King Fahd University of Petroleum & Minerals
College of Environmental Design
Construction Engineering & Management Department

CEM – 520

Thesis's Summary

"Development of mechanical Work's Assembly Cost Data Model for Residential Buildings in Saudi Arabia"

Done By : Mohammed Bokhari
ID : 938560
Prepared for : Dr. Sadi Assaf

Date
DEC 20, 2004

TABLE OF CONTENTS

ABSTRACT

One of the main causes of project's poor cost estimation in Saudi Arabia is lack of the cost data in which results in contractor's failures especially residential building's contractors. Research develops a cost data model for preparation of detailed estimates for plumbing and heating, ventilating and air conditioning (HVAC) works for small size residential buildings. The research use MEANS Cost Data Book published in USA as the assembly estimate method.

INTRODUCTION

Residential buildings represent a major part of the Saudi Arabia industry. In 1939 the residential construction starts booming after the increasing in the oil price and its demand. In this period, 90 % of the construction permits issued annually.

ASSEMBLY COST ESTIMATE

Assembly cost estimate is defined as “a collection of group of precise line items unit price data into a single unit price line item for faster and more convenient estimating” (Bledsoe 1992). The assembly estimate is very important tool to estimate costs of residential buildings construction due to the repetitive performed.

THE NEED OF THE RESEARCH

In Saudi Arabia, the contractors depend mainly on their historical cost data which are incorrect, incomplete or unorganized data which lead to poor estimation practice. And according to many studies before, the construction industry in Saudi Arabia in need of development of cost data to assist them in performing a correct cost estimate.

STATEMENT OF THE PROBLEM

In the United States, the contractor can use cost data books plus his own historical data to come up with a correct estimate. These books contain data collected from many construction contractors firms. On the other hand, there is a lack of these books in Saudi Arabia construction market.

The main purposes of using these books are to improve estimate practices and to minimize errors. The data cost books will provide the contractor with the labor productivity in addition to labor, material and equipment costs and profit.

Plumbing and HVAC works in residential buildings are selected for the development of the cost data model.

PREVIOUS STUDIES

Al Barrak (1993) found out that the poor estimating practices were ranked the third of fourteen factors that cause contractor failure in Saudi Arabia. Saudi building's contractors ranked lack of cost data as the tenth out of twenty problems facing their estimators in preparing costs (Al- Harbi 1994). Shash (1992) found out that the productivity standard is ranked second out of ten factors affecting the contractor estimating process.

There are lacks of assemblies cost data books on mechanical works in Saudi Arabia that show the cost and the manpower productivity but, in United Stats there are many assemblies cost data books have been published.

OBJECTIVE AND LIMITATIONS

The main objective of this study is to prepare an assembly cost data model for mechanical works in residential buildings which include plumbing and HVAC works. The following steps show how to achieve the study objective:

1. Identifying the types and major components of systems and assemblies required for mechanical works in residential buildings.

2. Classifying the materials and equipment type of mechanical works.

3. Use the current methods in estimating the productivity of the man power and the costs of materials and labors.

4. Tabulating all the collected information

5. Develop the required formula to quantify each work.

6. Find what are the overhead and profit costs.

7. Calculate all above costs and develop cost data model.

The research limitations are as follows:

1. For plumbing and HVAC works, this research is limited fro a small residential building: two-stories, middle-class house (Villa or four (4) apartment's building.

2. The direct costs in this research are labor and material; all other costs related to them are considered as overhead.

3. Only mechanical works for contractors , suppliers and manufacturers of equipment and materials are considered in this research

4. The area of this research is Dammam Metropolitan area in the Eastern Province of Saudi Arabia.

5. In this research, there is no preparation of cost indexes for forecasting of future cost of mechanical works.

RESEARCH METHODOLOGY

The research methodology of this study to develop the assembly cost data model is summarized as follow:

1. Study and review technical literature and cost data books for mechanical works in residential buildings

2. Summarizing the mechanical assemblies and related equipment, materials and accessories used in residential buildings

3. Preparing a standard format for interviews

4. Collect data through interviews to determine the methods utilized to prepare a detailed estimate for mechanical works, i.e., materials, labor, equipment, overhead and profit.

5. Analyzing the collected data

6. Providing recommendations as a result of data analysis.

This research is based on interviews with contractors, manufacturers, labors and suppliers of mechanical systems and accessories for residential buildings Dammam Metropolitan Area.

The thesis followed the WBS used by R.S. MEANS in the numbering and tabulation of systems and assemblies of the research **(Figure – 1**). There are two reasons for using this method. First, it is easy to use because it's well prepared & presented. Second, it follows the CSI coding mechanism.

The following are the systems and assemblies used in this thesis:

1. The same numbering code has been assigned to any systems or assemblies similar to the one indicated in the MEANS Cost Data Book. For example, the western water closet is assigned the code B8.1-470-2000 which is the same code given by the MEANS

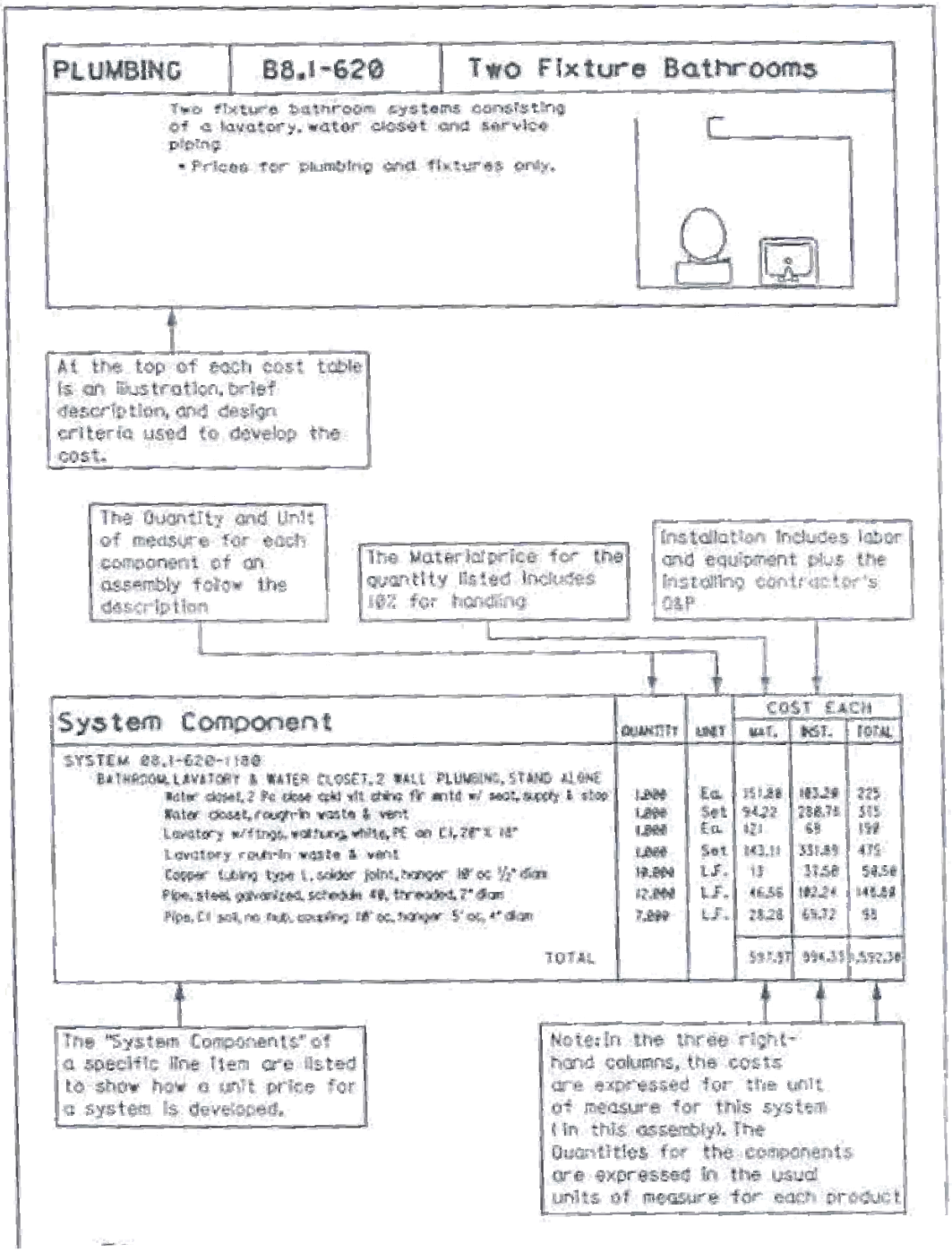

Figure # 1: MEANS Assembly of Cost Data Table

2. The systems or assemblies that are part of a major classification of the MEANS, but not listed, are given the numbering code **B8.1-XXX-99XX** for plumbing and **B8.3-XXX-99XX** for HVAC. For example, the eastern water closet system is given the code B8.1-470-9910.

3. New system or assemblies that are not classified in the MEANS are assigned the codes:

B8.1-999-91XX	(New Plumbing System)
B8.3-999-92XX	(New HVAC System)
B8.1-991-9XXX	(New Plumbing Assembly)
B8.3-992-9XXX	(New HVAC Assembly)

After the completion of the interviews with construction market, the lobar costs and types of crew had been formed. The labor costs had been determined by man- hour.

The data collection is obtained by using the following steps:

1. Reviewing MEANS Cost Data Books on unit and assembly estimates
2. Developing assembly cost data sheet which is more detailed than the one presented in the MEANS assembly Cost Data Book.
3. Reviewing some actual engineering drawings for residential buildings.
4. Visiting residential buildings under construction or in the finishing stage
5. Developing mechanical systems and assemblies (work package)
6. Preparing BOQ for each system and assembly.
7. Performing formal individuals' interviews to attain a high response rate and to clarify any confusion with representatives from;
   7.1. Mechanical equipment manufactures and suppliers for price quotations
   7.2. Suppliers of materials and accessories for price quotations
   7.3. Contractors for determination of crew size, labor productivity and cost.
   7.4. Construction engineers and trades

8. Arranging collected data in standard format.

In next the division, analyzes and evaluation is going to be discussed to develop the cost data model and their findings.

RESULTS & DATA ANALYSIS

The thesis has developed (10) new plumbing systems, forty (40) new plumbing assemblies and twenty – one (21) new HVAC assemblies. Moreover, it identified four (4) plumbing systems and seven (7) plumbing assemblies same as the one that MEANS specified.

From the previous interviews, the overhead cost and profit were in the ranges of 40 - 60% of the labor cost for plumbing works and 15 – 25 % of the material direct cost for HVAC works.
In this, thesis the overhead cost and profit is calculated as 50% of labor direct cost for plumbing works and 20 % of the material direct cost for HVAC.

The following table **(Table- 1)** had been used for the system and assemblies costs:

1. From interviews the crew type and daily output are obtained
2. From interviews the crew cost per hour is obtained
3. Man-hours / unit = 8 (hours / day) / Daily output
4. As per type of the system or assembly component the unit is determined
5. Material cost is the market purchasing cost
6. Assembly Bare Costs
    6.1. All assembly quantities will be determined by BOQ
    6.2. material Cost = market purchasing cost X Quantity
    6.3. Labor Cost = {Crew direct cost / hour} X quantity
    6.4. Equipment Cost = the rental rate of similar equipment from the local market
    6.5. Assembly total bare cost = material + labor + equipment
7. Total including overhead and profit:
    7.1. For plumbing = material + (1.5 * labor) + equipment
    7.2. For HVAC = (1.2 * material) + labor + equipment

8. Assembly total costs for all components (material, labor, equipment, overhead and profit) are indicted at the bottom of the table.

The following table (**Table- 2**) shows the actual direct cost for the mechanical labors which form the required crews, are an HVAC mechanic, a plumber and helper

Assembly Components	Crew type	Crew Coat Per Hour	Crew daily Output	Man-hours Per unit	Unit	Mat. Cost per Unit	Cost Development Per Assembly					
							1998 Bare Costs Per assembly					Total inc, O&P
							Quantity	Mat.	Labor	Equip.	Total	
Total												

TABLE - 1

Assembly Cost Data Table

Table – 2

Labor's Crew Direct Cost

Crew No.	Crew Labor	Bare Cost (SR)	
		Hourly	Daily
H -1	A/c mechanic	15	120
	Crew Total	**15**	**120**
H – 2	A/c mechanic	15	120
	Helper	7	56
	Crew Total	**22**	**176**
H – 3	A/c Mechanic	15	120
	Helper	7	56
	Helper	7	56
	Crew Total	**29**	**232**
P – 1	Plumber	10	80
	Crew Total	10	80
	Crew Total	**10**	**80**
P – 2	Plumber	10	80
	Helper	7	56
	Crew Total	**17**	**136**

The cost data prepared for plumbing works is divided as follows:

1. System: which consist of each plumbing fixture including its valves, accessories, piping and fitting
2. Assemblies: which a combination of more than one system

For plumbing system, the thesis developed ten (10) plumbing systems: nine for plumbing fixtures which had fixed BOQ and one (1) for piping and fittings which had variable BOQ since it depend on the number of fixtures installed in the toilet.

Since the plumbing contractors could not estimate labor productivity for each component of the system as MEANS Cost Data Book estimated, **table – 3** shows the labors productivity which is divided into two categories as follows:

1. The crew size and time needed for complete installation of each system
2. The crew size and time needed for complete installation of piping and fittings for each plumbing system

Table- 4 summarizes the total costs for each plumbing system.

System	Crew Type	Labor productivity (man-hours)
Recessed	P – 2	8
Stall shower	P -2	4
Corner Bathball	P – 2	12
Eastern Water Closet	P – 2	4
Western Water Closet	P – 2	4
Bidet	P – 2	4
Lavatory	P – 2	4
50 –liters electric heater	P – 2	3
80 liter electric heater	P – 2	3
One Fixture Toilet Piping & Fittings	P – 2	4
Two Fixtures Toilet Piping & Fittings	P – 2	8
Three Fixtures Toilet Piping & Fittings	P – 2	8
Four Fixtures Toilet Piping & Fittings	P – 2	10
Five Fixtures Toilet Piping & Fittings	P – 2	12

TABLE – 3

Labor's Productivity for Plumbing Systems

CODE	System	Unit	Cost Development Per Assembly					
			1998 Bare Costs Per assembly					Total inc, O&P
			Quantity	Mat.	Labor	Equip.	Total	
B8.1 - 410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1- 410-9900	Stall Shower	System	1	383	40		423	443
B8.1- 410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1- 470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1 - 470-2000	Western Water Closet	System	1	722	68		790	825
B8.1 - 470-9920	Bidet	System	1	655	68		723	757
B8.1- 433 – 2240	Single Compartment Lavatory	System	1	769	68		837	871

TABLE – 4

Plumbing Systems Cost Summary

The thesis identified seven (7) plumbing assemblies:

1. Toilets which are classified based on the number of fixtures
    1.1. One-fixture toilet (2 types) toilets
    1.2. Two–fixture toilet (10 types)
    1.3. Three–fixture toilet (14 types)
    1.4. Four–fixture toilet (7 types)
    1.5. Five–fixture toilet (6 types)

Following layout is one example of the above thirty – nine (39) layouts that have been discussed above.

2. Double compartment lavatory
3. Kitchen sinks (2 type)
4. Building main drainage, waste and vent piping assembly external to toilets (2 type)
5. Building main water supply piping assembly external to the toilets (2 types)
6. Water tank
7. Booster pump

Plumbing BOQ for each system include pipes, fittings, valves, fixtures and applications. The estimator has to measure the length of the main line including fittings and state the type of fittings, method of joining, kind and quality of material. Valves are listed by size, method of joining and quality. Fixtures and appliances are specified by type, quantity and accessories.

The BOQ for any plumbing assembly is the total number of the systems. For example, the toilet in figure 11 consists of four (4) systems: recessed bathtub, western water closet, bidet and lavatory. Figure 12 & 13 show the piping isometric diagrams. In **Table 5**, the total cost of the assembly is represented.

No.	System	Referenced Table No.	Materials (SR)	Labor (SR)	Total (SR)
1	Recessed Bath Tub	19	1058	136	1262
2	Western Water Closet	23	722	68	824
3	Bidet	24	655	68	757
4	Lavatory	25	769	68	871
5	Electric Water heater	26	392	51	469
6	Piping & fittings	29	585	170	840
Total			**4181**	**561**	**5023**

Table - 5

Method of Preparing a Plumbing Assembly Cost Data

HVAC Works in Residential Building:

The thesis developed cost data for the following assemblies:

1. Room air conditioner (4 type, **Table -6**)
2. Mini-Spilt air conditioning unit (12 type)
3. Central station air conditioning

HVAC BOQ includes equipment, ductwork, air terminal devices, ventilators, control, and insulation. Room air conditioners, cost include purchasing, delivery and installation and is affected by the selection of either cooling and cooling and heating unit.

From comparing the study's data to R. S. MEANS Assembly Cost Data for similar systems and assemblies, the following are observed:

- The cost in the R. S. MEANS Assembly Cost Data is much higher than the study cost
- The material cost in the study is much lower than the R.S. MEANS Assembly Cost Data.

HVAC	B8. 3-992	Room Conditioners

Code	Assembly Components	Crew type	Crew Cost Per Hour	Crew daily Output	Man-hours Per unit	Unit	Mat. Cost per Unit	Cost Development Per Assembly					
								1998 Bare Costs Per assembly					Total inc, O&P
								Quantity	Mat.	Labor	Equip.	Total	
9110	18000 BTHU (1- ½ Ton) Cooling	Q – 2	16	4	2	Assembly	1450	1	1450	32	0	1482	1500
9120	24000 BTHU (2 Tons) Cooling	Q -2	16	4	2	Assembly	1700	1	1700	32	0	1732	1750
9130	18000 BTHU (1- ½ Ton) Cooling & heating	Q - 2	16	4	2	Assembly	1475	1	1475	32	0	1507	1525
9140	24000 BTHU (2 Tons) Cooling & heating	Q – 2	16	4	2	Assembly	1750	1	1750	32	0	1782	1800

Table – 6

CONCLUSION

1. To develop an assembly cost data, this thesis has clarified the procedures and efforts.

2. Any local residential contractor can utilize the data available in this thesis since it is a practical study on cost estimation.

3. Utilizing the assembly cost estimation method in any repetitive construction activity is very efficient. Moreover, it is more accurate and quick in preparation the residential building detailed estimates.

4. The development of cost data requires collection of a lot of information summarized in large number of tables.

5. 14 plumbing systems, 47 plumbing assemblies and 21 HVAC assemblies had been developed as cost data in this research.

6. The material BOQ and cost were identified for each system and assembly.

7. The current methods in estimating labor productivity and cost were provided for each system and assembly.

8. The profit and overhead costs were found to be 40 %- 60 % pf the labor direct costs for plumbing and 15- 25 % of the materials direct cost for HVAC

9. The researcher established the required formula to calculate cost of labor, material, equipment, overhead and profit.

10. The researcher used the WBS method in numbering of the systems amd assemblies.

11. All calculated costs for each system and assembly have been tabulated clearly

12. The labor cost in the MEANS Assembly Cost Data Book is much higher than the labor cost in Saudi Arabia as found though the study.

13. The plumbing labor productivity is estimated for a complete assembly installation nod per each component as in the MEANS Cost Data Book.

14. The owner provides all materials required for plumbing works while the contractor provides all materials for HVAC works as part of the contract, hence, 10 % extra cost for material handling was not considered as in the MEANS

15. The price calculated for HVAC works are sometimes less than the ones available in the market. The different is considered as the bargaining range.

16. The HVAC equipment cost is mainly handled by one person such as project manager or engineer which puts the firm under risk if he decides to leave

17. The contractors cost data is not systematically organized

RECOMMENDATIONS

1. This thesis can be used as a model to develop any assembly construction cast data in the future

2. Further studies can be performed for other types of works in residential buildings such as architectural, civil and electrical works with the aim of having a complete cost data package for residential building in Saudi Arabia

3. Mechanical works cost data can be further expanded and developed for commercial and industrial facilities.

4. The cost data developed in this thesis can be loaded into one of the available cost estimation programs for quick estimate and continuous updating. Also, the data can be used on computer spread sheets.

5. Construction cost indexes shall be developed for Saudi Arabia construction industry for forecasting of future construction.

REFERENCES

Adrian, J.J., 1982, ***Construction Estimating***, Prentice-Hall, Inc., Englewood Cliffs, New jersey.

Al-Bani, M.f., 1994, ***Developing a concrete Cost Estimating model for Small Residential Buildings,*** master Thesis, King Fahd University Of Petroleum and Minerals, Dhahran.

Al-Barrak, A.A., 1993, ***Causes of Contractor's Failures in Saudi Arabia***, Master Thesis, King Fahd University of Petroleum and Minerals, Dhahran.

Al-Hammad, A.A., 1998, ***Recruitment and development of GCC nationals***, Al-Qafilah, Volume 46, pp. 12-15, Dhahran

Al-Harbi, K., Johnson, D.w. and Fayadah, h., 1994, ***Building Construction detailed estimating Practices in Saudi Arabia***, Journal of construction Engineering and management, ASCE, Volume 120, No. 4pp. 774-784.

Al-Subaie, O.S., 1987, ***Construction claims in Residential Houses in Saudi Arabia***, Master Thesis, King Fahd University of Petroleum and Minerals, Dhahran.

Asharq Al-Awsat Newspaper, 1996, ***Preparation to Face Population Growth in the Year 2020***, London.

Babaqi, A., 1993, ***Construction Sectors in the Coming Future***, Al-Benaa , Volume 12, No.71, pp. 55-57.

Bledsoe, J.D., 1992, ***Successful Estimating Methods***, R.S. means Company, Inc., Kingston, Massachusetts.

Dodge Construction Cost Information System, 1985. Manual for Building Construction Pricing Scheduling, McGraw- Hill Inc., Princeton, New Jersey

Drewin, F.J., 1982, ***Construction Productivity***, Elsevier Science Publishing Co., Inc., New York.

Engineering Economics Notes, 1993, King Fahd University of Petroleum and Minerals.

Ferrey, D.J., and Brandon, P.S., 1980, ***Cost Planning Of Buildings***, Fourth Edition , Granada Publishing Limited , London.

G.C.C main Economic Indicators, 1991. Research Institute, King Fahd University Of Petroleum and Minerals

Hardie, G.M., 1987, ***Construction Estimating Techniques***, Prentice-hall, Inc., Englewood Cliffs, New Jersey.

Manazerna, I., 1992, ***Cost Engineering References***, Saudi Aramco, Dhahran

Means Assembly Cost Data, 1992, R.S. Means Company, Inc., Kingston, Massachusetts.

Means Estimating Handbook, 1990, R.S. Means Company, Inc., Kingston, Massachusetts.

Means Graphic Construction Standards, 1986, R.S. Means Company. Inc., Kingston, Massachusetts

Means Light Commercial Cost Data (1993), 1992, 12th Annual Edition, R.S. Means Company, Inc., Kingston, Massachusetts.

Means Mechanical Estimating – Standard and Procedures, 1987, R. S. means Company, Inc., Kingston, Massachusetts

Metra Consulting Group Limited, 1975, ***Saudi Arabia: Business Opportunities***, The Financial Times Limited, London.

Ministry of Finance and national Economy, 1407 A.H., ***Labor Law and Workmen***, Sixth Edition, Riyadh.

Ministry of Finance and national Economy, 1992, ***Annual Report***, Middle East Print, Riyadh.

Ministry of Municipalities and rural Affairs, 1992, ***Annual Report***, Research and Statistics Department, Volume 42, 26 th Year, Riyadh.

Ministry of Municipalities and rural Affairs, 1996, ***Annual Report***, Research and Statistics Department, Volume 46, 30th Year, Riyadh.

Ministry of Planning, 1992, ***Fifth Development Plan (1996 – 1995),*** Ministry of Planning Print, Riyadh.

Ministry of Planning, 1993, ***Achievement of the Development Plans (1970 – 1992): Facts and Figures***, Ministry of planning Print, Riyadh

Paulson, B.C., 1975, ***Estimation and Control of Construction labor Costs***, Journal of the Construction Division , ASCE, Volume 101, NoC03, pp.623 – 633.

Purify, R.L., 1975, ***Estimating Construction Cost***, 3rd Edition, McGraw- Hill, Inc., New York

Real Estate Development Fund, 1995, ***Annual Report***, Real report, Real Estate Public Relation, Al- Hyatt Printing Riyadh.

Saudi Arabia Oil Company, 1998, ***Saudi Aramco Diary***, Public relation Department Dhahran.

Shash, A.A., and Al-Khaldi , Z., 1992, ***The Production of Accurate Construction Cost Estimate in Saudi Arabia***, Cost Engineering Journal, Volume 34, No.8, pp.15 – 24

Stewart, R&D., 1982, Cost Estimating, John Wiley & Sons, Inc., New York.

Stewart, R&D., and Wayside, R.M., 1987, ***Cost Estimator's Reference manual***, John Wily & Sons, Inc., New York.

Uman, D.M., 1990, ***Is Standard Needed for Estimating Building Design and Construction Costs?***, Cost Engineering Journal, volume 32, No. 8, pp.15-24.

Zahran, A.Z., 1997, ***Will Limiting Working Hours in the Market and Commercial Sector Help to Achieve Saudization?,*** Al-Ikitsad, Volume 295, pp.26 – 33.