179050.70	160160.45	+ 11.79%
4. FINISHING WORK :			
a. Ceiling finishes	20366.64	19019.84	+ 7.08%
b. Wall finishes	116957.16	105644.16	+ 10.70%
Skirting	11529.00	9587.76	+ 20.24%
c. Floor finishes	152744.03	164192.77	- 6.97%
5. PLUMBING WORKS :			
a. Sanitary ware	29361.96	28856.96	+ 1.75%
b. Bath room ware	9768.00	9600.00	+ 1.75%
c. Kitchen ware :	11412.00	9600.00	+ 18.87%
6. ELECTRICAL WORKS : Lighting points	32007.50	32000.00	+ 0.02%
Power outlet points	9322.00	9600.00	- 2.89%
Fan points	86050.00	100000.00	- 13.95%
7. OTHER WORKS :			
a. Brick soling	38221.99	39416.25	- 3.02%
b. Sand filling	5586.75	5736.46	- 2.60%
c. L.C.C.	49498.97	45979.98	+ 7.65%
d. Cement Cancrete	68367.22	53642.95	+ 27.44%
PROJECT COST	2648339.40	2691537.90	- 1.60%

CHAPTER 5

DISCUSSIONS

5.1 Cost Controls and Alternative Design Solution

Cost control in predesign stages has three main objective: (i) to ensure that the actual cost of the building does not exceed the owner's budget, (ii) to give the owner good value for his money and (iii) to achieve a proper balance of expenditure over the various building components. For this purpose, the building design should have several possible alternative solution to be chosen. The choice might be, for example, the proportions of using patent stone flooring and mosaic flooring. This study provides a more flexible solution for alternative design and help cost control at the predesign stages.

5.2 Effect of Price Escalation

There is no question that rising costs and limited fund creates a crisis at all level of private and Govt. Price forecasts based on the cost data are always proved to have changed due to the price escalation. In the Turner Building cost Index-1980; First Quarter Forecast [4] there are interesting figures. From 1967-1974, the index went from 100 to 190; an increase of 90% in 7 years or 12.85% per year. From 1974-1979, it went from 190 to 246; an

increase of 56% in 5 years or 11% per year using 1974 as the base.

The result of this study shows that from FY-1984-85 to FY-1988-89, the cost index went from 100 to 148; an increase of 48% in 4 years or 12% per year using Fy-1984-85 as the base.

The design consultant may have to prepare a predesign estimate on a project which may not start construction two years or more. During this period, he should be able to change the project cost due to the price escalation. The present study provides a better way to determine the effect of cost escalation. The estimator will be able to prepare a revise estimate of the project by directly changing the unit price of the work items and then multiplying by the quantities of the work items as determined earlier.

The effect of price escalation during the period of construction can be evaluated by using eqn. 4.4.

5.3 Effect of Type of Different Floor System on Predesign Cost Estimate

In Bangladesh, three types of floor design system are in common; they are:

i) Load bearing wall and normal reinforced concrete slab system.

ii) Normal reinforced concrete slab and beam system (Frame structure), and

iii) Normal reinforced concrete flat slab floor system.

This study is concerned only with load bearing wall and normal reinforced concrete slab type residential buildings.

Different design system has different in quantities of concrete, reinforcing steel, partition walls etc. Table 5.1 shows the ratio of work to floor area in load bearing wall and normal reinforced concrete slabs (Type 1) and normal reinforced concrete slab and beam (Type 2) floor system.

Table 5.1 Ratio of work to gross floor area in load bearing wall and normal reinforced concrete slab type building and normal reinforced concrete beam and slab (frame-structure) floor system.

Description of item	Type 1	Type 2
Reinforced cement concrete (m^3/m^2)	0.2043	0.4418
Reinforcing steel (kg/m^2)	22.1584	78.6403
5" partition wall (m^2/m^2)	0.2395	0.9245
Load bearing brick work (m^3/m^2)	0.5289	0.1449

5.4 Accuracy of the Estimation

From the results of testing models, it is indicated that the estimation method provided a good prediction regarding the cost of a building project which have an error less than 5%. It is to be noted that the using average value to estimate the quantities of 5" brick wall and some other work items is not accurate enough because of their larger coefficient of variation. It is recommended to proceed with different approach for those work items.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

From the results of this study, it is observed that most of the ratios of work to floor area have co-efficient of variation less than 20%. The values, which have co-efficient of variation larger than 20% are not accurate enough and hence these values are not recommended for use in estimating. The effect of price escalation can also be determined by directly changing the unit price and re-evaluating project cost. The results of present study is examined with a new projects and it is found that the total estimated project cost is quite accurate with an error of less than 5%. For some of the work items like 5" partitions walls, earthwork in foundation excavation etc. which have larger coefficient of variation, it is recommended to use another methodology.

Due to the limit of time and the availability of information, only one type of building construction is studied. Also the floor to floor height of all buildings are 3.05 meter and foundations were designed under average soil condition. So, it is considered that the following topics could be of significant interest and use to further knowledge in this field:

i) A study of buildings with different floor to floor height in order to establish relationships between quantities of work and floor height.

ii) An investigation of buildings under different soil condition in order to correlate quantities of work with soil condition.

REFERENCES

1. Park. W.R., Pre-design Estimates in Civil Engineering Project, Journal of the Construction Division, ASCE Vol. 89, No. CO2, Proc Paper 3627, September, 1963, pp. 11-22.

2. Kouskoulas and Koehn, Pre-design Cost Estimation Function for Buildings, Journal of the Construction Division, ASCE, Vol. 100, NO. CO4, December, 1974, pp. 589-604.

3. Saeed Karshenas, A.M., Pre-design cost Estimating Method for Multistory Buildings, Journal of the Construction Division, ASCE, Vol. 110, No.1, March, 1984.

4. Alpred C. Maevis, construction Cost Control By the Owner, Journal of the construction Division, ASCE, Vol. 106, No. CO4, December, 1980, pp. 435-446.

APPENDIX

Questionnaires

1. General information

   Project Number:

   Number of apartment units;

   Year built:

   Total floor Area (m^2):

   Number of stories:

   Typical floor height (m):

   Floor Area of one story (m^2):

   Floor area of one apartment unit (m^2):

2. Earthwork in Foundation Excavation (m^3):

3. Structural works

   Reinforced cement concrete (m^3):

   Reinforcing steel (kg):

   Load bearing brick work (m^3):

4. Wall & partitions

   5" brick wall (m^2):

   Doors (m^2):

   Windows (m^2):

5. Finishing work

   a) Ceiling finishes (m^2):

   b) Wall finishes

      Total finishes area (m^2):

      Skirting (m^2):

   c) Floor finishes (m^2):

6. Plumbing works

   Total number of toilet (unit):

   Total number of kitchen (unit):

   Total number of bath showers (unit):

7. Electrical works

   Lighting (points):

   Power outlet (points):

   Electric fan (points):

8. Other works

   Brick soling (m^2):

   Sand filling (m^3):

   Lime terracing (m^3):

   Cement concrete (m^3):