Development of Mechanical Works' Assembly Cost Data Model for Residential Buildings in Saudi Arabia

by

Saleh Abdallah Al-Ghamdi

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

June, 1998

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COLLEGE OF GRADUATE STUDIES

This thesis, written by **SALEH ABDALLAH AL-GHAMDI** under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of the College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT**.

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14-6-98

Date

This thesis is dedicated to my sons: Abdallah and Osamah

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THESIS ABSTRACT

FULL NAME OF STUDENT : Saleh Abdallah Al-Ghamdi

TITLE OF THE STUDY : Development of Mechanical Works' Assembly Cost Data Model for Residential Buildings in Saudi Arabia

MAJOR FIELD : Construction Engineering and Management

DATE OF DEGREE : June, 1998.

The lack of cost data in Saudi construction industry is one of the main causes of projects' poor cost estimation that results in contractors failures especially residential buildings' contractors.

This research develops a cost data model for preparation of detailed estimates of mechanical works in residential buildings. The mechanical works include plumbing and heating, ventilating and air conditioning (HVAC) for small size villa or two (2) storey building consisting of four (4) apartments.

The research utilized the assembly estimate method of MEANS Cost Data Book published in the United States as a basis for the development of the model. The method considers all the system components as one work package or assembly.

The research began by identifying the mechanical works' systems and assemblies available in residential buildings. Next, interviews were performed for data collection of material

cost, labor productivity and contractors' current estimating practices. A simple mathematical relationship was developed to calculate the costs of material, labor, equipment, overhead and profit.

The data was collected through interviews with selected firms and personnel who can contribute to the research through their expertise such as equipment and material suppliers, project managers, engineers and tradesmen.

The research focused on Dammam Metropolitan Area which is located in the Eastern Province of Saudi Arabia.

MASTER OF SCIENCE DEGREE
KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
Dhahran, Saudi Arabia
June, 1998

خلاصة الرساله

اسم الطالب : صالح عبد الله الغامدي

عنوان الرساله : تطوير نموذج لقاعدة معلومات تكلفة الأعمال الميكانيكية في المباني السكنيه

التخصص : هندسة و إدارة التشييد

تاريخ الرساله : صفر ١٤١٩هـ/ يونيه ١٩٩٨ م

يعتبر النقص في قاعدة معلومات التكلفة في صناعة التشييد في المملكة العربية السعوديه أحد العوامل الأساسية لسوء إعداد حسابات تكلفة المشاريع التي تتسبب في خسارة و خروج المقاولين من هذا المجال خاصة مقاولي المباني السكنيه.

تقدم هذه الرساله نموذجا لقاعدة معلومات يمكن استخدامها في تقدير حسابات التكلفة التفصيلية للأعمال الميكانيكية التي تشمل التمديدات الصحية والتكييف في المباني السكنية الصغيرة الخاصة (فيلا) أو المباني المكونة من دورين و تحتوي على أربع شقق سكنيه كحد أقصى.

استخدم البحث قاعدة معلومات التكلفة المسماة (ميتر) التي تطبع و توزع في الولايات المتحدة الأمريكية كأساس لتطوير نموذج ينطبق على المباني السكنية في المملكة العربية السعودية.

بدأ البحث بتحديد الأعمال الميكانيكية ثم تم القيام بعمل مقابلات شخصيه لجمع المعلومات المتعلقة بتكلفة المواد و إنتاجية العمالة و الطرق المستخدمة في حسابات التكلفة. بعد ذلك تم ربط هذه المعلومات من خلال معادلات رياضية بسيطة لحساب تكلفة المواد، العمالة، المعدات، التكاليف الإدارية العامة و الربح.

تم جمع المعلومات عن طريق المقابلات الشخصية مع مؤسسات و أفراد مختارين لما لديهم من خبرات تساهم في هذا البحث مثل موردين المعدات، مد راء المشاريع، المهندسون و أصحاب المهن المتعلقة بالبحث.

ركز هذا البحث على مدينة الدمام و ما يتبعها و الواقعة في المنطقة الشرقية مـــــن المملكـــة العربيـــة السعودية.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول و المعادن

الظهران، المملكة العربية السعودية

١٤١٩هـ / ١٩٩٨ م

CHAPTER 1

INTRODUCTION

1.1. GENERAL

Residential buildings represent a major part of the Saudi construction industry. It actually started after the discovery of oil in Saudi Arabia in commercial quantities in 1939 and has grown rapidly since 1973 due to both the increase in oil demand and its prices. More than 90% of the construction permits issued annually in Saudi Arabia are for the construction of residential buildings as indicated in Table-1 (Ministry of Municipalities and Rural Affairs 1996).

1.1.1. DEMAND FOR RESIDENTIAL BUILDINGS

Residential buildings' construction is affected by economic conditions; however, the demand for housing will remain steady. This is due to the increase of Saudi population from 6 million in 1970 (the start of the first government five-year development plan) to

TABLE-1

Comparison of Building Construction Permits in Saudi Arabia

1409-1416 (1989-1996)

Year	Residential / Commercial		Industrial or Commercial		Educational, Health & Mosques		Social & Government		Total Permits
	NO.	% of Total	NO.	% of Total	NO.	% of Total	NO.	% of Total	
1409.A.H.	28114	90.1	2673	8.6	336	1.1	64	0.2	31187
1410.A.H.	27956	92.7	1727	5.7	435	1.4	48	0.2	30166
1411.A.H.	28850	94.0	1218	4.0	470	1.4	182	0.6	30720
1412.A.H.	42952	93.1	2415	5.2	719	1.6	50	0.1	46136
1413.A.H.	51731	92.9	2882	5.2	997	1.8	79	0.1	55689
1414.A.H.	69543	95.8	2199	3.0	799	1.1	99	0.1	72620
1415.A.H.	40381	92.3	2504	5.7	757	1.7	91	0.3	43733
1416.A.H.	27243	91.2	1848	6.2	704	2.4	77	0.2	29872

Source: Ministry of Municipalities And Rural Affairs 1412 (1992).

Ministry of Municipalities And Rural Affairs 1416 (1996).

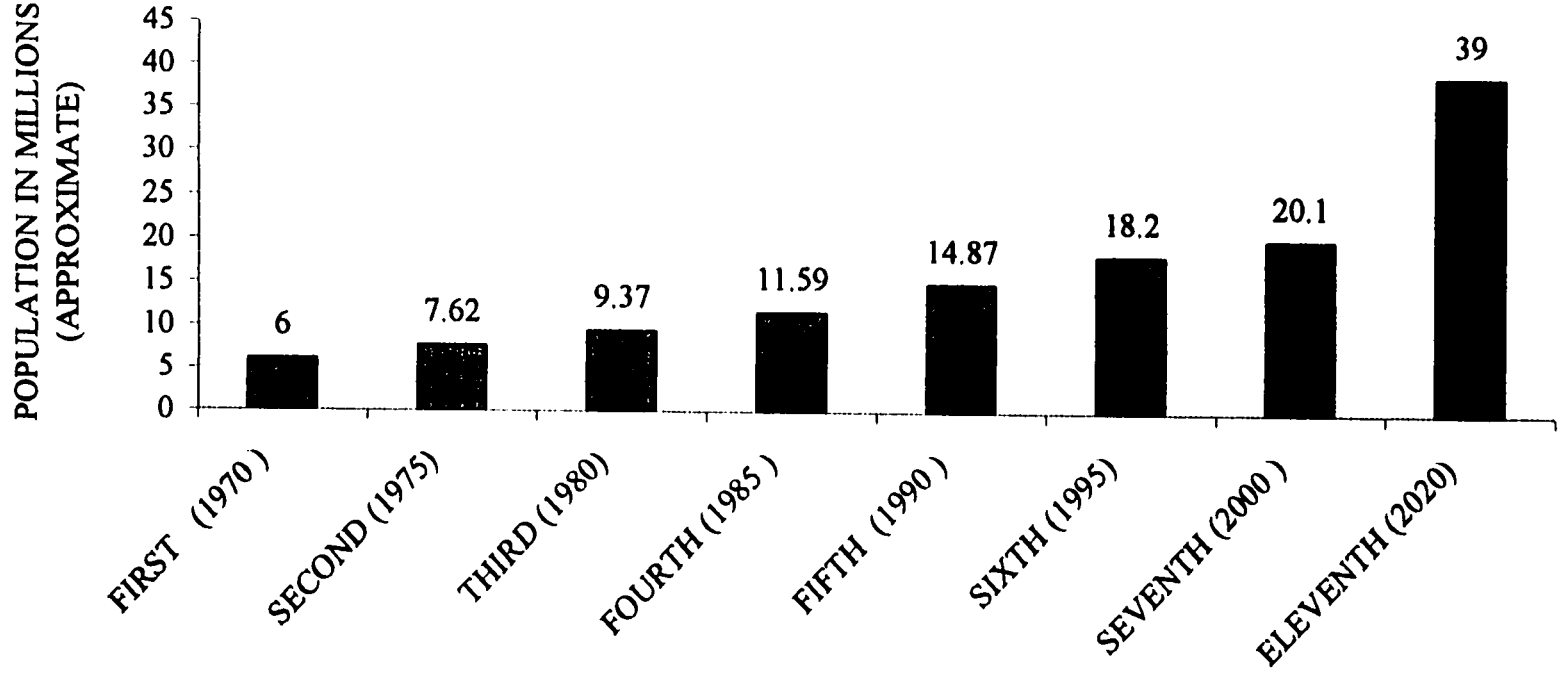
18.2 million in 1995 (Figure-1). At the start of the government's sixth five-year development plan in 1995, fifty-percent (50 %) of the population is under the age of fifteen (15) years (Al-Hammad 1998). This indicates the high future demand for residential buildings within the next ten (10) years.

In a recent study prepared by the City Planning Division of the Ministry of Municipalities and Rural Affairs, the Saudi population is expected to reach thirty-nine (39) million by the year 2020. This rapid growth in population will require 4.5 millions residential housing units that will need a financial funding of 982 billions of Saudi Riyals (Asharq Al-Awsat 1996).

The Eastern Province of Saudi Arabia is characterized by a huge oil industry in addition to the government agencies and military bases. This will continue to attract Saudi citizens from other areas to come and settle down in the cities of the Eastern Province especially in Dammam Metropolitan Area for which this research has been conducted.

In 1996, the total number of building construction permits issued all over Saudi Arabia was 29,872 (Table-1). 4,539 permits representing 15.2% of the total were issued in Dammam Metropolitan Area out of which 4,286 permits were residential buildings representing 94.4% of the total permits for Dammam Metropolitan Area (Table-2).

Figure-1
Population Growth in Saudi Arabia



Reference:
1. GCC Main Economic Indicators, 1991.
2. Al-Hammad, A.A., 1998.
3. Asharq Al-Awsat, 1996.
4. Zahran, A.Z., 1997.

TABLE-2

Building Construction Permits in Dammam Metropolitan Area

1416 A.H. (1996)

Building Type	Number of Permits	%
Residential/Commercial	4286	94.4
Industrial Or Commercial	198	4.4
Educational, Health & Mosques	10	0.2
Social & Government	45	1.0
TOTAL	**4539**	**100**

Source: Ministry of Municipalities And Rural Affairs 1416 (1996).

The previous statements support the expectation of the high demand for residential housings in the future.

1.1.2. RESIDENTIAL CONTRACTOR

The construction industry is always subjected to the variations in both local and international economy that impacts the number of construction contracts available and their cost. Table-1 shows that the total building construction permits issued in Saudi Arabia increased from 31,187 in 1989 to 72,620 in 1994, then dropped to 43,733 in 1995 and 29,872 in 1996. Also, the residential building construction permits issued increased from 28,114 in 1989 to 69,543 in 1994, then sharply dropped to 40,381 in 1995 and 27,243 in 1996 (Ministry of Municipalities 1996). The swing in the work volume creates a high potential failure rate especially for residential contractors. This is mainly due to two (2) reasons. First, the number of residential contractors is numerous causing excessive competition, low profit margin and sometimes bankruptcy. Second, the estimating and accounting systems for residential contractors are weak (Adrian 1982). Successful residential contractors are only those who can balance the workload with available cash flow.

1.1.3. IMPORTANCE OF COST ESTIMATE

In any construction process, there are three parties involved: owner, designer and the contractor. Cost estimation is necessary for all of the involved parties. The owner needs the estimate to determine project feasibility and to allocate resources to potential projects. The designer needs the estimate to keep the project within the owner's allocated budget. The contractor needs the estimate for bidding.

In the late 1970s and early 1980s (the boom years of Saudi Arabia), the high bid markup for overhead and profit costs protected contractors from losses due to estimating errors. After the boom years, the construction environment became very competitive and required estimate preparation to be as detailed as possible for contractor's survival in the construction market (Al-Harbi 1994).

1.1.4. ASSEMBLY COST ESTIMATE

It is a method of preparing a project's detailed estimate. Bledsoe (1992) defines the assembly estimate as "a collection of a group of precise line items unit price data into a single unit price line item for faster and more convenient estimating". For example, a toilet

plumbing assembly includes piping, fittings, valves and fixtures. The assemblies developed assist in the cost comparison of different alternatives of packages during the design stage.

The assembly estimate is a very important tool to estimate costs of residential buildings' construction due to the repetitive activities performed as will be discussed in Chapter-2.

1.2. THE NEED FOR THE RESEARCH

In Saudi Arabia, the contractors depend mainly on their historical cost data as the basis for estimate development. The data is either incorrect, incomplete or unorganized causing poor estimating practices and errors.

Poor estimating practices were ranked the third out of fourteen (14) factors that cause contractor's failure in Saudi Arabia (Al-Barrak 1993).

Al-Subaie (1987) found out that estimating errors are considered as an indirect cause of claims in residential houses in Saudi Arabia. The residential contractor usually tries to make claims if he is losing money due to errors in estimating or he may delay the project which creates a lot of problems between himself and the owner.

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). Saudi medium-size contractors, in particular, ranked lack of productivity standards as the second out of ten factors affecting their estimating process (Shash 1992). Estimators using computers in preparing estimates will not be able to produce the required reports for analysis due to unavailability of cost database (Al-Harbi 1992).

Al-Harbi (1994) indicated that "a well-organized historical cost data should be maintained in a single suitable location accessible to cost estimators".

As indicated in the above mentioned studies, the construction industry in Saudi Arabia is in need of development of cost data to assist contractors in the preparation of their estimates.

1.3. STATEMENT OF THE PROBLEM

Preparation and accuracy of a detailed cost estimate depends mainly on available cost data from the company cost data records or past experience of the estimator. In the United States, published cost data books are also used as a guide to prepare the estimate if such data is unavailable. These books contain data from the collected experience of the construction firms in which the books were originated. Unfortunately, the Saudi construction industry lacks the availability of historical cost data which contributes to production of inaccurate estimates as stated in section 1.3.

The cost data will improve contractors estimate practices and minimize errors since it provides the labor productivity in addition to the main construction cost components: labor, material, equipment, overhead and profit. Also, the cost data will help to minimize

the time required in the preparation of the estimates and the big gap between the lowest and highest bidders.

Mechanical works in residential buildings are selected for the development of the cost data model since the mechanical works represent 15-20 % of the building total cost and are usually performed by two (2) different contractors (one for plumbing and one for HVAC).

1.4. OBJECTIVE OF THE STUDY

The main objective of this study is to prepare an assembly cost data model for mechanical works in residential buildings which include plumbing, heating, ventilation and air conditioning. This is achieved as indicated in the following steps:

1. Identifying the types of systems and assemblies required for mechanical works in residential buildings.
2. Identifying the major components or systems of each assembly.
3. Identifying the type of materials and equipment required for mechanical systems
4. Obtaining the current methods used in estimating manpower productivity and the costs of material and labor.
5. Tabulating all the collected information.

6. Establishing the required formula to quantify each work.
7. Establishing the costs of overhead and profit.
8. Calculating all related costs (material, labor, equipment, overhead and profit) and presentation of the developed cost data model.

1.5. PREVIOUS STUDIES

Many assemblies cost data books have been published in United States on mechanical works, but, there is no such data book available for Saudi Arabia.

1.6. APPROACH TO THE PROBLEM

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

1. Reviewing technical literature and cost data books regarding 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. Gathering data through interviews to determine the methods utilized to prepare a detailed estimate for mechanical works, i.e., material, labor, equipment, overhead and profit.
5. Analyzing the gathered data.
6. Providing recommendations as a result of data analysis.

1.7. SCOPE AND LIMITATIONS

The scope and limitations of this research are as follows:

1. This study is limited to plumbing and HVAC required for a small residential building: two-story, middle-class house (Villa) or four (4) apartments' building.
2. The labor and material costs are the direct costs. Any additional costs related to both of them are included under the overhead costs.
3. This research will be limited to contractors, suppliers and manufacturers of equipment and materials for mechanical works.
4. The research will only cover Dammam Metropolitan area located in the Eastern Province of Saudi Arabia.
5. Preparation of cost indexes for forecasting of future cost of mechanical works is not part of this research.

1.8. SIGNIFICANCE OF THE STUDY

The significance of this thesis can be attributed to five main factors. First, all studies mentioned under section 1.2 on Saudi construction industry have indicated directly or indirectly the need to develop cost data applicable to Saudi Arabia. Second, a lot of cost data books have been published in the United States and Europe which reflect the importance of such data. Third, this study is the first in Saudi Arabia to prepare a practical model for estimating mechanical works in residential buildings Fourth, the collected information will help local residential contractors in preparing their detailed estimates for mechanical works which are considered as a major cost factor in the residential building total cost. Fifth, estimators using computers in preparing cost estimates can utilize the information presented in this research.

1.9. THESIS ORGANIZATION

The thesis is divided into five chapters. Chapter one gives a general background on importance of residential building construction in Saudi Arabia, a statement of the problem, the objective of the study, previous studies, approach to the problem, scope and limitations and the significance of the study. Chapter two presents a summary of literature review. Chapter three discusses the methodology used in the research. Chapter four

discusses and presents data analysis and the results. Finally, Chapter five provides summary, conclusion and recommendations for further studies.

CHAPTER 2

LITERATURE REVIEW

2.1. SOURCES OF FUNDING FOR RESIDENTIAL BUILDINGS' CONSTRUCTION

The sources of funding for residential buildings' construction are government and private sectors. The government funds are provided through Real Estate Development Fund (REDF), Ministry of Public Works and Housing and other government agencies. The private sectors consist of individuals and real estate investors. Dammam Metropolitan Area for which this research has been conducted is characterized by an additional source of funding which is Saudi Arabian Oil Company (Saudi Aramco).

2.1.1. REAL ESTSTE DEVELOPMENT FUND (REDF)

The Saudi government established in 1974 a specialized financial lending institution for residential buildings' construction named Real Estate Development Fund (REDF). It

provides interest-free private and investment loans for Saudi citizens paid back over a long period of time: twenty-five (25) years for private and ten to fifteen (10-15) years for investment loans. The fund started out originally with a capital of 250 millions Saudi Riyals (SR) and has grown to a total of 73,769 millions SR in 1995. The loans contributed to the construction of 505,718 houses all over Saudi Arabia from 1977 to 1995 with a funding of 111,701 millions SR as indicated in Table-3 (REDF 1995).

2.1.2. MINISTRY OF PUBLIC WORKS AND HOUSING

The Ministry of Public Works and Housing constructs houses and apartments then distributes them to Saudi citizens who are unable to build their own houses due to limited financial income. During the year 1992, a total of 11,016 houses and 14,686 apartments were constructed all over Saudi Arabia (Table-4) out of which 600 houses and 5,770 apartments were located in Dammam Metropolitan Area (Ministry of Finance 1992).

TABLE-3

Private Home Loans: 1396-1415 H (1977-1995)

FISCAL YEAR (H)	NO. OF LOANS PAID	NO. OF HOUSING UNITS COMPLETED	TOTAL AMOUNT OF LOANS IN MILLIONS (SR)
1396/95	32705	41017	7827
1397/96	47063	56346	12694
1398/97	4196	4598	1068
1399/98	35394	41288	8913
1400/99	32727	39828	8060
1401/00	28742	34312	7058
1402/01	31684	37360	8185
1403/02	35727	42430	9546
1404/03	29334	35280	7935
1405/04	26225	31458	7134
1406/05	18842	22613	5158
1407/06	11182	13450	3059
1408/07	11633	13978	3193
1409/08	12279	14725	3377
1410/09	8174	9806	2243
1411/10	8121	9744	2224
1412/11	5476	6270	1565
1413/12	8867	6892	2276
1414/13	23340	29009	6432
1415/14	13595	16314	3754
TOTAL	425,306	505,718	111,701

Source: Real Estate Development Fund 1995.

TABLE-4

Housing Projects in Saudi Arabia (1992)

City	Villa	Apartment	Total	Cost (SR)*
Accelerated Housing Projects				
Dammam	**---**	**1664**	**1664**	**2030.2**
Jeddah	---	1936	1936	2182.7
Riyadh	---	1152	1152	998.8
General Housing Projects				
Khobar	**---**	**4106**	**4106**	**2054.3**
Qatif	**600**	**---**	**600**	**424.6**
Al-Hasa	400	---	400	243.5
Jeddah	---	3420	3420	1718.4
Riyadh	3891	2408	6299	5000.8
Buraidah	949	---	949	878
Madinah	2084	---	2084	1183.5
Makkah	2592	---	2592	1842.2
Simple Housing Projects				
Al-Hasa	500	---	500	98.2
TOTALS	11016	14686	25702	18655.2

Source: Ministry Of Monetary And National Economy 1992.

Cost In Millions Of Saudi Riyals (SR). 1US $=3.75 SR.

2.1.3. OTHER GOVERNMENT AGENCIES

Some of the government agencies construct residential buildings for their personnel such as Ministry of Defense, Ministry of Health and Universities. A total of 221,600 housing units were constructed by these government agencies (Ministry of Planning 1993).

2.1.4. PRIVATE SECTORS

Private sector consists of individuals and local residential contractors. The individuals provide funding for construction of their own houses or for investment purposes. Also, some of the local residential contractors utilize their manpower during low workload to construct houses with the aim of selling them after completion to cover expenses and make some profit.

2.1.5. REAL ESTATE INVESTORS

Real estate investors construct housing compounds and complexes and rent them to individuals or business companies for housing of their employees. The Saudi Company for

Hotels and Tourism started in 1992 the construction of the Gulf Village at Dammam Half-Moon Bay which contains one-thousand (1,000) housing units (Ba-baqi 1992).

2.1.6. SAUDI ARABIAN OIL COMPANY (SAUDI ARAMCO)

Saudi Aramco, the main oil producer in Saudi Arabia and one of the largest in the world, established in 1951 a program called "Home Ownership Program" which provides free-company developed lot or lot allowance to enable eligible Saudi employees to build or purchase their own houses. Almost 40,400 homes have been built or purchased since the start of the program. In 1997, 1500 houses were constructed under this program (Saudi Aramco 1998).

2.2. COST ESTIMATION

Hardie (1987) defined estimating as "an expression of opinion or the prediction of probable future costs of certain construction activities, usually based on some data having an acceptable degree of reliability".

The objective of the estimate is to maximize information about any given set of proposed construction circumstances, to minimize the unknowns and the risks and to permit reasonably reliable project cost predictions.

The two main components of an estimating process are measurement and pricing. Measurement includes description of work, establishment of dimensions and the calculations of quantities of work. Pricing includes the establishment of data related to cost and productivity, the computation of prices based on the data and the application of prices to measured data.

The accuracy of the cost estimate is mainly based on available information from different sources such as data collected from previous identical work, drawings, specifications, productivity records, cost data handbooks, professional associations and personal knowledge.

The type of the estimate whether an approximate estimate or a detailed estimate impacts the time and accuracy required for the preparation of each type.

2.2.1. WORK BREAKDOWN STRUCTURE (WBS)

WBS is a hierarchical structure of work element developed by breaking down the work into its major tasks, then breaking the major tasks into minor tasks, the minor tasks into sub-tasks. The WBS is a method used by estimators to allocate the required resources and calculate the associated costs for each work activity. The purpose of developing the heirarical WBS can be summarized as follows (Stewart 1982):

1. To provide a lower breakdown of small tasks that are easy to identify and estimate.
2. To provide assurance that all required work elements are included in the work output.
3. To reduce the possibility of duplication of tasks.
4. To furnish a convenient hierarical structure for the accumulation of resources estimates.
5. To give greater overall visibility regarding the direct and indirect costs as well as profit made for each work activity.

The Construction Specification Institute (CSI) utilizes WBS concept in publishing a master list of titles and numbers used to organize construction information into a standard order of sequence (Uman 1990). The CSI divides construction work into sixteen (16) divisions as follows:

Division 1	General Requirements
Division 2	Site Work
Division 3	Concrete
Division 4	Masonry
Division 5	Metals
Division 6	Wood & Plastics
Division 7	Thermal Moisture Protection
Division 8	Doors & Windows
Division 9	Finishes
Division 10	Specialties
Division 11	Equipment
Division 12	Furnishing
Division 13	Special Construction
Division 14	Conveying Systems
Division 15	Mechanical
Division 16	Electrical

Mechanical work (Division 15) is further divided into sections as follows:

15.1	Pipe and Fittings
15.2	Plumbing Fixtures
15.3	Plumbing Appliances
15.4	Fire Extinguishing System
15.5	Heating
15.6	HVAC Piping Specialties
15.7	Air Conditioning and Ventilating

2.2.2. BILL OF QUANTITIES (BOQ)

It is also called material take-off or bill of materials. BOQ is the first step in preparing a detailed cost estimate. It consists of four main parts (Hardie 1987):

1. The classification of work to be done at different levels. For example, plumbing is classified separately from HVAC in mechanical work. This can be achieved by utilization of WBS techniques.
2. Words or numbers are used to describe all significant features of each item of work at each level to be measured. Under plumbing, many items can be found such as piping, fittings, valves and accessories.

3. The dimensions of items of work extracted or calculated from drawings and specifications.
4. The extension of dimensions indicating the total additions of calculated lengths, areas and volumes.

2.2.3. COST ESTIMATOR

The cost estimator is a key professional person in the very competitive construction industry. The knowledge he gained through his work experience plays an important role in the accuracy and reliability of the estimate. He should have the following knowledge and skills (Hardie 1987):

1. The bidding procedures
2. The types of contracts
3. Factors affecting costs of labor, material and equipment
4. Construction cost accounting
5. Construction terminology presented in design documents
6. Physical and chemical properties of common construction materials
7. Methods of assembling building components in the field
8. Labor productivity and equipment output
9. Government construction regulations

10. Mathematical calculations
11. Ability to communicate ideas to others using graphical, verbal or numerical representations
12. Ability to interpret meanings of verbal, graphical and numerical data
13. Skill and techniques of measuring quantities of materials, labors and other items
14. Ability to apply formula for a number of basic geometric plane shapes and solid figures
15. Skill and technique of negotiation

Some of the problems that cost estimators face in Saudi Arabia are (Al-Harbi 1994):

1. Tough competition
2. Contract period
3. Incomplete drawings and specifications
4. Incomplete project scope definition
5. Unforeseeable change in material prices
6. Changes of owner requirements
7. Current workload
8. Judgment errors
9. Inadequate time
10. Lack of historical data for similar jobs

11. Lack of experience in similar jobs
12. Unfamiliarity with government regulations
13. Work item omission
14. Lack of confidence in workforce
15. Difficulty of project
16. Lack of productivity information in Saudi Arabia
17. Content of arbitration clauses
18. Lack of cost data indices in Saudi Arabia
19. Calculation errors
20. Portion of work to be subcontracted

2.2.4. TYPES OF COST ESTIMATES

Estimators use three (3) basic types of cost estimates that are referred to by different names: order of magnitude, conceptual and detailed estimates.

2.2.4.1. ORDER OF MAGNITUDE ESTIMATE

Different names are used to describe order of magnitude estimates such as preliminary, feasibility, ballpark, blue sky or guesstimate. It is usually prepared in less than two (2) hours and the drawings and plans are non-existent at the time of preparation of the estimate.

This estimate provides the owner with an indication of the cost of the project at completion. In fact, it is a tool to compare the anticipated benefits and costs of a project at early stages in order to evaluate the potential risks associated and helps the owner to decide whether to proceed with the project or not.

In accordance to American Association of Cost Engineers (AACE), the order of magnitude estimate has the following characteristics (Manzanera 1991):

Accuracy Range	-30% to +30%
Basis	Cost Capacity Curves

	Cost Capacity Ratios
Use	Investment Screening
Information Required	Capacity
	Location
	Utility Requirement
	Service Requirement
	Building Requirement
	Raw Material and Storage Requirement
	Finished Products and its Storage Requirement

This estimate is usually prepared on the basis of comparison of similar completed projects or unit cost such as square foot, cubic foot or number of beds. Published cost data books provide the estimators with the unit cost data for variety of buildings.

2.2.4.2. CONCEPTUAL ESTIMATE

This type of estimate is referred to as design, advanced preliminary or intermediate estimate (Bledsoe 1992). It is prepared by the project designer to support the order of magnitude estimate and evaluate possible design modifications to keep project within the owner's budget (Adrian 1982). This estimate takes into consideration the design concept

for the project. It is usually prepared at an early stage of the design where 10-60% of the project drawings is completed.

The characteristics of the conceptual estimate are as follows (Manzanera 1991):

Accuracy	-15% to +30%
Basis	Flow Sheets
	Layouts
	Equipment Details
Information Required	Site Description, Survey and Soil Studies
	Preliminary Process Flow Sheets
	Equipment Engineering Specifications
	Preliminary Architectural Design
	Preliminary Structural Design
	Preliminary Construction Plan
	Preliminary Utility Heat
	Balance/ Flow Sheets
	Preliminary Piping & Instrument Diagram (P&ID)
	Rough insulation specifications
	Preliminary Motor list and sizes
	Substations specifications

Preliminary lighting specifications

Engineering & drafting man-hours

2.2.4.3. DETAILED ESTIMATE

Detailed estimate is the prediction, forecasting, or approximation of costs of proposed future construction activities. It is usually based on historical data in order to determine the necessary resources expenditures (money, manpower, material, machines and time) to perform the work. In fact, it is a description of a step-by-step plan of how the project will be done (Drewin 1982). This type of estimate is referred to as definitive or bid estimate.

Detailed estimate is usually prepared after the completion of design drawings and construction specifications. It is needed by the contractor for bidding and by the owner for budget preparation and bid evaluation. This estimate includes the detailed cost of labors, materials, equipment, overhead and profit.

Preparation of a detailed cost estimate consists of four parts. First is the review of all design documents such as conditions of contract, drawings, technical specifications, addenda and any other relevant information. Second is the preparation of bill of quantities (BOQ) which is a summary of all measured quantities of materials. Third is the pricing of

the measured quantities of work. Fourth is the summary of the estimate which consists of the following (Hardie 1987):

1. Material take-off indicating quantities and their measurements.
2. Unit prices for the measured quantities.
3. Summary showing the cost of various trades.

The characteristics of the detailed estimate are as follows (Manzanera 1991):

Accuracy	-5% to +15%
Information Required	Full Site Information
	Process Flow Sheets
	Equipment Vessels Specifications and Engineering Arrangements
	Detailed Engineering and Structure Drawings
	Insulation Drawings and Specifications
	Electrical Installations Drawings and Specifications
	Utility Installations Drawings and Specifications

Man-hours calculations for Engineering, Drafting, Labor and Supervision.

Detailed estimate can be prepared using two methods: unit price and assembly (work packages) methods.

2.2.4.3.1. Unit Price Method

It is the most accurate but time consuming method. Detailed engineering and specifications are required to prepare the estimate (Figure-2). The accuracy is plus or minus five (5) percent. Unit price method utilizes the Work Breakdown Structure technique (WBS). The total cost estimate is the total addition of the costs of each unit price found from the cost data tables.

2.2.4.3.2. Assembly Method

It is also called systems or work packages estimate. The assembly estimate is fast and accurate and can be substituted for many line items in the final detailed estimate. The assembly estimate utilizes the "Uniformat" twelve (12) divisions.

	151 550 Plastic Pipe		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1993 BARE COSTS				TOTAL INC. O&P	
							MAT.	LABOR	EQUIP.	TOTAL		
551	5380	Schedule 40										551
	5460	1/2" diameter	1 Plum	54	0.148	L.F.	2.40	2.64		5.04	7.00	
	5470	3/4" diameter	1 Plum	51	0.157	L.F.	2.95	2.79		5.74	7.85	
	5480	1" diameter	1 Plum	46	0.174	L.F.	3.68	3.10		6.78	9.15	
	5490	1-1/4" diameter	1 Plum	42	0.190	L.F.	4.18	3.39		7.57	10.20	
	5500	1-1/2" diameter	1 Plum	36	0.222	L.F.	4.65	3.96		8.61	11.65	

Note: All costs are in US Dollars

Reference: MEANS Light Commercial Cost Data - 1993.

Figure-2: MEANS Unit Cost Data

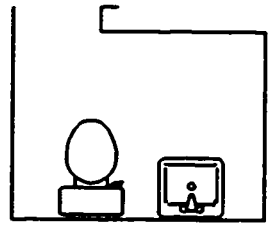
Division 1	Foundation
Division 2	Substructure
Division 3	Superstructure
Division 4	Exterior Closure
Division 5	Roofing
Division 6	Interior Construction
Division 7	Conveying
Division 8	Mechanical
Division 9	Electrical
Division 10	General Conditions
Division 11	Special
Division 12	Site Work

Each division is further divided into systems. For example, Mechanical (Division 8) is broken down into four (4) main systems: plumbing, fire protection, heating and air conditioning, and special systems. Figure-3 shows a cost data sheet for a plumbing system.

PLUMBING	08.1-620	Two Fixture Bathrooms

Two fixture bathroom systems consisting of a lavatory, water closet and service piping

• Prices for plumbing and fixtures only



System Component	QUANTITY	UNIT	COST EACH MAT.	COST EACH INST.	COST EACH TOTAL
SYSTEM 08.1-620-1180					
BATHROOM, LAVATORY & WATER CLOSET, 2 WALL PLUMBING, STAND ALONE					
Water closet, 2 Pc close cpld vit china flr mntd w/ seat, supply & stop	1.000	Ea.	151.80	103.20	225
Water closet, rough-in waste & vent	1.000	Set	94.22	280.78	375
Lavatory w/ftngs, wallhung, white, PE on CI, 20" X 18"	1.000	Ea.	121	69	190
Lavatory rough-in waste & vent	1.000	Set	143.11	331.89	475
Copper tubing type L, solder joint, hanger 10' oc ½" diam	10.000	L.F.	13	37.50	50.50
Pipe, steel, galvanized, schedule 40, threaded, 2" diam	12.000	L.F.	46.56	102.24	148.80
Pipe, CI soil, no hub, coupling 10' oc, hanger 5' oc, 4" diam	7.000	L.F.	28.28	69.72	98
TOTAL			597.97	994.33	1,592.30

8.1-620	Two Fixture Bathroom, One Wall Plumbing	COST EACH MAT.	COST EACH INST.	COST EACH TOTAL
2220	Bathroom, lavatory & water closet, one wall plumbing stand alone	560	905	1,465
2240	Share common plumbing wall	510	785	1,295

Figure-3: Means Assembly Cost Data Sheet

Reference: Means Assembly Cost Data - 1992

2.3. COST COMPONENTS

The detailed estimate can be classified into two categories: direct and indirect costs. The direct costs are labor, material and equipment. The indirect costs are overhead and profit.

2.3.1. LABOR COST

The labor cost is defined as the production rate multiplied by the gross hourly rate. Peurifoy (1975) defines a production rate as "the number of units of work produced by a man in a specified time usually an hour or day". The gross hourly rate is the combined wage rate and some additional fringe costs. The wage rate is the actual hourly rate agreed between the employee and the employer. In Saudi Arabia, the fringe costs that sometimes called "payroll burden" include:

1. Government fees for recruitment visa, resident permit (Iqamah) and work permit
2. Insurance and medical expenses
3. Travel time
4. Payments for time not worked such as vacation, official holidays and sick leave.

5. Service award which is half a month's pay for each of the first five years and one month's pay for each of the subsequent years as stated in article 87 of the Saudi Labor and Workmen Law
6. Food and housing allowances

After the preparation of the material bill of quantities, the estimator will determine the required time and crew size to execute the work using his experience and cost standards (Stewart 1987). Some of the factors that affect labor cost are worker moral, size of the crew, prior training, prior experience, age of worker, weather conditions, degree of management leadership, repetitive nature of work and complexity of work (Adrian 1982).

2.3.2. MATERIAL COST

Material cost can be derived from handbooks, supplier's catalogs or supplier's quotations (Stewart 1987). Also, some suppliers and manufacturers circulate materials current prices to contractors and designers. The material cost is affected by many factors such as supply of material, demand for material, quantity purchased, location of material purchased, the need for storage of materials and quality of material required (Adrian 1982). The estimator should use the latest editions of published price data due to the rapid changes in prices and market conditions.

2.3.3. EQUIPMENT COST

Equipment costs are hard to estimate due to the variety of equipment used in construction and the method of use. i.e., buy, rental, lease or loan. The cost of equipment includes operating and owning costs. The owning cost consists of investment, maintenance and depreciation. The operating costs include running costs, repairs and operator's wages and expenses.

2.3.4. OVERHEAD COST

The overhead costs are classified as direct job overhead and indirect contractor operating overhead costs. The job overhead cost consists of administrative items such as permit fees, site office, scaffolding and all items necessary to execute construction. The contractor operating overhead costs include administrative items such as head-office rental, salaries for head-office staff, advertising and any other items required to run the business (Hardie 1987).

In Saudi Arabia, overhead cost is estimated as 5-15% of the total cost (Al-Harbi 1994).

2.3.5. PROFIT

Profit is the additional amount of money desired by the contractor in excess of the project cost estimate. Determination of profit is critical since it may result in wining or losing the work. If the contractor bids with high profit, he may lose the contract. Also, if he bids with low profit margin, he will be under the risk of losing money. In order to get work from the owner, the contractor must make sure the profit added to the cost estimate will result in a competitive bid with those of other contractors.

In Saudi Arabia, profit is estimated as 10-20% of the direct cost or direct cost plus overhead (Al-Harbi 1994).

2.4. COST DATA

It is difficult to get an accurate and reliable cost data for construction industry due to many reasons. First is the competitive nature of the industry. Second is the secrecy that surrounds much of cost data. Third is the poor handling of cost data. Fourth is the sheer amount and types of data available. Fifth is the fluctuation in the world economy.

Stewart (1987) stated that "The most valid historical data is that which is developed by the organization that is doing the estimating". The development of in-house historical data is a necessity for construction companies due to the uniqueness of each company operation.

2.4.1. SOURCES OF COST DATA

The sources of cost data can be classified into two types: actualities and probabilities (Hardie 1987). The actualities means that the sources are factual, current and adequate for immediate utilization such as:

1. Contractor historical data that are well maintained and prepared
2. Price quotations from subcontractors, advertised equipment rental rates and published prices of materials, systems or services

3. Organizations fees such as government agencies and insurance companies
4. Specialized firms in construction costs and trends such as construction economists, quantity surveyors and project consultants

The probabilities means that the sources are historically projected from formerly factual data such as:

1. Cost data books published for regional and international markets
2. Monthly or annual tabulated cost reports prepared by professional organizations for regional and international markets with modifying factors. The data is updated periodically and quotes some manufacturers, requirements for special prices, restrictions and delivery rates
3. Government offices and agencies statistical data on periodical basis indicating the trends of construction industry, defaulted loans, housing rates, inflation rates, interest rates, population trend, unemployment and projects (proposed, on-going and completed)
4. Articles and advertisement on construction costs in newspapers, journals, magazines and other forms of print media

In Saudi Arabia, contractors have access to some sources of cost data that help in preparing estimates such as construction company records, subcontractor's quotation to do part of work, suppliers' published prices, advertised rental rates or fees for equipment.

2.4.2. USES OF COST DATA

Cost data are being used for many reasons that can be summarized as follows (Ferry 1980):

1. Comparison of cost between items of similar functions to decide which is more suitable
2. Forecasting the cost of future projects by the use of cost indexes
3. Negotiation of rates with a contractor
4. Evaluation of subcontractors' bids
5. Establishing the required resources, i.e., labor, material and equipment
6. Balancing of cost by spending money in accordance to client's requirement which can be achieved by allocating money to various major components of the building

2.4.3. COST DATA BOOKS

There are many published cost data books that are of interest to different users such as estimators, designers, developers, specialized subcontractors and consultants (Hardie 1987). Such books contain information on work type, material, labor productivity and costs which are accumulation of cost data from several firms and projects (Adrian 1982). For that, users shall consider the following two factors when utilizing data books. First, data indicated represents average values for material, productivity and cost. Second, some books do not consider the geographical location of the building which has impact on cost of material, labor productivity and equipment. However, cost data books are very useful especially when contractor's historical cost data are incomplete or unavailable. Some of the published cost data books in the United States are (Stewart 1982):

1. R.S. Means Company, Inc.
2. Thomas Register
3. Information Handling Services
4. Sweet Division
5. Richardson Engineering Services
6. Craftsman Book Company

Some of the above cost data books include cost indexes for the purpose of adjustment for specific location from the average values and are updated either quarterly or yearly.

2.4.4. R.S.MEANS COST DATA BOOK

The thesis followed the WBS used by R.S. MEANS in the numbering and tabulation of systems and assemblies as will be explained in Chapters 3 and 4.

R.S. MEANS cost data books are published in the United States to provide construction industry with comprehensive cost data. They utilize the basic numbering format developed by Construction Specification Institute (CSI). Each book describes the work item and lists the crew size, the daily labor productivity, the unit of measurement, and the time required per unit. It also includes the cost of material, labor, equipment, overhead and profit. The materials costs are determined as a result of contacting manufacturers, dealers and distributors across the U.S. and Canada. Labor costs are based on the average wage rates from seven major regions in U.S. for construction trades. The overhead cost is 18-20% of the bare cost while profit is 10% on material, labor and equipment (MEANS 1993).

2.5. LABOR PRODUCTIVITY

The two main components that determine the labor cost are the productivity and its pricing. Productivity is a hard task to determine and needs a great deal of experience and judgment. Calculation of prices is complex, however, most of cost parameters can be quantified (Paulson 1975).

The U.S. Department of Commerce defines productivity as dollars of output per man-hour of labor input (Adrian 1982). The cost of doing work depends mainly on the amount of work that a man or a crew can accomplish in a defined period of time.

Productivity is affected by many factors. Some of them are worker moral, job-site management, skill of workers, local climate, job-site location, crew size, labor mix, flow of material to project and degree of equipment utilization. It can be improved if the following recommendations are considered (Adrian 1982):

1. Substitution of labor with equipment
2. Use of efficient equipment and tools
3. Use of better materials
4. Efficient production management
5. Training of labor

CHAPTER 3

METHODOLOGY

3.1. RESEARCH DESIGN

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

The WBS for mechanical systems and assemblies has followed the method specified in MEANS Assembly Cost Data Book published in the United States (Figure-4). The reason behind this specific selection is due to two reasons. First, it is well prepared and presented. Second, it follows the CSI coding mechanism that is widely used in Saudi Arabia. In this thesis, the systems and assemblies codes used are as follows:

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

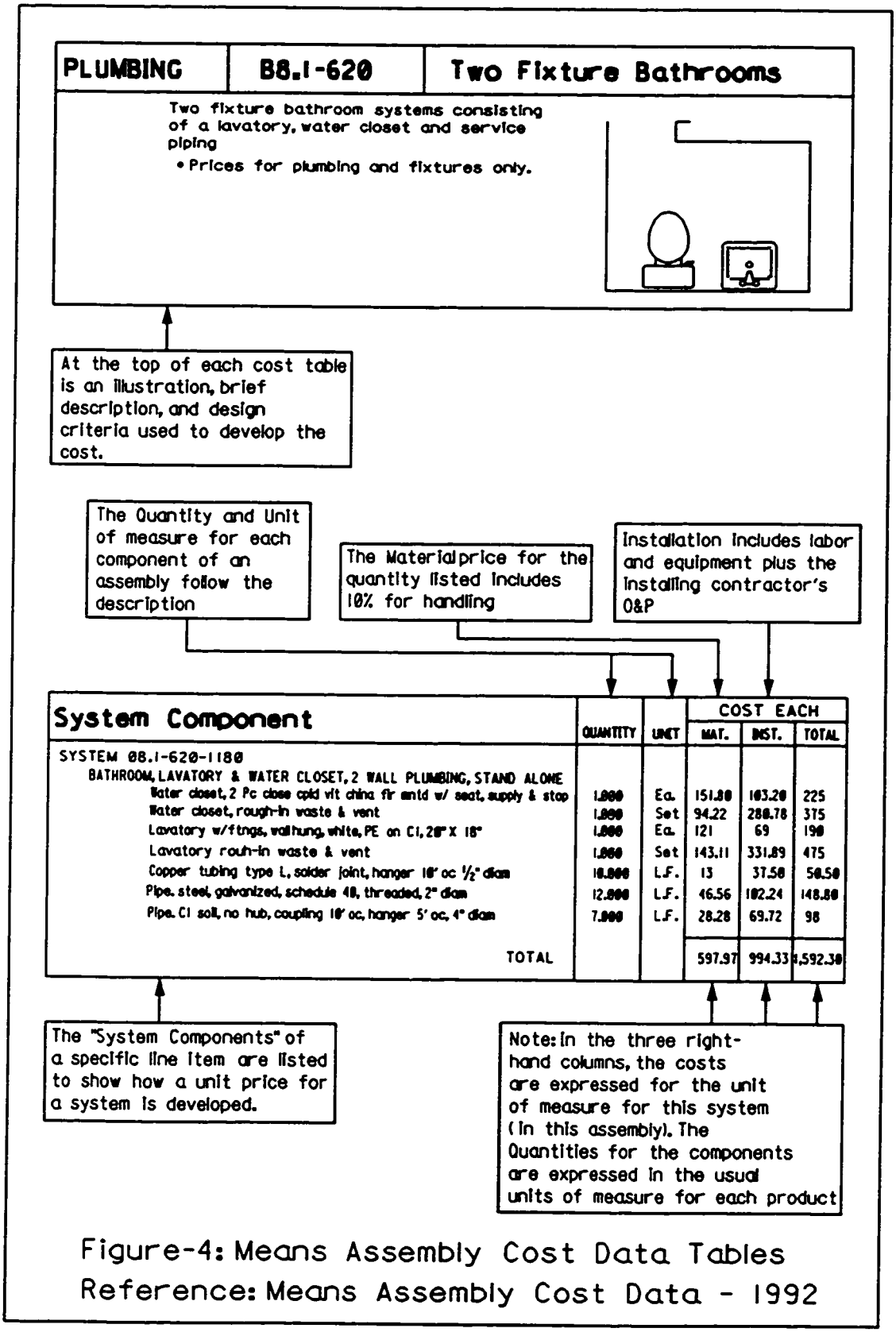


Figure-4: Means Assembly Cost Data Tables
Reference: Means Assembly Cost Data - 1992

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 systems 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)

3.1.1. CREW TYPES AND COSTS

The crew types were formed after the completion of the interviews. The labor costs listed in Chapter-4 are found as a result of the interviews and are utilized in the construction market. The man-hour was used as the unit of time to determine the labor costs.

3.1.2. COST CURRENCY UNIT

All costs indicated in this thesis are in Saudi Riyal (SR). One U.S. Dollar is equivalent to 3.75 SR.

3.1.3. POPULATION AND SAMPLE

The population sample for the research was on selective basis due to the following:

1. Expertise required for effective contribution during the interviews.
2. The interviewees represent different professions and firms: contractors, manufacturers, material suppliers, engineers and tradesmen.
3. Firms of similar profession may have specific specialties such as plumbing materials that are supplied by different firms.
4. Some of mechanical equipment and material are supplied by a single dealer as in the field of HVAC.

3.2. DATA COLLECTION

The data collection has gone through sequential steps where a certain information is obtained at each step as follows:

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 packages).
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 manufacturers and suppliers for price quotations.
    - 7.2. Suppliers of material and accessories for price quotations.
    - 7.3. Contractors for determination of crew size, labor productivity and cost.
    - 7.4. Construction engineers and traders.
8. Arranging collected data in standard formats.

3.3. DATA ANALYSIS

The collected data were evaluated and analyzed to develop the cost data model and the findings. The results are summarized in Chapter-4.

CHAPTER 4

FINDING AND RESULTS

4.1. SYSTEMS AND ASSEMBLIES

The thesis has identified four (4) plumbing systems and seven (7) plumbing assemblies similar to the ones specified in the MEANS. It also developed ten (10) new plumbing systems, forty (40) new plumbing assemblies and twenty-one (21) new HVAC assemblies as will be described later in this Chapter.

4.1.1. OVERHEAD COST AND PROFIT

The overhead cost and profit were found from the interviews conducted in the ranges of 40-60% of the labor direct cost for plumbing works and 15-25% of the material direct cost for HVAC works.

In the calculation of costs, the research considered the overhead cost and profit as 50% of the labor direct cost for plumbing works and 20% of the material direct cost for HVAC.

4.1.2. CALCULATION FORMULA

Table-5 was used for the calculations of costs of systems and assemblies as follows:

1. The crew type and daily output are obtained from the interviews.
2. The crew cost per hour is the bare cost obtained from the interviews.
3. Man-hours/unit = 8 (hours/day) / Daily output. (4-1)
4. The unit is determined based on the type of system or assembly component.
5. Material cost = market purchasing cost. (4-2)
6. Assembly Bare Costs
   - 6.1. The quantities are determined for each assembly through the preparation of BOQ.
   - 6.2. Material cost = market purchasing cost X quantity (4-3)
   - 6.3. Labor cost = crew direct cost/hour X man-hours. (4-4)
   - 6.4. Equipment cost = the rental rate of a similar equipment from the local market. (4-5)
   - 6.5. Assembly total bare cost = material + labor + equipment (4-6)

TABLE-5

Asembly Cost Data Tble

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
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
TOTAL												

7. Total including overhead and profit:

   7.1. For plumbing = material +(1.5 X labor) + equipment (4-7)

   7.2. For HVAC = (1.2 X material) + labor + equipment (4-8)

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

4.1.3. MECHANICAL LABORS

The mechanical labors, which form the required crews, are an air conditioning mechanic, a plumber and a helper. Their actual direct cost as found from the interviews are listed in Table-6.

TABLE-6

Labor's Crew Direct Cost

Crew No.	Crew Labor	Bare Cost (SR)	
		Hourly	Daily
H-1	a/c mechanic	15	120
	Crew Totals	**15**	**120**
H-2	a/c mechanic	15	120
	helper	7	56
	Crew Totals	**22**	**176**
H-3	a/c mechanic	15	120
	helper	7	56
	helper	7	56
	Crew Totals	**29**	**232**
P-1	plumber	10	80
	Crew Totals	**10**	**80**
P-2	plumber	10	80
	helper	7	56
	Crew Totals	**17**	**136**

H: HVAC

P: Plumbing

4.2. PLUMBING WORKS IN RESIDENTIAL BUILDINGS

The cost data prepared for plumbing works is divided into two (2) main categories: systems and assemblies. Each plumbing fixture including its valves, accessories, piping and fittings is classified as a system while an assembly is a combination of more than one system.

4.2.1. PLUMBING SYSTEMS

Ten (10) plumbing systems were developed for the use in the estimation of the plumbing assemblies in the residential buildings: nine (9) for plumbing fixtures and one (1) for piping and fittings:

1. Recessed bathtub
2. Stall shower
3. Corner bathtub
4. Eastern water closet
5. Western water closet
6. Bidet
7. Lavatory
8. 50-liters electric water heater

9. 80-liters electric water heater
10. Piping and fittings for drainage, waste and water supply

The BOQ for the first nine (9) systems of the plumbing fixtures is fixed while it is variable for piping and fittings since it depends on the number of fixtures installed in the toilet.

The plumbing contractors were not able to estimate labor productivity for each component of the system as in the MEANS Cost Data Books. Instead, the labor productivity is divided into two (2) parts (Table-7):

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-8 summarizes the total costs for each plumbing system while a detailed breakdown of the costs and BOQ is indicated in Appendix-A.

TABL-7

Labors' Productivity for Plumbing Systems

SYSTEM	CREW TYPE	LABOR PRODUCTIVITY (MAN-HOURS)
Recessed Bathtub	P-2	8
Stall Shower	P-2	4
Corner Bathtub	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 Water Heater	P-2	3
80-Liters Electric Water Heater	P-2	3
One-Fixture Toilet Piping & Fittings	P-2	4
Two-Fixture Toilet Piping & Fittings	P-2	8
Three-Fixture Toilet Piping & Fittings	P-2	8
Four-Fixture Toilet Piping & Fittings	P-2	10
Five-Fixture Toilet Piping & Fittings	P-2	12

TABLE-8

Plumbing Systems Cost Summary

CODE	SYSTEM	UNIT	1998 COST PER SYSTEM					
			BARE COSTS					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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	824
B8.1-470-9920	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9110	One Fixture Toilet Piping & Fittings	System	1	348	68		416	450
B8.1-999-9120	Two Fixture Toilet Piping & Fittings	System	1	402	136		538	606
B8.1-999-9130	Three Fixture Toilet Piping & Fittings	System	1	571	136		707	775
B8.1-999-9140	Four Fixture Toilet Piping & Fittings	System	1	585	170		755	840
B8.1-999-9150	Five Fixture Toilet Piping & Fittings	System	1	617	204		821	923

4.2.2 PLUMBING ASSEMBLIES

The thesis identified seven (7) plumbing assemblies:

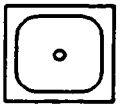
1. Toilets which are classified based on the number of fixtures:
    1.1. One-fixture toilet (2 types)
    1.2. Two-fixture toilet (10 types)
    1.3. Three-fixture toilet (14 types)
    1.4 Four-fixture toilet (7 types)
    1.5. Five-fixture toilet (6 types)

The layouts of the thirty-nine (39) toilets are shown in figures 5, 6, 7, 8, 9 and 10.

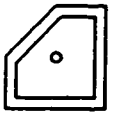
2. Double compartment lavatory.
3. Kitchen sinks (2 types).
4. Building main drainage, waste and vent piping assembly external to the toilets (2 types).
5. Building main water supply piping assembly external to the toilets (2 types).
6. Water tank.
7. Booster pump.

The assemblies' total costs are listed in Table-9 while a cost breakdown of each assembly is indicated in Appendix-B.

RECESSED BATHTUB



STALL SHOWER



CORNER BATHTUB

EASTERN WATER CLOSET (EWC)

WESTERN WATER CLOSET (WWC)

BIDET (BD)

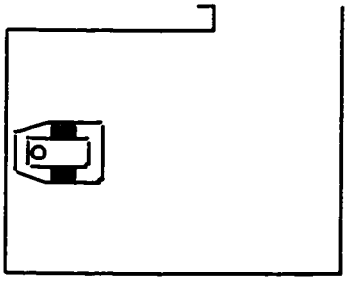
LAVATORY (LAV)

ELECTRIC WATER HEATER (EWH)

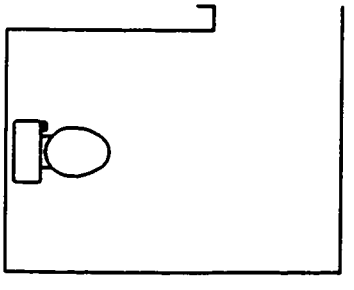
FD — FLOOR DRAIN

FCO — FLOOR CLEAN-OUT

Figure-5: Plumbing Systems Symbols and legend



(a)



(b)

Figure-6: One-Fixture Toilet

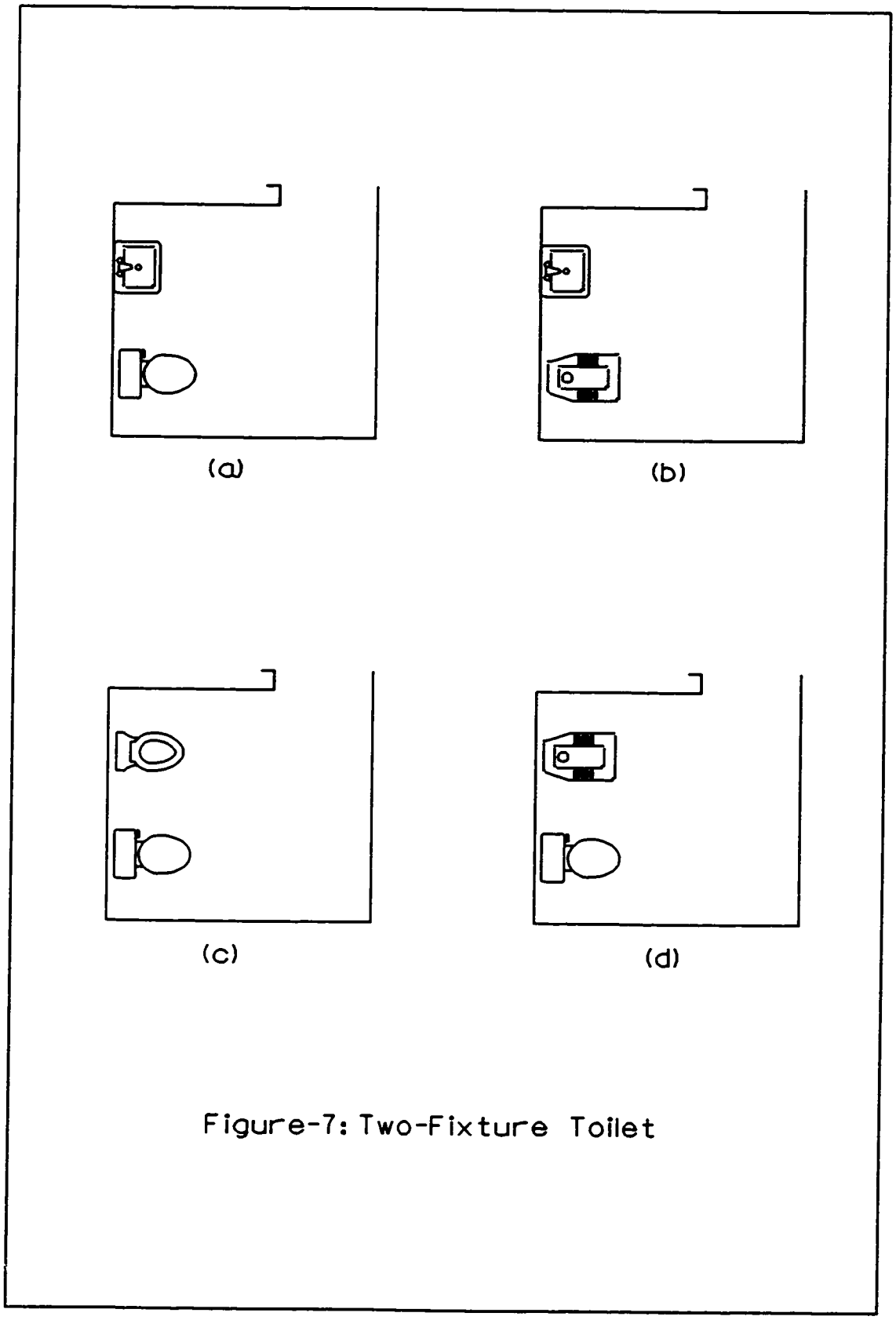
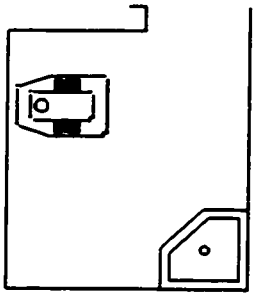


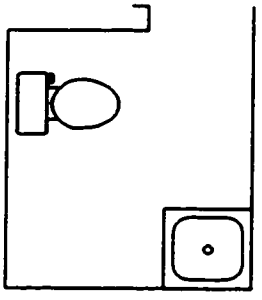
Figure-7: Two-Fixture Toilet

(e)

(f)

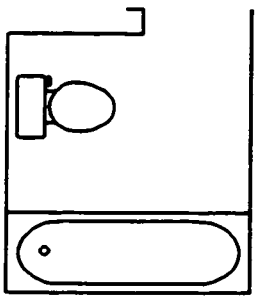


(g)



(h)

Figure-7: Two-Fixture Toilet(Continued)



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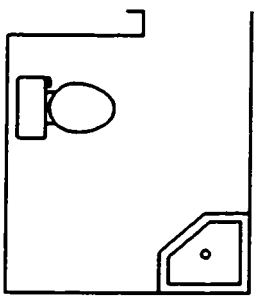

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Figure-7: Two-Fixture Toilet(Continued)

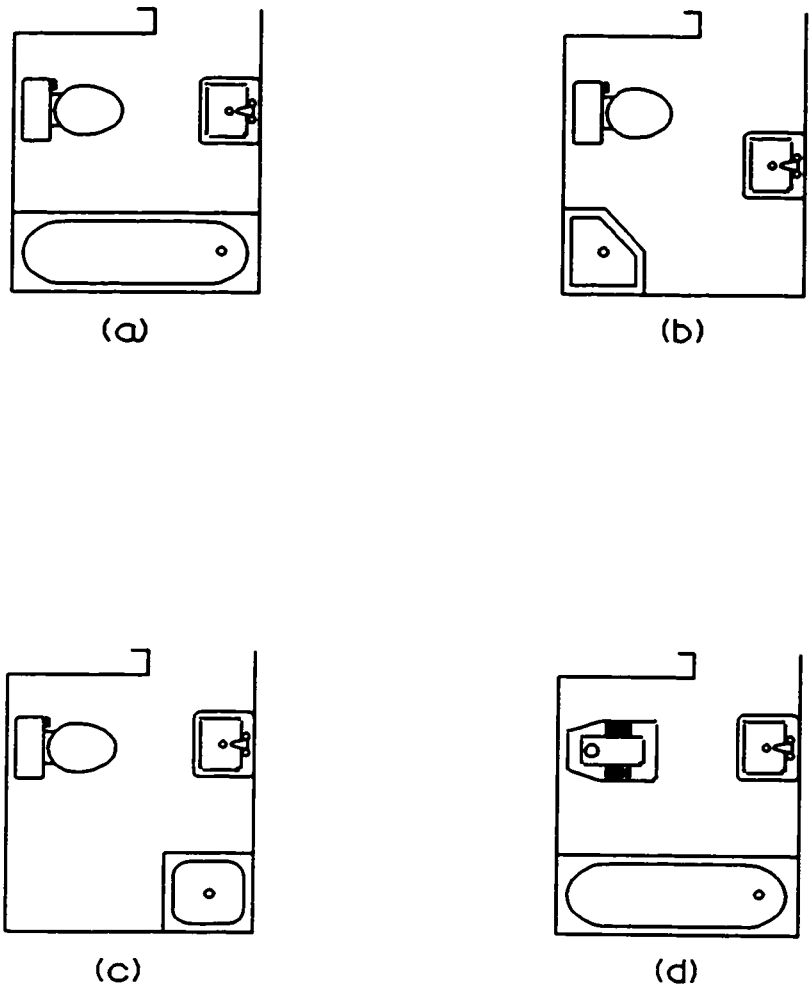
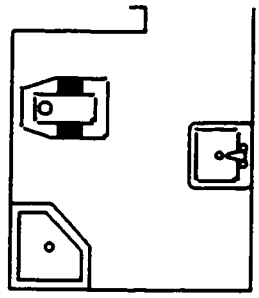


Figure-8: Three-Fixture Toilet



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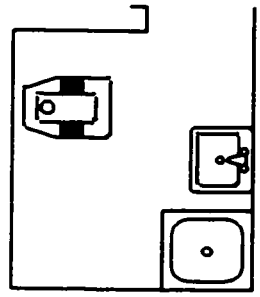

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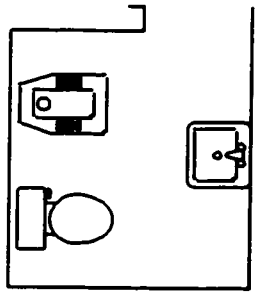

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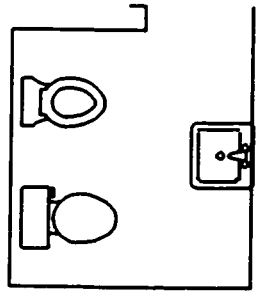
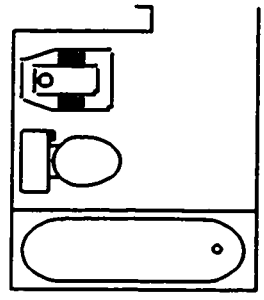
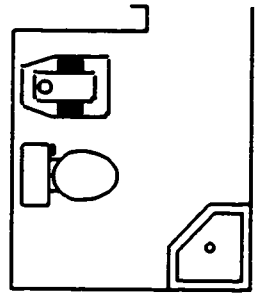


(h)

Figure-8: Three-Fixture Toilet(Continued)



(i)



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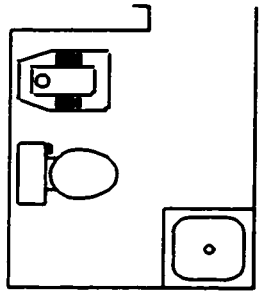
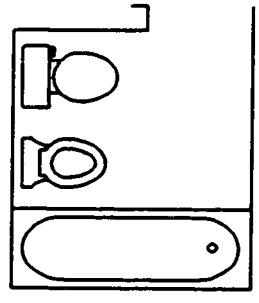


(k)



(l)

Figure-8: Three-Fixture Toilet(Continued)

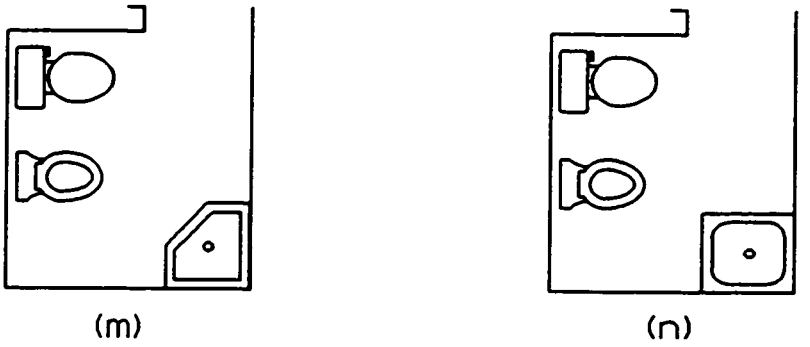


Figure-8: Three-Fixture Toilet(Continued)

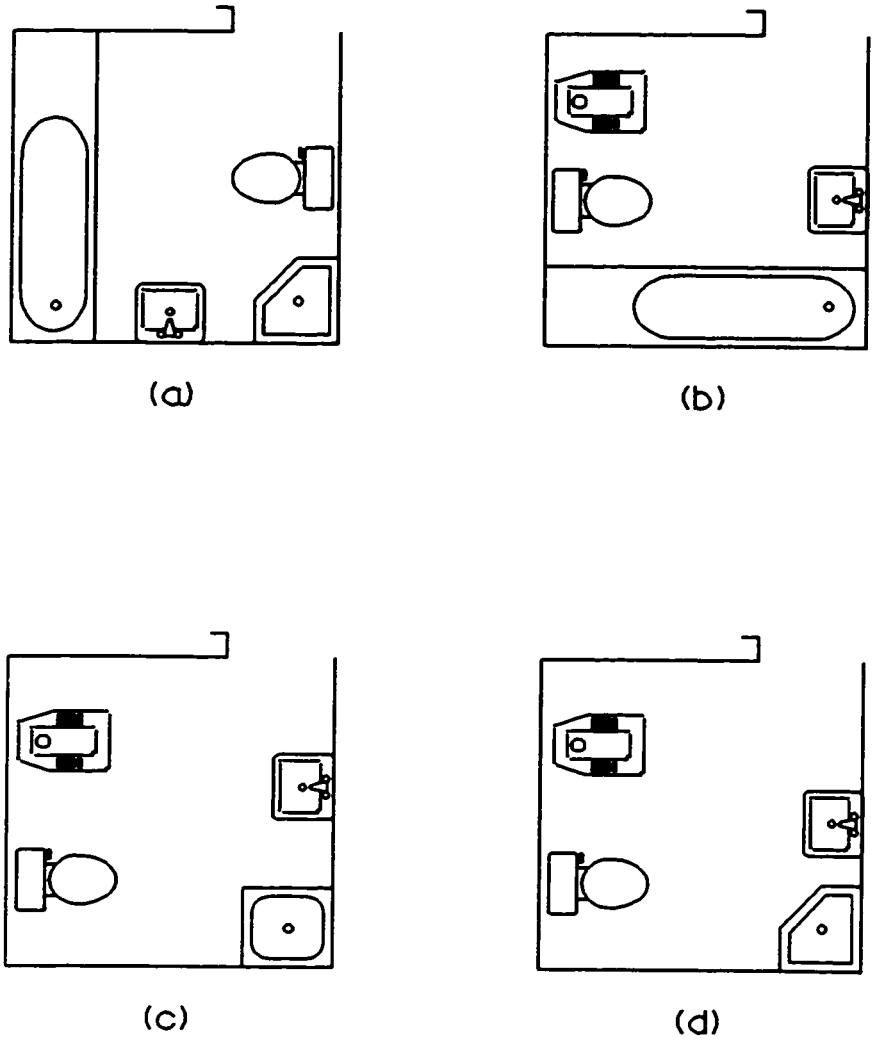
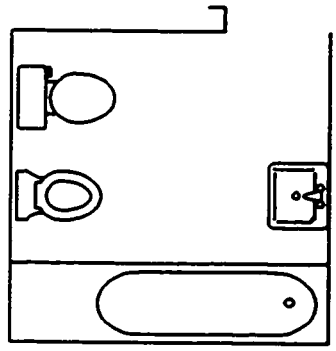


Figure-9: Four-Fixture Toilet



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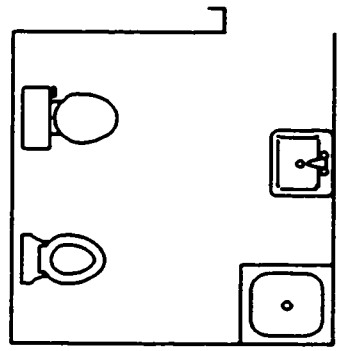

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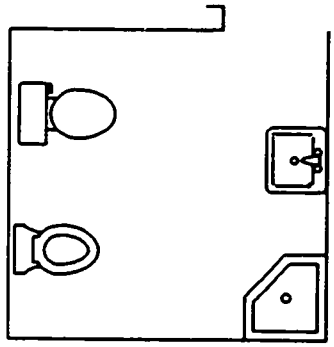

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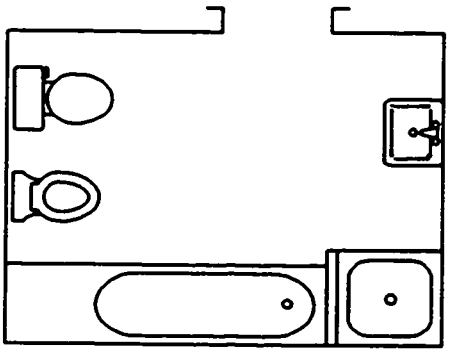
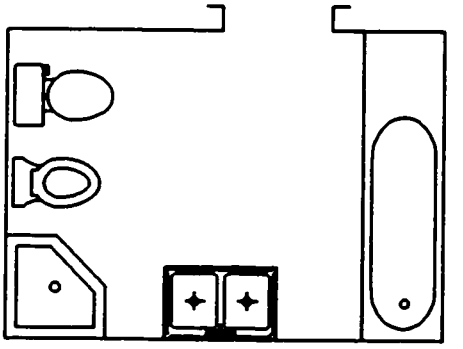
Figure-9: Four-Fixture Toilet(Continued)



(a)



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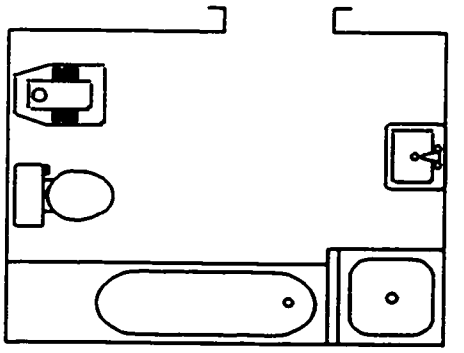
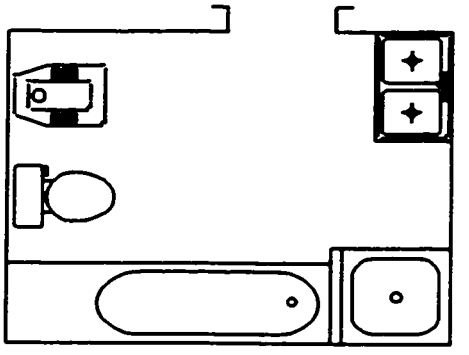
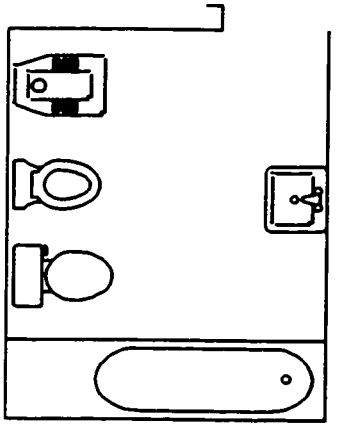


(c)

Figure-10: Five-Fixture Toilet



(d)



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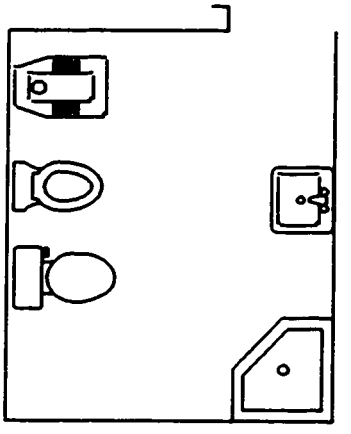

(f)

Figure-10: Five-Fixture Toilet(Continued)

TABLE-9

Plumbing Assemblies Cost Summary

CODE	ASSEMBLY COMPONENTS	MAT.	LABOR	TOTAL
B8.1-610	**ONE-FIXTURE TOILET**			
9910	Eastern Water Closet	853	204	1057
9920	Western Water Closet	1070	204	1274
B8.1-620	**TWO-FIXTURE TOILET**			
2220	Western Water Closet and Lavatory	1891	485	2376
9910	Eastern Water Closet and Lavatory	1913	485	2398
9915	Western Water Closet and Bidet	2016	485	2501
9920	Eastern and Western Water Closets	1866	485	2351
9925	Stall Shower and Eastern Water Closet	1527	443	1970
9930	Recessed Bathtub and Eastern Water Closet	2202	587	2789
9935	Corner Tub and Eastern Water Closet	2902	689	3591
9940	Stall Shower and Western Water Closet	1744	443	2187
9945	Recessed Bathtub and Western Water Closet	2419	587	3006
9950	Corner Tub and Western Water Closet	3119	689	3808
B8.1-630	**THREE-FIXTURE TOILET**			
2160	Recessed Bathtub, Western Water Closet and Lavatory	3512	689	4201
4680	Corner Tub, Western Water Closet and Lavatory	4212	791	5003
7080	Stall Shower, Western Water Closet and Lavatory	2837	545	3382
9910	Recessed Bathtub, Eastern Water Closet and Lavatory	3295	689	3984
9915	Corner Tub, Eastern Water Closet and Lavatory	3995	791	4786
9920	Stall Shower, Eastern Water Closet and Lavatory	2620	545	3165
9925	Eastern Water Closet, Western Water Closet and Lavatory	2959	587	3546
9930	Western Water Closet, Bidet and Lavatory	3109	587	3696
9935	Recessed Bathtub, Eastern and Western Water Closets	3248	689	3937
9940	Corner Tub, Eastern and Western Water Closets	3948	791	4739
9945	Stall Shower, Eastern and Western Water Closet	2573	545	3118
9950	Recessed Bathtub, Western Water Closet Bidet	3398	689	4087

TABLE-9

Plumbing Assemblies Cost Summary (Continued)

CODE	ASSEMBLY COMPONENTS	MAT.	LABOR	TOTAL
9955	Corner Tub, Western Water Closet Bidet	4098	791	4889
9960	Stall Shower, Western Water Closet Bidet	2723	545	3268
B8.1-640	**FOUR-FIXTURE TOILET**			
2280	Recessed Bathtub, Corner Tub, Western Water Closet and Lavatory	5284	1046	6330
9910	Recessed Bathtub, Eastern Water Closet, Western Water Closet and Lavatory	4031	842	4873
9915	Stall Shower, Eastern Water Closet, Western Water Closet and Lavatory	3356	698	4054
9920	Corner Tub, Eastern Water Closet, Western Water Closet and Lavatory	4731	944	5675
9925	Recessed Bathtub, Western Water Closet, Bidet and Lavatory	4181	842	5023
9930	Stall Shower, Western Water Closet, Bidet and Lavatory	3506	698	4204
9935	Corner Tub, Western Water, Bidet Closet and Lavatory	4881	944	5825
B8.1-650	**FIVE-FIXTURE TOILET**			
1520	Recessed Bathtub, Stall Shower, Western Water Closet, Bidet and Lavatory	4596	953	5549
2400	Recessed Bathtub, Corner Tub, Western Water Closet, Bidet and two Lavatory	6740	1316	8056
9910	Recessed Bathtub, Stall Shower, Eastern Water Closet, Western Water Closet and Lavatory	4446	953	5399
9915	Recessed Bathtub, Stall Shower, Western Water Closet, Eastern Water Closet and Lavatory	5215	1055	6270
9920	Recessed Bathtub, Eastern Water Closet, Western Water Closet, Bidet and Lavatory	4718	995	5713
9930	Corner Tub, Eastern Water Closet, Western Water Closet, Bidet and Lavatory	5418	1112	6530
B8.1-991	**OTHER PLUMBING ASSEMBLIES**			
9010	Double Compartment Lavatory	1848	153	2001
9020	Kitchen Sink - Fiberglass Type	1961	255	2216
9030	Kitchen Sink - Stainless Steel Type	721	255	976
9040	Building Drainage, Waste and Vent Piping Assembly (Villa Type)	2917	1836	4753
9050	Building Drainage, Waste and Vent Piping Assembly (Apartment Type)	3463	2040	5503
9060	Building External Water Supply Piping (Villa Type)	1258	714	1972
9070	Building External Water Supply Piping (Apartment Type)	1624	714	2338
9080	Water Tank	741	60	801
9090	Booster Pump	1155	30	1185

4.2.3 BOQ FOR PLUMBING SYSTEMS AND ASSEMBLIES

Plumbing BOQ for each system includes pipes, fittings, valves, fixtures and appliances. Pipes are usually classified on the basis of service provided: hot water, cold water, sewer, drainage or vent. The estimator has to measure the length of the main line including fittings and state the type of fittings, method of jointing, kind and quality of material. Valves are listed by size, method of jointing and quality. Fixtures and appliances are specified by type, quantity and accessories.

The BOQ for any plumbing assembly is the total number of systems. For example, the toilet in Figure 11 consists of four (4) systems: recessed bathtub, western water closet, bidet and lavatory. Figures 12 and 13 show the piping isometric diagrams. The total cost of the assembly is the addition of all systems' costs summarized from tables in Appendix-A as described in Table-10. The detailed breakdown of the assembly cost is presented in Table-60 of Appendix-E.

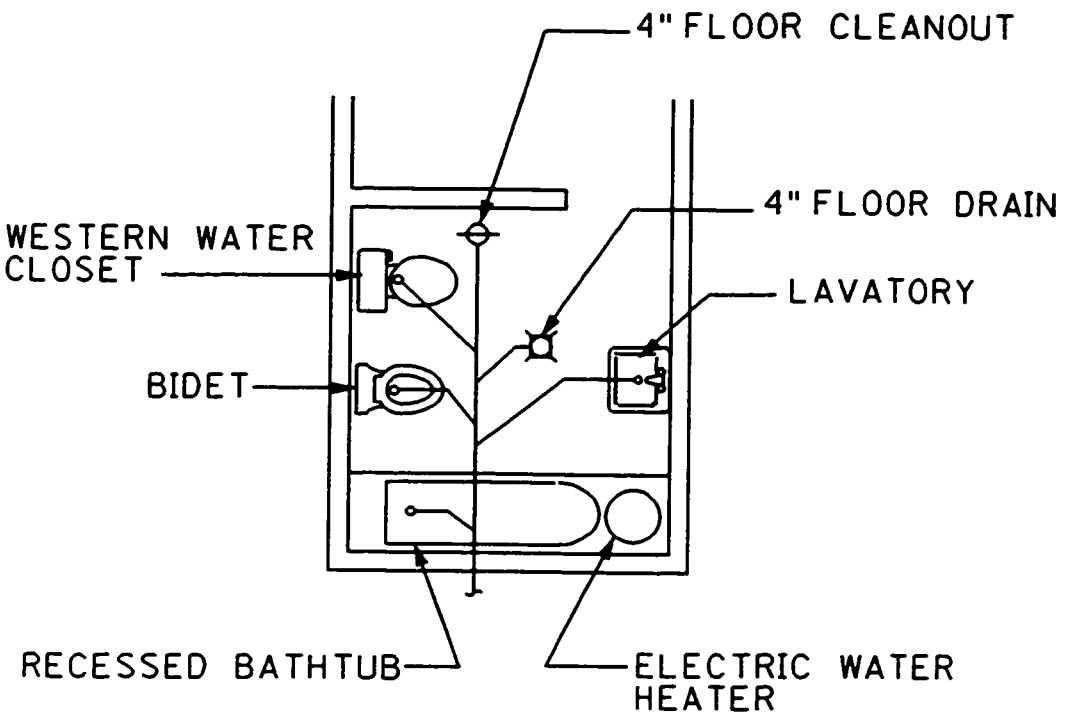

Figure-11: Toilet Layout

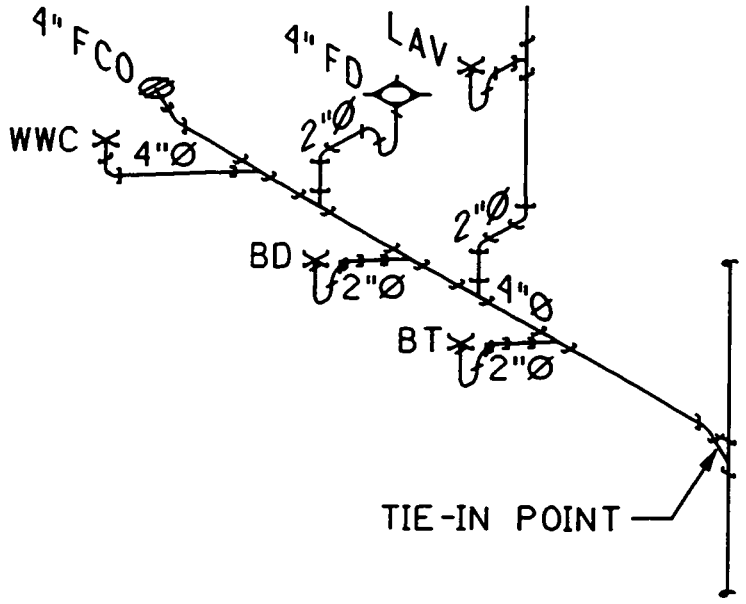

Figure-12: Isometric-Drainage and Waste Piping

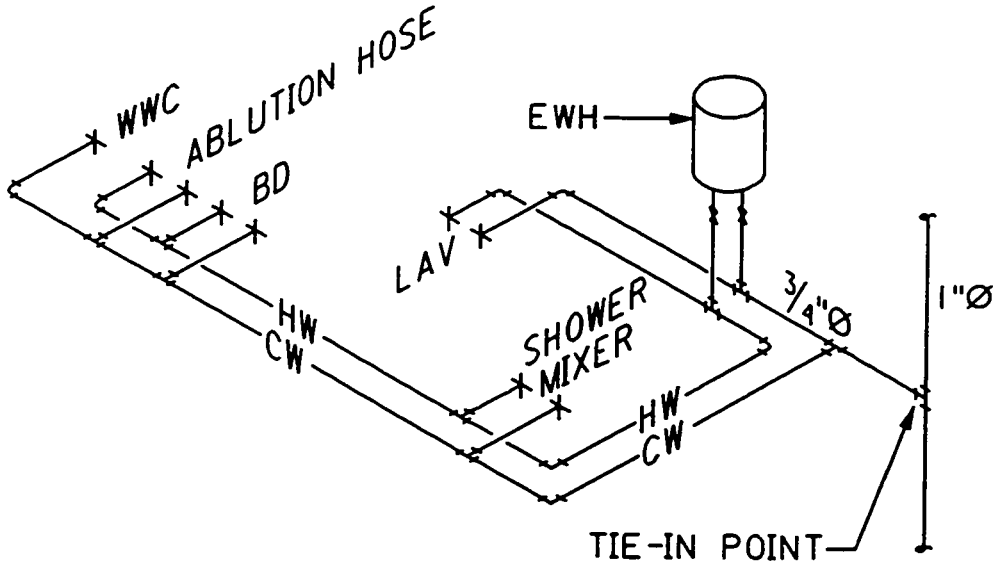

Figure-13: Isometric-Water supply Piping

TABLE-10

Method of Preparing a Plumbing Assembly Cost Data

NO.	SYSTEM	REFERENCED TABLE NO.	MAT. (SR)	LABOR (SR)	TOTAL (SR)
1.	Recessed Bathtub	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

4.3. HVAC WORKS IN RESIDENTIAL BUILDINGS

The air conditioning unit capacity is the tonnage of refrigeration which is the ability of the unit to remove an equivalent of 12000 BTU (British Thermal Unit) of heat from the space.

4.3.1 AIR CONDITIONING TYPES

1. Room air conditioner (through the wall)
2. Mini-split air conditioning unit consisting of indoor fan-coil unit, outdoor air-cooled condensing unit, refrigerant piping and accessories. These units are floor, wall or ceiling mounted.
3. Central station air conditioning which includes packaged and split type units. The packaged type is a factory assembled, single piece, heating and cooling units. The split type unit is a combination of air handling unit, outdoor air-cooled condensing unit, refrigerant piping and associated accessories. The air-handling unit is a factory assembled fan section with motor, cooling coil, heater and filters.

4.3.2. HVAC ASSEMBLIES

The thesis developed cost data for the three assemblies mentioned in paragraph 4.3.1 with their capacities:

1. Room air conditioner (4 types, Table -11).
2. Mini-split air conditioning unit (12 types, Table -12).
3. Central station air conditioning (cost table, Table -13).

4.3.3. HVAC BOQ

HVAC BOQ includes equipment, ductwork, air terminal devices, ventilators, controls, and insulation. Measurement of HVAC installation requires detailed design package specifying the type of required system (window, split, packaged or central), its capacity and accessories.

Room air conditioners' costs include purchasing, delivery and installation and is affected by the selection of either cooling or cooling and heating unit.

TABLE-11

HVAC	B8.3-992	ROOM CONDITIONERS

CODE	ASSEMBLY	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
								1998 BARE COSTS PER ASSEMBLY					TOTAL
								QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
9110	18000 BTUH (1-1/2 Ton) Cooling	Q-2	16	4	2	Assem.	1450	1	1450	32	0	1482	1500
9120	24000 BTUH (2 Ton) Cooling	Q-2	16	4	2	Assem.	1700	1	1700	32	0	1732	1750
9130	18000 BTUH (1-1/2 Ton) Cooling & Heating	Q-2	16	4	2	Assem.	1475	1	1475	32	0	1507	1525
9140	24000 BTUH (2 Ton) Cooling & Heating	Q-2	16	4	2	Assem.	1750	1	1750	32	0	1782	1800

TABLE-12

HVAC	B8.3-992	MINI-SPLIT AIR CONDITIONERS DIRECT EXPANSION

Note: 150 SR is included in the material cost for outdoor steel stand.

CODE	ASSEMBLY	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
								1998 BARE COSTS PER ASSEMBLY					TOTAL
								QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
	FLOOR MOUNTED-COOLING												
9210	18000 BTUH (1-1/2 Ton) Cooling	Q-2	16	2	4	each	3785	1	3935	64		3999	4786
9215	24000 BTUH (2 Ton) Cooling	Q-2	16	2	4	each	4270	1	4420	64		4484	5368
	FLOOR MOUNTED- COOLING & HEATING												
9220	18000 BTUH (1-1/2 Ton) Cooling & Heating	Q-2	16	2	4	each	4075	1	4207	64		4271	5112
9225	24000 BTUH (2 Ton) Cooling & Heating	Q-2	16	2	4	each	4580	1	4730	64		4794	5740
	WALL MOUNTED- COOLING												
9230	18000 BTUH (1-1/2 Ton) Cooling	Q-2	16	2	4	each	3935	1	4085	64		4149	4966
9235	24000 BTUH (2 Ton) Cooling	Q-2	16	2	4	each	4570	1	4720	64		4784	5728
	WALL MOUNTED- COOLING & HEATING												
9240	18000 BTUH (1-1/2 Ton) Cooling & Heating	Q-2	16	2	4	each	4275	1	4425	64		4489	5374
9245	24000 BTUH (2 Ton) Cooling & Heating	Q-2	16	2	4	each	4895	1	5045	64		5109	6118
	CEILING SUSPENDED-COOLING												
9250	18000 BTUH (1-1/2 Ton) Cooling	Q-2	16	2	4	each	3860	1	4010	64		4074	4876
9255	24000 BTUH (2 Ton) Cooling	Q-2	16	2	4	each	4370	1	4520	64		4584	5488
	CEILING SUSPENDED-COOLING & HEATING												
9260	18000 BTUH (1-1/2 Ton) Cooling & Heating	Q-2	16	2	4	each	4175	1	4325	64		4389	5254
9265	24000 BTUH (2 Ton) Cooling & Heating	Q-2	16	2	4	each	4670	1	4820	64		4884	5848

TABLE-13

HVAC	B8.3-992-9300	CENTRAL STATION AIR CONDITIONING UNIT

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER UNIT	UNIT	MAT. COST PER UNIT	ASSEMBLY DEVELOPMENT COSTS PER ASSEMBLY					
							1997 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
5-TON PACKAGED UNIT	Q-2	22	0.67	12	Each	8475	1	8475	264	500	9239	10934
7.5-TON PACKAGED UNIT	Q-2	22	0.67	12	Each	14000	1	14000	264	500	14764	17564
10-TON PACKAGED UNIT	Q-2	22	0.33	24	Each	17050	1	17050	528	500	18078	21488
12.5-TON PACKAGED UNIT	Q-2	22	0.33	24	Each	20925	1	20925	528	500	21953	26138
15-TON PACKAGED UNIT	Q-2	22	0.33	24	Each	25900	1	25900	528	500	26928	32108
5-TON SPLIT UNIT	Q-2	22	0.67	12	Each	8520	1	8520	264		8784	10488
7.5-TON SPLIT UNIT	Q-2	22	0.67	12	Each	14000	1	14000	264		14264	17064
10-TON SPLIT UNIT	Q-2	22	0.33	24	Each	17350	1	17350	528		17878	21348
12.5-TON SPLIT UNIT	Q-2	22	0.33	24	Each	24545	1	24545	528		25073	29982
15-TON SPLIT UNIT	Q-2	22	0.33	24	Each	29210	1	29210	528		29738	35580
RIGID DUCTWORK & FITTINGS	Q-2	22	4.00	2	M2	85	1	85	44		129	146
FLEXIBLE DUCTWORK	Q-2	22	16.00	0.5	LM	35	1	35	11		46	53
DIFFUSERS	Q-1	15	8.00	1	Each	160	1	160	15		175	207
GRILLES	Q-1	15	8.00	1	Each	160	1	160	15		175	207
SLOT DIFFUSER	Q-1	15	2.67	3	Each	300	1	300	45		345	405
REFRIGERANT PIPING					LM	100	1	100	0		100	120
DRAIN PVC PIPE					LM	5	1	5	0		5	6
UNIT STEEL SUPPORT					Each	500	1	500	0		500	600
WALL MOUNTD EXHAUST FAN (500 CFM)	Q-1	15	5.33	1.5	Each	200	1	200	22.5		222.5	263
TOTALS												

Mini-split air conditioners' costs include purchasing, delivery and installation and are affected by the method of installation (floor, wall or ceiling mounted) and the selection of either cooling or cooling and heating unit.

Central HVAC system costs include mounting, installation and balancing. The units include both heating and cooling.

Rigid ductworks include fabrication, hangers, insulation and balancing. The cost is based on the surface area of the duct.

Flexible ductworks include hangers, insulation and balancing. The cost is based on the duct diameter and length.

Diffusers, grilles and slot diffusers are enumerated from drawings.

Each unit is provided with five (5) meter long refrigerant piping as part of its purchasing cost. Any additional length required costs 150 (SR) per linear meter.

4.4. COMPARISON OF COSTS (THESIS VS. R.S. MEANS)

Table-14 compares the cost data prepared by the thesis and R.S. MEANS Assembly Cost Data for similar systems and assemblies. The comparison shows that the MEANS Assemblies Cost is much higher than the ones prepared by the thesis especially the labor cost which ranges between five (5) to ten (10) times the cost in Saudi Arabia.

The material costs in R.S. MEANS Assembly Cost Data is relatively higher. But, the owner may select material with a cost either similar or higher than the ones specified in R.S. MEANS.

TABLE-14

Cost Comparison (Thesis vs. MEANS)

CODE	SYSTEM/ASSEMBLY	MATERIAL		LABOR		TOTAL	
		THESIS	MEANS	THESIS	MEANS	THESIS	MEANS
	SYSTEMS						
B8.1-410-2040	Recessed Bathtub	1058	4031	204	1556	1262	5587
B8.1-410-2160	Corner Tub	1758	4594	306	321	2064	6079
B8.1-433-2240	Lavatory	769	1388	102	1369	871	2756
B8.1-470-2000	Western Water Closet	722	919	102	1294	824	2213
	ASSEMBLIES						
B8.1-620-2220	Western Water Closet and Lavatory	1891	2100	485	3394	2376	5493
B8.1-630-2160	Recessed Bathtub, Western Water Closet and Lavatory	3512	3450	689	4312	4201	7762
B8.1-630-4680	Corner Tub, Western Water Closet and Lavatory	4212	6375	791	4406	5003	8006
B8.1-630-7080	Stall Shower, Western Water Closet and Lavatory	2837	4594	545	5063	3382	9656
B8.1-640-2280	Recessed Bathtub, Corner Tub, Western Water Closet and Lavatory	5284	5719	1046	5438	6330	11157
B8.1-650-1520	Recessed Bathtub, Stall Shower, Western Water Closet, Bidet and Lavatory	4596	7219	953	8062	5549	15281
B8.1-650-2400	Recessed Bathtub, Corner Tub, Western Water Closet, Bidet and two Lavatory	6740	7219	1316	8062	8056	15281

4.5. VERIFICATION OF THE DEVELOPED COST DATA (AN EXAMPLE)

A residential building located in Ad-danah Area of Dhahran is selected as an example to apply the collected cost data and to clarify the method. The building is a family two story residential building (villa) having a main central air conditioning system and five toilets. The quantities for plumbing and HVAC works have been summarized from design drawings.

The total cost for the mechanical works is 154,687 Saudi Riyals (SR): 34,805 SR for plumbing and 119,882 SR for HVAC as shown in Tables 15 and 16.

The owner has no records on the plumbing total cost. On the other hand the HVAC works was contracted at a total cost of 104,000 SR. The contractor stopped the work after the installation of the HVAC air duct since the remaining money was not enough to purchase the equipment and complete the installation. The owner has filed a claim and the case is still in the court.

Since the accuracy of the detailed estimate is –5% to +15% (Manzanera 1991), the estimate range is 113,888 to 137,865 SR. This indicates that the HVAC cost was underestimated.

TABLE-15

Building Plumbing Assemblies Costs- An Example

Cost per Assembly					Installed Assemblies Total Cost			
CODE	ASSEMBLY COMPONENTS	MAT.	LABOR	TOTAL	QUANTITY	MAT.	LABOR	TOTAL
B8.1-620-9940	Stall Shower and Western Water Closet	1744	443	2187	1	1744	443	2187
B8.1-630-7080	Stall Shower, Western Water Closet and Lavatory	2837	545	3382	1	2837	545	3382
B8.1-630-9930	Western Water Closet, Bidet and Lavatory	3109	587	3696	1	3109	587	3696
B8.1-640-9930	Stall Shower, Western Water Closet, Bidet and Lavatory	3506	698	4204	3	10518	2094	12612
B8.1-991-9010	Double Compartment Lavatory	1848	153	2001	1	1848	153	2001
B8.1-991-9020	Kitchen Sink - Fiberglass Type	1961	255	2216	1	1961	255	2216
B8.1-991-9040	Building Drainage, Waste and Vent Piping Assembly (Villa Type)	2917	1836	4753	1	2917	1836	4753
B8.1-991-9060	Building External Water Supply Piping (Villa Type)	1258	714	1972	1	1258	714	1972
B8.1-991-9080	Water Tank	741	60	801	1	741	60	801
B8.1-991-9090	Booster Pump	1155	30	1185	1	1155	30	1185
TOTAL						28088	6717	34805

TABLE-16

Building HVAC Assemblies Costs- An Example

HVAC	B8.3-992-9300	CENTRAL STATION AIR CONDITIONING UNIT

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
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
5-TON PACKAGED UNIT	Q-2	22	0.67	12	Each	8475	3	25425	792	500	26717	31802
5-TON SPLIT UNIT	Q-2	22	0.67	12	Each	8520	2	17040	528		17568	20976
RIGID DUCTWORK & FITTINGS	Q-2	22	4.00	2	M2	85	223	18955	9812		28767	32558
FLEXIBLE DUCTWORK	Q-2	22	16.00	0.5	LM	35	10	350	110		460	530
DIFFUSERS	Q-1	15	8.00	1	Each	160	8	1280	120		1400	1656
GRILLES	Q-1	15	8.00	1	Each	160	6	960	90		1050	1242
SLOT DIFFUSER	Q-1	15	2.67	3	Each	300	61	18300	2745		21045	24705
REFRIGERANT PIPING					LM	100	17	1700	0		1700	2040
DRAIN PVC PIPE					LM	5	10	50	0		50	60
UNIT STEEL SUPPORT					Each	500	5	2500	0		2500	3000
WALL MOUNTD EXHAUST FAN (500 CFM)	Q-1	15	5.33	1.5	Each	200	5	1000	112.5		1112.5	1313
TOTAL								87560	14309.5	500	102370	119882

4.6. FUTURE USE OF THE DEVELOPED COST DATA

The data developed in this thesis identified the mechanical systems and assemblies for residential buildings. It also established the labor productivity, material types, bill of quantities, calculation formulas and the related costs. However, the data can be easily adjusted or forecasted by the contractors.

4.6.1. COST ADJUSTMENT

The material costs can be adjusted based on new price quotations while the labor cost can be adjusted by calculating the labor annual paid hours and the adjustment factor.

The Labor and Workmen Law states under article 147 that the workman should work 8 hours a day with a total of 48 hours a week for all months of the year except the month of Ramadan with 6 hours a day and a total of 36 hours a week.

The worker is entitled for paid leaves for all of the following cases:

1. During the fasting month of Ramadan, the labor works approximately twenty-six (26) days with two (2) hours less than the normal day. This creates a difference of fifty-two (52) working hours less than the other months.

2. The approved medical leave is assumed as one (1) week per year that is equivalent to forty-eight (48) hours per year.
3. The annual vacation is two (2) weeks per year that is equivalent to ninety-six (96) hours per year.
4. The two (2) Eids official holidays are seven (7) working days per year that is equivalent to fifty-six (56) hours per year.

The total working hours / year = 52 (weeks/year) * 48 (hours/week) = 2,496 hours (4-9)

The total paid leaves/year = 52+48+96+56 = 252 hours/year (4-10)

The total productive working hours/year = 2496 - 252 = 2,244 hours/year (4-11)

The labor cost adjustment factor can be calculated as follows:

1. Calculating the total annual direct and indirect costs of labor.
2. Dividing the total annual costs by the labor's annual productive working hours (2,244 hours/year) to find out the total hourly cost of the labor.
3. Calculating the adjustment factor by dividing the calculated hourly cost (from item number 2) by the hourly cost listed previously in Table-6.

4. Multiplying the adjustment factor by the figures listed under labor cost in the cost data tables.

4.6.2. COST FORECAST

The costs produced can be forecasted using the single-payment compound-amount factor (F/P, i %, n) in the following formula (Engineering Economics, 1993):

$$F = P\ (F/P, i\ \%, n) \qquad (4\text{-}12)$$

where: F = future value

P = present value

i = interest rate

n = the number of periods involved.

The "n" value was selected for two (2) years which is approximately the required time to complete the construction of a residential building. The interest rate was varied at different values: 0.25, 0.5, 1, 2, 4, 6 and 8% (Table-17). The result of the future value calculations is summarized in Table-18 for all plumbing assemblies.

TABLE-17

Single-payment Compound-amount Factor at Fixed Period

PERIOD (n) YEAR	INTEREST RATE (i%)	F/P	FUTURE VALUE (F)
2	0.25	1.005	F= 1.005 P
2	0.5	1.01	F= 1.01 P
2	1.0	1.0201	F= 1.0201 P
2	2.0	1.0404	F= 1.0404 P
2	4.0	1.0616	F= 1.0616 P
2	6.0	1.1236	F= 1.1236 P
2	8.0	1.1664	F= 1.1664 P

Reference: Engineering Economics-1993.

TABLE-18

Forecasted Costs for the Year 2000 at Different Interest Rates-An Example

CODE	ASSEMBLY COMPONENTS	ASSEMBLY TOTAL COST	COMPOUND INTEREST FACTOR						
			0.25%	0.50%	1%	2%	4%	6%	8%
			COMPOUND AMOUNT (F/P)						
			1.005	1.01	1.0201	1.0404	1.0616	1.1236	1.1664
B8.1-610	**ONE-FIXTURE TOILET**								
9910	Eastern Water Closet	1057	1062	1068	1078	1100	1122	1188	1233
9920	Western Water Closet	1274	1280	1287	1300	1325	1352	1431	1486
B8.1-620	**TWO-FIXTURE TOILET**								
2220	Western Water Closet and Lavatory	2376	2388	2400	2424	2472	2522	2670	2771
9910	Eastern Water Closet and Lavatory	2398	2410	2422	2446	2495	2546	2694	2797
9915	Western Water Closet and Bidet	2501	2514	2526	2551	2602	2655	2810	2917
9920	Eastern and Western Water Closets	2351	2363	2375	2398	2446	2496	2642	2742
9925	Stall Shower and Eastern Water Closet	1970	1980	1990	2010	2050	2091	2213	2298
9930	Recessed Bathtub and Eastern Water Closet	2789	2803	2817	2845	2902	2961	3134	3253
9935	Corner Tub and Eastern Water Closet	3591	3609	3627	3663	3736	3812	4035	4189
9940	Stall Shower and Western Water Closet	2187	2198	2209	2231	2275	2322	2457	2551
9945	Recessed Bathtub and Western Water Closet	3006	3021	3036	3066	3127	3191	3378	3506
9950	Corner Tub and Western Water Closet	3808	3827	3846	3885	3962	4043	4279	4442
B8.1-630	**THREE-FIXTURE TOILET**								
2160	Recessed Bathtub, Western Water Closet and Lavatory	4201	4222	4243	4285	4371	4460	4720	4900
4680	Corner Tub, Western Water Closet and Lavatory	5003	5028	5053	5104	5205	5311	5621	5835
7080	Stall Shower, Western Water Closet and Lavatory	3382	3399	3416	3450	3519	3590	3800	3945
9910	Recessed Bathtub, Eastern Water Closet and Lavatory	3984	4004	4024	4064	4145	4229	4476	4647
9915	Corner Tub, Eastern Water Closet and Lavatory	4786	4810	4834	4882	4979	5081	5378	5582

TABLE-18

Forecasted Costs for the Year 2000 at Different Interest Rates-An Example(Continued)

CODE	ASSEMBLY COMPONENTS	ASSEMBLY TOTAL COST	COMPOUND INTEREST FACTOR						
			0.25%	0.50%	1%	2%	4%	6%	8%
			COMPOUND AMOUNT (F/P)						
			1.005	1.01	1.0201	1.0404	1.0616	1.1236	1.1664
9920	Stall Shower, Eastern Water Closet and Lavatory	3165	3181	3197	3229	3293	3360	3556	3692
9925	Eastern Water Closet, Western Water Closet and Lavatory	3546	3564	3581	3617	3689	3764	3984	4136
9930	Western Water Closet, Bidet and Lavatory	3696	3714	3733	3770	3845	3924	4153	4311
9935	Recessed Bathtub, Eastern and Western Water Closets	3937	3957	3976	4016	4096	4180	4424	4592
9940	Corner Tub, Eastern and Western Water Closets	4739	4763	4786	4834	4930	5031	5325	5528
9945	Stall Shower, Eastern and Western Water Closet	3118	3134	3149	3181	3244	3310	3503	3637
9950	Recessed Bathtub, Western Water Closet Bidet	4087	4107	4128	4169	4252	4339	4592	4767
9955	Corner Tub, Western Water Closet Bidet	4889	4913	4938	4987	5087	5190	5493	5703
9960	Stall Shower, Western Water Closet Bidet	3268	3284	3301	3334	3400	3469	3672	3812

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. SUMMARY

A lot of studies on Saudi construction industry indicated the need to develop a cost data applicable to Saudi Arabia in order to improve the accuracy of cost estimates and minimize errors.

This research has developed an assembly cost data for mechanical works in residential buildings. The mechanical works includes plumbing and HVAC and represent 15-20% of the building total cost.

Residential buildings are considered as a major part of the Saudi construction industry. The future demand on housing will continue due to expected high population growth in Saudi Arabia. The assembly cost data is very suitable for the estimate preparation in residential buildings due to the repetitive nature of the construction activities performed.

The cost data developed is limited to small residential buildings: two (2) story, middle class house (villa) or four (4) apartment building. The geographic area coverage is limited to Dammam Metropolitan Area that is located in the Eastern Province of Saudi Arabia.

The methodology followed the MEANS Cost Data Book published in the United States. It utilized the WBS coding mechanism for systems and assemblies. The developed assembly cost data model provides the cost of labor, material, equipment, overhead and profit.

The data was collected as a result of interviews with contractors, manufacturers, labors and salesmen for mechanical systems and assemblies. The result has been tabulated and the methods to adjust or forecast the costs were described.

5.2. CONCLUSION

1. This thesis clarified the procedures and efforts required to develop an assembly cost data.

2. This research is a practical study on cost estimation since any local residential contractor can immediately utilize the data available.

3. The assembly cost estimation method is very effective for any repetitive construction activity. It is simple, more accurate and quick in preparation of detailed estimates for residential buildings.

4. The development of cost data requires collection of a lot of information summarized in large number of tables. For example, the cost data presented in Tables eight (8) and nine (9) is a summary of fifty-eight (58) tables indicated in Appendices A through K. This type of work is usually performed in the United States by companies specialized in cost data collection and publications.

5. The research developed cost data for fourteen (14) plumbing systems, forty-seven (47) plumbing assemblies and twenty-one (21) HVAC assemblies.

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% of the labor direct costs for plumbing and 15-25% of the material direct cost for HVAC.

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

10. The research used the WBS method in numbering of systems and 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 through the study.

13. The plumbing labor productivity is estimated for a complete assembly installation not 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 prices calculated for HVAC works are sometimes less than the ones available in the market. The difference is considered as the bargaining range.

16. The HVAC contractors were conservative in supplying the information because of the competitive market that requires a high confidentiality on cost data. On the other hand, plumbing cost data is known by the contractor and his labors.

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

18. The HVAC equipment suppliers do not install equipment in order to avoid competition with the local contractors who purchase their equipment. Additionally, their overhead cost and profit are higher resulting in a higher installation cost.

19. HVAC equipment manufacturers and material suppliers provide a minimum of 5% price discount to their dealers (HVAC contractors) than the one time customer (walk-in-customer). This amount is an addition to the contractor profit.

20. The contractors' cost data is not systematically organized. This was found through the request of interviewed personnel to have blank copies of the assembly estimate form in order to organize their cost data in a standard format.

5.3. RECOMMENDATIONS

1. This research can be used as the basis for development of any assembly construction cost 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 buildings 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 research can be loaded into one of the available cost estimation programs for quick estimates and continuous updating. Also, the data can be used on computer spread sheets.

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

APPENDIX-A

COST BREAKDOWN FOR PLUMBING SYSTEMS

TABLE-19

PLUMBING	B8.1-410-2040	RECESSED BATH TUB

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Fiberglass Bath Tub (170 CM * 80CM)					Each	800	1	800	0		800	800
Shower Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	7	1	7	0		7	7
2"*4" PVC Bushing					Each	12	1	12	0		12	12
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
System Installation	P-2	17	1.00	8	System	0	1	0	136		136	204
TOTAL								1058	136	0	1194	1262

TABLE-20

PLUMBING	B8.1-410-9900	STALL SHOWER

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Shower Tub (80CM * 80CM)					Each	125	1	125	0		125	125
Shower Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	7	1	7	0		7	7
2"*4" PVC Bushing					Each	12	1	12	0		12	12
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
System Installation	P-1	10	2.00	4	System	0	1	0	40		40	60
TOTAL								383	40	0	423	443

TABLE-21

PLUMBING	B8.1-410-2160	CORNER TUB

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Corner Tub					Each	1500	1	1500	0		1500	1500
Shower Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	7	1	7	0		7	7
2"*4" PVC Bushing					Each	12	1	12	0		12	12
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
System Installation	P-2	17	0.67	12	System	0	1	0	204		204	306
TOTAL								1758	204	0	1962	2064

TABLE-22

PLUMBING	B8.1-470-9910	EASTERN WATER CLOSET

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Eastern Water Closet w/Flush Tank					Each	175	1	175	0		175	175
Shower Hot/Cold Water Mixer					Each	200	1	200	0		200	200
Ablution Hose					Each	25	1	25	0		25	25
4" P-trap					Each	20	1	20	0		20	20
1/2" Angle Valave					Each	14	1	14	0		14	14
3/4"*1/2" PVC elbow-brass thread					Each	6	2	12	0		12	12
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
4 inch PVC DWV Pipe					Each	65	0.5	33	0		33	33
Flexible Hose					Each	5	1	5	0		5	5
C-Clamp					Each	1	3	3	0		3	3
System Installation	P-2	17	2.00	4	System	0	1	0	68		68	102
TOTAL								505	68	0	573	607

TABLE-23

PLUMBING	B8.1-470-2000	WESTERN WATER CLOSET

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Western Water Closet					Each	400	1	400	0		400	400
Shower Hot/Cold Water Mixer					Each	200	1	200	0		200	200
Ablution Hose					Each	25	1	25	0		25	25
4"- 90 deg. PVC Elbow					Each	10	1	10	0		10	10
1/2" Angle Valave					Each	14	1	14	0		14	14
3/4"*1/2" PVC elbow-brass thread					Each	6	2	12	0		12	12
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	2	10	0		10	10
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
4 inch PVC DWV Pipe					Each	65	0.5	33	0		33	33
Flexible Hose					Each	5	1	5	0		5	5
System Installation	P-2	17	2.00	4	System	0	1	0	68		68	102
TOTAL								722	68	0	790	824

TABLE-24

PLUMBING	B8.1-470-9920	BIDET

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Bidet					Each	350	1	350	0		350	350
Bidet Hot/Cold Water Mixer					Each	200	1	200	0		200	200
4"- 90 deg. PVC Elbow					Each	10	1	10	0		10	10
1/2" Angle Valave					Each	14	2	28	0		28	28
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
4 inch PVC DWV Pipe					Each	65	0.5	33	0		33	33
Flexible Hose					Each	5	2	10	0		10	10
System Installation	P-2	17	2.00	4	System	0	1	0	68		68	102
TOTAL								655	68	0	723	757

TABLE-25

PLUMBING	B8.1-433-2240	SINGLE COMPARTMENT LAVATORY

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Lavatory					Each	450	1	450	0		450	450
Lavatory Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	30	1	30	0		30	30
2"*4" PVC Bushing					Each	12	1	12	0		12	12
1/2" Angle Valave					Each	14	2	28	0		28	28
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
Flexible Hose					Each	5	2	10	0		10	10
System Installation	P-2	17	2.00	4	System	0	1	0	68		68	102
TOTAL								769	68	0	837	871

TABLE-26

PLUMBING	B8.1-160-9900	50 LITERS ELECTRIC WATER HEATER

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Electric Water Heater (50 Liters)					Each	175	1	175	0		175	175
1/2" Angle Valave					Each	14	2	28	0		28	28
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
Flexible Hose					Each	5	2	10	0		10	10
System Installation	P-2	17	2.67	3	System	0	1	0	51		51	77
TOTAL.								237	51	0	288	314

TABLE-27

PLUMBING	B8.1-160-9910	80 LITERS ELECTRIC WATER HEATER

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Electric Water Heater (80 Liters)					Each	330	1	330	0		330	330
1/2" Angle Valave					Each	14	2	28	0		28	28
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
Flexible Hose					Each	5	2	10	0		10	10
System Installation	P-2	17	2.67	3	System	0	1	0	51		51	77
TOTAL								392	51	0	443	469

TABLE-28

PLUMBING	B8.1-999-9100	TOILET PIPING & FITTINGS

SYSTEM COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER SYSTEM	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER SYSTEM					
							1998 BARE COSTS PER SYSTEM					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
This table is a standard formt for the calculation of the cost of piping and fittings.												
3/4 inch CPVC Pipe					Each	55		0	0		0	0
3/4 inch PVC Pipe					Each	18		0	0		0	0
2 inch PVC DWV Pipe					Each	30		0	0		0	0
4 inch PVC DWV Pipe					Each	65		0	0		0	0
4*4*2 inch Y-connection					Each	16		0	0		0	0
4*4*4 inch Y-connection					Each	16		0	0		0	0
2 inch Elbow					Each	3		0	0		0	0
4 inch Elbow					Each	10		0	0		0	0
3/4 inch 45 deg. PVC Elbow					Each	3.5		0	0		0	0
3/4 inch 90 deg. PVC Elbow					Each	3		0	0		0	0
3/4 inch 45 deg. CPVC Elbow					Each	4		0	0		0	0
3/4 inch 90 deg. CPVC Elbow					Each	4		0	0		0	0
1*3/4 PVC Reducer					Each	2		0	0		0	0
3/4 inch PVC Tee					Each	4		0	0		0	0
4" Floor Drain					Each	7		0	0		0	0
4" Cleanout					Each	18		0	0		0	0
4 inch P-trap					Each	20		0	0		0	0
Solvent Cement					Each	25		0	0		0	0
Piping & Fittings Installation					System	0		0	0		0	0
TOTAL								0	0	0	0	0

TABLE-29

PLUMBING	B8.1-999	PIPING & FITTINGS

CODE	SYSTEM	UNIT	COST DEVELOPMENT PER SYSTEM					
			1998 BARE COSTS PER SYSTEM					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
9910	One-fixture toilet piping & fitting	Each	1	348	68		416	450
9920	Two-fixture toilet piping & fitting	Each	1	402	136		538	606
9930	Three-fixture toilet piping & fitting	Each	1	571	136		707	775
9940	Four-fixture toilet piping & fitting	Each	1	585	170		755	840
9950	Five-fixture toilet piping & fitting	Each	1	617	204		821	923

APPENDIX-B

COST BREAKDOWN FOR ONE-FIXTURE TOILETS

TABLE-30

PLUMBING	B8.1-610-9910	ONE-FIXTURE TOILET

Figure 6-a

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-999-9110	Piping & Fittings	System	1	348	68		416	450
TOTAL				853	136	0	989	1057

TABLE-31

PLUMBING	B8.1-610-9920	ONE-FIXTURE TOILET

Figure 6-b

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-999-9110	Piping & Fittings	System	1	348	68		416	450
TOTAL				1070	136	0	1206	1274

APPENDIX-C

COST BREAKDOWN FOR TWO-FIXTURE TOILETS

TABLE-32

PLUMBING	B8.1-620-2220	TWO FIXTURES TOILET

Figure 7-a

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	163	136		299	367
TOTAL				1891	323	0	2214	2376

TABLE-33

PLUMBING	B8.1-620-9910	TWO FIXTURES TOILET

Figure 7-b

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				1913	323	0	2236	2398

TABLE-34

PLUMBING	B8.1-620-9915	TWO FIXTURES TOILET

Figure 7-c

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9920	Bidet	System	1	655	68		723	757
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				2016	323	0	2339	2501

TABLE-35

PLUMBING	B8.1-620-9920	TWO FIXTURES TOILET

Figure 7-d

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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	824
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9020	Piping & Fittings	System	1	402	136		538	606
TOTAL				1866	323	0	2189	2351

TABLE-36

PLUMBING	B8.1-620-9925	TWO FIXTURES TOILET

Figure 7-e

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				1527	295	0	1822	1970

TABLE-37

PLUMBING	B8.1-620-9930	TWO FIXTURES TOILET

Figure7-f

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				2202	391	0	2593	2789

TABLE-38

PLUMBING	B8.1-620-9935	TWO FIXTURES TOILET

Figure 7-g

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				2902	459	0	3361	3591

TABLE-39

PLUMBING	B8.1-620-9940	TWO FIXTURES TOILET

Figure7-h

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				1744	295	0	2039	2187

TABLE-40

PLUMBING	B8.1-620-9945	TWO FIXTURES TOILET

Figure 7-i.

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				2419	391	0	2810	3006

TABLE-41

PLUMBING	B8.1-620-9950	TWO FIXTURES TOILET

Figure 7-j

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-160-9900	50 Liters Electric Water Heater	System	1	237	51		288	314
B8.1-999-9120	Piping & Fittings	System	1	402	136		538	606
TOTAL				3119	459	0	3578	3808

APPENDIX-D

COST BREAKDOWN FOR THREE-FIXTURE TOILETS

TABLE-42

PLUMBING	B8.1-630-2160	THREE FIXTURES TOILET

Figure 8-a

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3512	459	0	3971	4201

TABLE-43

PLUMBING	B8.1-630-4460	THREE FIXTURES TOILET

Figure 8-b

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				4212	527	0	4739	5003

TABLE-44

PLUMBING	B8.1-630-7080	THREE FIXTURES TOILET

Figure 8-c

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				2837	363	0	3200	3382

TABLE-45

PLUMBING	B8.1-630-9910	THREE FIXTURES TOILET

Figure 8-d

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3295	459	0	3754	3984

TABLE-46

PLUMBING	B8.1-630-9915	THREE FIXTURES TOILET

Figure 8-e

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3995	527	0	4522	4786

TABLE-47

PLUMBING	B8.1-630-9920	THREE FIXTURES TOILET

Figure 8-f

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				2620	363	0	2983	3165

TABLE-48

PLUMBING	B8.1-630-9925	THREE FIXTURES TOILET

Figure 8-g

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				2959	391	0	3350	3546

TABLE-49

PLUMBING	B8.1-630-9930	THREE FIXTURES TOILET

Figure 8-h

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3109	391	0	3500	3696

TABLE-50

PLUMBING	B8.1-630-9935	THREE FIXTURES TOILET

Figure 8-i.

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-410-9900	Eastern Water Closet	System	1	505	68		573	607
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3248	459	0	3707	3937

TABLE-51

PLUMBING	B8.1-630-9940	THREE FIXTURES TOILET

Figure 8-j

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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	824
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3948	527	0	4475	4739

TABLE-52

PLUMBING	B8.1-630-9945	THREE FIXTURES TOILET

Figure 8-k

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
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	824
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				2573	363	0	2936	3118

TABLE-53

PLUMBING	B8.1-630-9950	THREE FIXTURES TOILET

Figure 8-1

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				3398	459	0	3857	4087

TABLE-54

PLUMBING	B8.1-630-9955	THREE FIXTURES TOILET

Figure 8-m

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				4098	527	0	4625	4889

TABLE-55

PLUMBING	B8.1-630-9960	THREE FIXTURES TOILET

Figure 8-n

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9130	Piping & Fittings	System	1	571	136		707	775
TOTAL				2723	363	0	3086	3268

APPENDIX-E

COST BREAKDOWN FOR FOUR-FIXTURE TOILETS

TABLE-56

PLUMBING	B8.1-640-2280	FOUR FIXTURES TOILET

Figure 9-a

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				5284	697	0	5981	6330

TABLE-57

PLUMBING	B8.1-640-9910	FOUR FIXTURES TOILET

Figure 9-b

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
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	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				4031	561	0	4592	4873

TABLE-58

PLUMBING	B8.1-640-9915	FOUR FIXTURES TOILET

Figure 9-c

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
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	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				3356	465	0	3821	4054

TABLE-59

PLUMBING	B8.1-640-9920	FOUR FIXTURES TOILET

Figure 9-d

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				4731	629	0	5360	5675

TABLE-60

PLUMBING	B8.1-640-9925	FOUR FIXTURES TOILET

Figure 9-e

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				4181	561	0	4742	5023

TABLE-61

PLUMBING	B8.1-640-9930	FOUR FIXTURES TOILET

Figure 9-f

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-9900	Stall Shower	System	1	383	40		423	443
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				3506	465	0	3971	4204

TABLE-62

PLUMBING	B8.1-640-9935	FOUR FIXTURES TOILET

Figure 9-g

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2160	Corner Tub	System	1	1758	204		1962	2064
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9140	Piping & Fittings	System	1	585	170		755	840
TOTAL				4881	629	0	5510	5825

APPENDIX-F

COST BREAKDOWN FOR FIVE-FIXTURE TOILETS

TABLE-63

PLUMBING	B8.1-650-1520	FIVE FIXTURES TOILET

Figure 10-a

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8,1-470-9920	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9050	Piping & Fittings	System	1	617	204		821	923
TOTAL				4596	635	0	5231	5549

TABLE-64

PLUMBING	B8.1-650-2400	FIVE FIXTURES TOILET

Figure10-b

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
B8.1-410-2160	Corner Tub	System	1	1758	214		1972	2079
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8,1-470-9920	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	2	1538	136		1674	1742
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9150	Piping & Fittings	System	1	617	204		821	923
TOTAL				6740	877	0	7617	8056

TABLE-65

PLUMBING	B8.1-650-9910	FIVE FIXTURES TOILET

Figure10-c

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9150	Piping & Fittings	System	1	617	204		821	923
TOTAL				4446	635	0	5081	5399

TABLE-66

PLUMBING	B8.1-650-9915	FIVE FIXTURES TOILET

Figure 10-d

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
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
B8.1-470-2000	Western Water Closet	System	1	722	68		790	824
B8.1-470-9910	Eastern Water Closet	System	1	505	68		573	607
B8.1-433-2240	Single Compartment Lavatory	System	2	1538	136		1674	1742
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9150	Piping & Fittings	System	1	617	204		821	923
TOTAL				5215	703	0	5918	6270

TABLE-67

PLUMBING	B8.1-650-9920	FIVE FIXTURES TOILET

Figure 10-e

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2040	Recessed Bath Tub	System	1	1058	136		1194	1262
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	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9150	Piping & Fittings	System	1	617	204		821	923
TOTAL				4718	663	0	5381	5713

TABLE-68

PLUMBING	B8.1-650-9930	FIVE FIXTURES TOILET

Figure 10-f

CODE	ASSEMBLY COMPONENTS	UNIT	COST DEVELOPMENT PER ASSEMBLY					
			1998 BARE COSTS PER ASSEMBLY					TOTAL
			QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
B8.1-410-2160	Corner Tub	System	1	1758	214		1972	2079
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	824
B8.1-470-9900	Bidet	System	1	655	68		723	757
B8.1-433-2240	Single Compartment Lavatory	System	1	769	68		837	871
B8.1-160-9910	80 Liters Electric Water Heater	System	1	392	51		443	469
B8.1-999-9150	Piping & Fittings	System	1	617	204		821	923
TOTAL				5418	741	0	6159	6530

APPENDIX-G

COST BREAKDOWN FOR DOUBLE COMPARTMENT LAVATORY ASSEMBLY

TABLE-69

PLUMBING	B8.1-991-9010	DOUBLE COMPARTMENT LAVATORY

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Double Compartment Lavatory					Each	1200	1	1200	0		1200	1200
Lavatory Hot/Cold Water Mixer					Each	200	2	400	0		400	400
2" P-trap					Each	70	1	70	0		70	70
2"*4" PVC Bushing					Each	12	2	24	0		24	24
1/2" Angle Valave					Each	14	4	56	0		56	56
3/4"*1/2" PVC elbow-brass thread					Each	6	2	12	0		12	12
3/4"*1/2" CPVC elbow-brass thread					Each	7	2	14	0		14	14
3/4 inch PVC Tee					Each	5	2	10	0		10	10
3/4 inch CPVC Tee					Each	6	2	12	0		12	12
2 inch PVC DWV Pipe					Each	30	1	30	0		30	30
Flexible Hose					Each	5	4	20	0		20	20
System Installation	P-2	17	1.33	6	System	0	1	0	102		102	153
TOTAL								1848	102	0	1950	2001

APPENDIX-H

COST BREAKDOWN FOR KITCHEN SINK ASSEMBLY

TABLE-70

PLUMBING	B8.1-991-9020	KITCHEN SINK

Fiber Glass

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Sink (Double Compartment)					Each	1400	1	1400	0		1400	1400
Lavatory Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	35	1	35	0		35	35
2"*4" PVC Bushing					Each	12	1	12	0		12	12
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
3/4 inch CPVC Pipe					Each	55	1	55	0		55	55
3/4 inch PVC Pipe					Each	18	1	18	0		18	18
2 inch PVC DWV Pipe					Each	30	1	30	0		30	30
4 inch PVC DWV Pipe					Each	65	1	65	0		65	65
4*4*2 inch Y-connection					Each	16	1	16	0		16	16
2 inch Elbow					Each	3	3	9	0		9	9
3/4 inch 90 deg. PVC Elbow					Each	3	1	3	0		3	3
3/4 inch PVC Tee					Each	4	1	4	0		4	4
3/4 inch CPVC Tee					Each	5	1	5	0		5	5
4" Floor Drain					Each	7	1	7	0		7	7
4" Cleanout					Each	18	1	18	0		18	18
4 inch P-trap					Each	20	1	20	0		20	20
Solvent Cement					Each	25	1	25	0		25	25
Piping & Fittings Installation	P-2	17	2	10	Assem	0	1	0	170		170	255
TOTAL								1961	170	0	2131	2216

TABLE-71

PLUMBING	B8.1-991-9030	KITCHEN SINK

Stainless Steel

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Sink (Double Compartment)					Each	160	1	160	0		160	160
Lavatory Hot/Cold Water Mixer					Each	200	1	200	0		200	200
2" P-trap					Each	35	1	35	0		35	35
2"*4" PVC Bushing					Each	12	1	12	0		12	12
3/4"*1/2" PVC elbow-brass thread					Each	6	1	6	0		6	6
3/4"*1/2" CPVC elbow-brass thread					Each	7	1	7	0		7	7
3/4 inch PVC Tee					Each	5	1	5	0		5	5
3/4 inch CPVC Tee					Each	6	1	6	0		6	6
2 inch PVC DWV Pipe					Each	30	0.5	15	0		15	15
3/4 inch CPVC Pipe					Each	55	1	55	0		55	55
3/4 inch PVC Pipe					Each	18	1	18	0		18	18
2 inch PVC DWV Pipe					Each	30	1	30	0		30	30
4 inch PVC DWV Pipe					Each	65	1	65	0		65	65
4*4*2 inch Y-connection					Each	16	1	16	0		16	16
2 inch Elbow					Each	3	3	9	0		9	9
3/4 inch 90 deg. PVC Elbow					Each	3	1	3	0		3	3
3/4 inch PVC Tee					Each	4	1	4	0		4	4
3/4 inch CPVC Tee					Each	5	1	5	0		5	5
4" Floor Drain					Each	7	1	7	0		7	7
4" Cleanout					Each	18	1	18	0		18	18
4 inch P-trap					Each	20	1	20	0		20	20
Solvent Cement					Each	25	1	25	0		25	25
Piping & Fittings Installation	P-2	17	2	10	Assem	0	1	0	170		170	255
TOTAL								721	170	0	891	976

APPENDIX-I

COST BREAKDOWN FOR BUILDING DRAINAGE, WASTE & VENT PIPING ASSEMBLY

TABLE-72

PLUMBING	B8.1-991-9040	BUILDING DRAINAGE, WASTE & VENT

Private Residential Building (Villa Type)

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
6-inch PVC pipe					Each	130	11	1430	0		1430	1430
6-inch 90deg. elbow					Each	20	5	100	0		100	100
6-inch coupling					Each	30	6	180	0		180	180
6"*6"*6" Y-connection					Each	35	1	35	0		35	35
6*6*4 inch Y-connection					Each	20	3	60	0		60	60
4*4*4 inch Y-connection					Each	16	11	176	0		176	176
4-inch PVC pipe					Each	65	6	390	0		390	390
4-inch coupling					Each	9	6	54	0		54	54
4-inch floor drain					Each	7	4	28	0		28	28
4-inch ground cleanout					Each	18	3	54	0		54	54
4-inch 90deg. elbow					Each	10	7	70	0		70	70
4-inch P-trap					Each	20	7	140	0		140	140
Cement Solvent					Can	25	8	200	0		200	200
Piping & Fittings Installation	P-2	17	0.1	72	Assem		1	0	1224		1224	1836
TOTAL								2917	1224	0	4141	4753

TABLE-73

PLUMBING	B8.1-991-9050	BUILDING DRAINAGE, WASTE & VENT

2-story 4-apartment Type Building

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
6-inch PVC pipe					Each	130	11	1430	0		1430	1430
6-inch 90deg. elbow					Each	20	5	100	0		100	100
6-inch coupling					Each	30	6	180	0		180	180
6"*6"*6" Y-connection					Each	35	1	35	0		35	35
6-inch Bushing					Each	26	4	104	0		104	104
6*6*4 inch Y-connection					Each	20	14	280	0		280	280
4*4*4 inch Y-connection					Each	16	7	112	0		112	112
4-inch PVC pipe					Each	65	7	455	0		455	455
4-inch coupling					Each	9	4	36	0		36	36
4-inch floor drain					Each	7	3	21	0		21	21
4-inch ground cleanout					Each	18	10	180	0		180	180
4-inch 90deg. elbow					Each	10	8	80	0		80	80
4-inch P-trap					Each	20	10	200	0		200	200
Cement Solvent					Can	25	10	250	0		250	250
Piping & Fittings Installation	P-2	17	0.1	80	Assem		1	0	1360		1360	2040
TOTAL								3463	1360	0	4823	5503

APPENDIX-J

COST BREAKDOWN FOR BUILDING WATER SUPPLY PIPING ASSEMBLY

TABLE-74

PLUMBING	B8.1-991-9060	BUILDING EXTERNAL WATER SUPPLY PIPING

For Private Residential Building (Villa Type)

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
1"PVC Pipe					Each	25	20	500	0		500	500
1" PVC Tee					Each	5	10	50	0		50	50
1" PVC Coupling					Each	5	20	100	0		100	100
1" PVC 90 deg. Elbow					Each	4	13	52	0		52	52
1" PVC Gate Valve					Each	35	6	210	0		210	210
1/2" Hose Bib Valve					Each	9	4	36	0		36	36
1"*3/4" Bushing					Each	2	10	20	0		20	20
3/4" PVC 90 deg. Elbow					Each	4	4	16	0		16	16
3/4"*1/2" Elbow w/Brass Thread					Each	6	4	24	0		24	24
Cement Solvent					Can	25	10	250	0		250	250
Piping & Fittings Installation	P-2	17	0.25	28	Assem	0	1	0	476		476	714
TOTAL								1258	476	0	1734	1972

TABLE-75

PLUMBING	B8.1-991-9070	BUILDING EXTERNAL WATER SUPPLY PIPING

For 2-Story 4-Apartment Residential Building

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
1"PVC Pipe					Each	25	25	625	0		625	625
1" PVC Tee					Each	5	14	70	0		70	70
1" PVC Coupling					Each	5	25	125	0		125	125
1" PVC 90 deg. Elbow					Each	4	20	80	0		80	80
1" PVC Gate Valve					Each	35	7	245	0		245	245
1/2" Hose Bib Valve					Each	9	4	36	0		36	36
1"*3/4" Bushing					Each	2	14	28	0		28	28
3/4" PVC 90 deg. Elbow					Each	4	4	16	0		16	16
3/4"*1/2" Elbow w/Brass Thread					Each	6	4	24	0		24	24
Cement Solvent					Can	25	15	375	0		375	375
Piping & Fittings Installation	P-2	17	0.25	28	Assem	0	1	0	476		476	714
TOTAL								1624	476	0	2100	2338

APPENDIX-K

COST BREAKDOWN FOR WATER TANK AND BOOSTER PUMP ASSEMBLIES

TABLE-76

PLUMBING	B8.1-991-9080	WATER TANK

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Water Tank (500 Gallon Capacity)					Each	600	1	600	0		600	600
1" PVC Union					Each	10	2	20	0		20	20
1"PVC 90 deg. Elbow					Each	4	4	16	0		16	16
1" PVC Gate Valve					Each	35	3	105	0		105	105
Assembly Installation	P-1	10	2	4	Assem	0	1	0	40		40	60
TOTAL								741	40	0	781	801

TABLE-77

PLUMBING	B8.1-991-9090	BOOSTER PUMP

ASSEMBLY COMPONENTS	CREW TYPE	CREW COST PER HOUR	CREW DAILY OUTPUT	MAN-HOURS PER ASSEM.	UNIT	MAT. COST PER UNIT	COST DEVELOPMENT PER ASSEMBLY					
							1998 BARE COSTS PER ASSEMBLY					TOTAL
							QUAN.	MAT.	LABOR	EQUIP.	TOTAL	INC. O&P
Booster Pump					Each	1000	1	1000	0		1000	1000
1"PVC Tee					Each	5	2	10	0		10	10
1' PVC 90deg. Elbow					Each	5	2	10	0		10	10
1" Check Valve					Each	30	1	30	0		30	30
1" PVC Gate Valve					Each	35	3	105	0		105	105
Assembly Installation	P-1	10	2	2	Assem	0	1	0	20		20	30
TOTAL								1155	20	0	1175	1185

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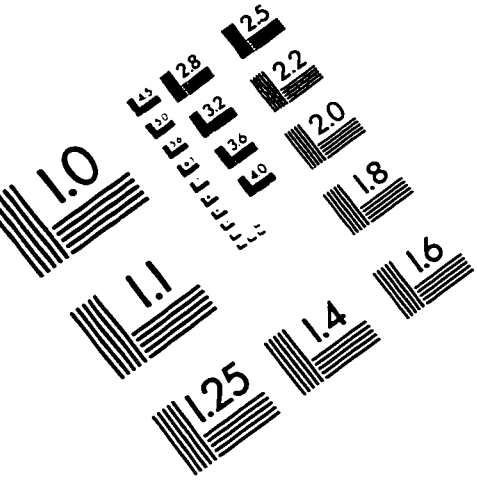
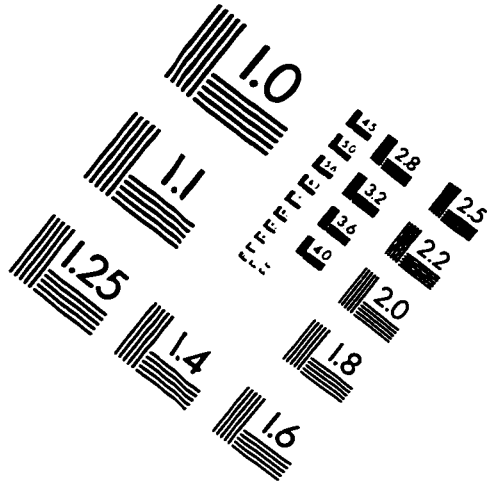
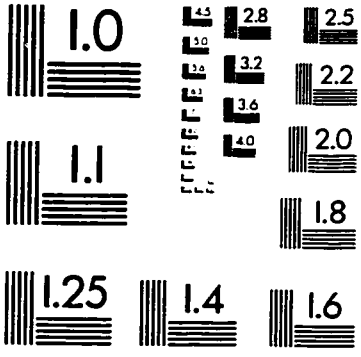
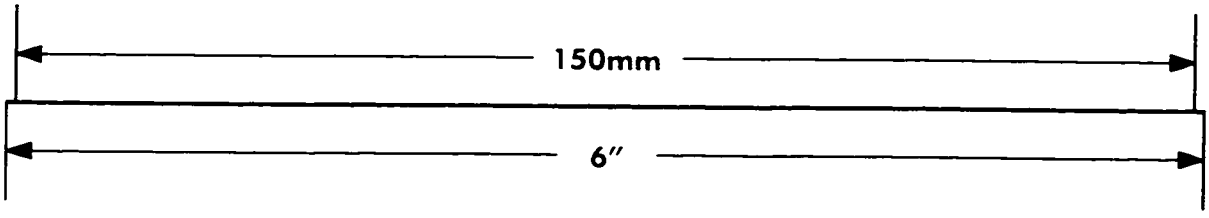
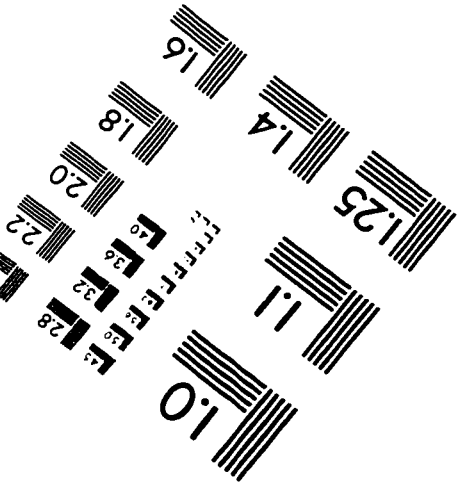
IMAGE EVALUATION TEST TARGET (QA-3)

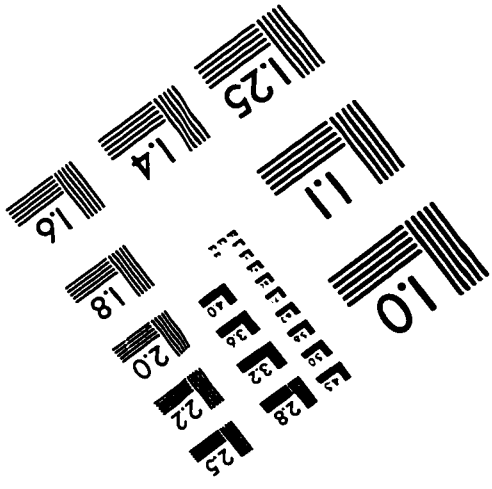












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