Cost Overrun in Public Construction Projects of Oman: Case Studies

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Abstract: *This paper discusses causes of cost overrun and their effects on construction projects in Oman. Tasks included study of 39 public construction projects of different types with emphasize on four projects as case studies. It was found that 82 percent of the projects suffered from cost overrun of* ***34.5*** *per cent of the contract values. The infrastructure and building projects experienced larger cost overrun than the power station projects. The average cost overrun of the four case studies was 12.8 per cent of the original contract values and the time overrun was 37.3 per cent of the original total contract time. Changes of scope of works and additional works ordered by the client were found to be the major causes of cost overrun in the cases studied with an average of 52.9 and 41.7 per cent respectively. Design errors, change of project location, changes in specification etc. were also found to cause cost overruns but with less extent. The average value-ratios of basic functions to the secondary functions was 0.435. An average of 26 change orders was issued during the construction of the four case studies. No relation trend was found between the percentages of cost overrun and the number of change order.*

Keywords—Cost overrun; Change orders; Construction; Oman

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I. INTRODUCTION

Change orders are issued to overcome mistakes or modify the original design or scope of work. As a result, cost overruns become inevitable in many cases. Changes are mostly requested by owners or consultants for improvement of design or required services. The consultant's fees are usually proportional to construction cost of the project. Similarly, the contractor's benefits from modifications. The causes and effects of cost overruns have been the concern of all involved parties as well as researchers. Kaming et al (1997) studied influencing factors on thirty one high-rise projects in Indonesia and found that design changes is one of the most important factors causing cost and time overruns. Al-Momani (2000) found that the additional requirements from the client are the main causes of cost overrun in 130 public projects in Jordan. Akpan and Igwe (2001) stated that the main causes of projects cost overruns are inadequate

information of the project requirements and the methodology used for controlling the cost. Wu et al (2005) studied the causes of 1,038 change orders issued for national highway projects in Taiwan and found that the improper design is the main factor for causing the cost overrun. Acharya et al (2006) carried out field survey on Korean construction projects and found that additional requirements are the factor causing conflict in construction projects. Arun and Rao (2007) stated that changes in design as well as correcting design errors are main factors causing cost overruns. Perkins (2007) examined the causes for cost overrun in private and public construction projects in the United States and found that undefined owner requirements and discrepancies in design of the project are the main factors causing cost overrun. Lee (2008) studied records of 161 completed transport projects. He concluded that 95% and 100% of road and rail projects, respectively, had a maximum cost overrun of 50%. The key causes of cost overruns were found to be: (1) changes in scope; (2) delays during construction; and (3) improper estimation of project cost. Alnuaimi et al (2010) found that the cost and time overruns due to change orders are causing confusion and disruption to the government strategic development plans. Yet, no unique method is available for avoiding or managing them effectively in Oman. The conventional approach is to include a percentage of the project cost as a contingency in the contract budget for their occurrence. Al Ghaithy (2003) studied the contractual claim reasons in construction industry and found that undefined owner requirements and unclear perception of the project are the main causes of cost overrun. Ambusaidi (2005) studied the project risk management in Omani construction industry and presented some case studies of construction projects. He found that client additional works and random requirement are the main causes of cost overrun. Al-Zadjali (2010) conducted a study to identify factors causing cost overrun in telecommunication projects in Oman. The results showed that undefined customer requirements and changes in scope of the project by the stakeholder or end users are the main factors in causing cost overrun. Al Mohsin and Alnuaimi (2013) carried out field survey on 46 projects constructed between 2007 and 2010 and found that 40 per cent of the projects experienced time overrun with an average of 59.53 percent and 42.18 percent for the periods of 2007-2008 and 2009-2010 respectively. They also found that the owner related causes are the main factors for time overrun. Al Ruqaishi (2011) stated that no formal record is available on the size of the project time-overrun problems in Oman. He also stated that, out of 40 construction projects that have been carried out for oil and gas organizations over the past three years, only 62 per cent of the projects have been completed within the stipulated time. Moreover, a review on one of the major oil and gas organization in Oman shows that 50 per cent of the construction projects are facing time and cost overruns. Investigating the causes of the cost overrun is very important to measure the size and effects of the problem as well as to contribute to the search of finding solutions and appraising the process system. The aim of this paper is to investigate the causes and effects of cost overruns in public construction projects in Oman.

II. METHODOLOGY

Data about 39 public construction projects from different types and sizes was collected from the records of the consultants who supervised the projects. In addition, some cases required face-to-face meetings with the project managers. For this purpose, 35 individual meetings were carried out with the concerned project managers to clarify some information. To ensure diversity, the projects were selected so that only one project was selected from each client, only one project per consultant and one project per contractor. All selected projects were delivered using the traditional method of design-bid-build. In this method, the client hires a consultant for the design and then a contractor is selected by means of open tendering process. Four, typical, major projects representing seaports, roads, and buildings are presented in this paper as case studies. The case studies present projects that were completed during the last three years (2010-2013). One full-day

workshop for value analysis was conducted to identify and analyze the functions of the projects and measure their values. Value analysis specialists from different consulting offices participated in the function analysis of the four cases. The components of the projects were categorized as basic and secondary functions. The cost of each function was measured to calculate the baseline costs of the basic and secondary functions. The cost index of the project, which is the ratio of the basic function to the secondary function, was determined to measure the ideality and value of the project. The study covered project's scope, function requirements, stages of the project, duration of construction and causes of change orders. Furthermore, the study investigated successive changes in the project budget from design stage to completion. The data was analyzed using Excel program. The findings of the previous researches were used for comparison.

III. DATA ANALYSIS AND DISCUSSION

General

Table 1 shows a list of the studied projects and costs. It is clear that 32 projects out of 39 projects studied (82 per cent) suffered cost overrun with a total value of overrun of 685,118,908.600 – **509,448,762.88** = R.O. 175,670,145.720 (34.48 % of the contract values). The percentages of positive minimum and maximum cost overruns in these projects were 1.7 and 360 respectively. The average cost overrun for the 39 projects was 692,841,514.99 - **517,728,672.66** = R.O. 175,112,842.300 (25 per cent of the contract values). Among all projects studied, only one project was completed with the same contract value and seven projects (17.9%) were completed with costs less than the contract values with total saving of 6,372,606.35 - 6,929,909.78 = R.O. -557,303.43 (8% of contracts values). The minimum and maximum savings were 3.6, 11.2 percent respectively. With exception to one project, the maximum cost overrun was less than 70 per cent of the original contract value. 74.4 per cent of the projects suffered positive cost overrun equal to or less than 50 per cent of the original contract value. With exception to one project, all of the 39 projects had contract values less than or equal to R.O. 104,000,000.000. 92.3 per cent of the project contracts values were equal to or less than R.O. 16,000,000.000. It was noticed that the construction of power sub-stations suffered the least cost overruns while the buildings and infrastructure projects suffered the largest cost overruns. This is expected as the substation works are usually designed with less ambiguities and unforeseen works than the infrastructure and building works. This is a large value of cost overrun which indicates lack of vision about the client's needs and improper planning. The main causes of the cost overruns were found to be changes of scope of works and additional works ordered by the clients. Other factors related to design errors, change of project location, changes in specification etc. were also found to cause cost overruns but for less effects. There is no data bank or general procedure that can be used for design and construction of projects in Oman. Each public agent is running its own projects independently. All experiences gained are localized in each agent with no master planning and share of information or knowledge.

Table 1. Summary of the projects survey

P. No.	Project type	Contract value (R.O)	Cost after completion (R.O)	Cost overrun (R.O)	% of cost increase	Main Causes of cost overrun
1	Infrastructure (Roads, Services, runways and earthworks)	250,000,000.00	380,000,000.00	130,000,000.00	52	Inadequate definition of scope
2	Building Complex and infrastructure works	5,000,000.00	23,000,000.00	18,000,000.00	360	Undefined works and client additional requirements
3	Roads and buildings	2,500,000.00	3,600,000.00	1,100,000.00	44	Unclear perception of the client, undefined scope, additional requirement
4	Building complex	2,500,000.00	3,200,000.00	700,000.00	28	Undefined scope of work, design errors, improper investigations
5	Building complex and internal	3,755,291.00	5,000,000.00	1,244,709.00	33	Additional client requirements, changing scope of work,
6	MEP Workshops	1,000,000.00	1,508,000.00	508,000.00	50.8	Additional random requirements, undefined scope of work
7	Network and service roads	3,000,000.00	3,505,000.00	505,000.00	16.8	Improper investigations, design errors, undefined requirements and authority in decision-making.
8	Building complex with substations and internal roads	16,000,000.00	20,000,000.00	4,000,000.00	25	Improper investigations, design errors , undefined requirements
9	Renovation of	850,000.00	1,250,000.00	400,000.00	47.1	Additional

	existing offices					requirement
10	Construction of Mailing offices	403,046.00	680,000.00	27,695.400	68.7	Unclear client perceptions and undefined scope of work
11	11 kva substation	300,000.00	350,000.00	50,000.00	16.7	Undefined requirements
12	Public multi floor car parking	1,420,220.00	1,480,000.00	59780.00	4.21	Unclear client perceptions and undefined scope of work
13	Building complex	5,514,621.368	6,250,000.00	735,378.632	13.3	Additional work
14	Office complex and infrastructure services	14,100,000.00	17,200,000.00	3,100,000.00	22	Additional works, undefined requirements and unclear scope
15	Port container terminal and berths	103,700,000.00	110,400,000.00	6,700,000.00	6.5	Additional works, unclear requirements and scope
16	Service and network roads	2,850,000.00	3,140,000.00	290,000.00	10.2	Additional works, unclear requirements and scope
17	Fast ferry service	8,100,000.00	9,100,000.00	1,000,000.00	12.3	Additional works, unclear requirements and scope
18	Const. of 2x10 MVA Power Substation and laying of 33KV cable feeders	2,970,000.00	3,200,000.00	230,000.00	7.7	No Proper survey done during the design stage.
19	Const. of Primary Power Substation	6,100,000.00	7,720,000.00	1,620,000.00	26.6	All authority approvals delay and additional works
20	Construction of 2x20Mva, 33/11KV Primary Substation with internal roads	1,800,000.00	1,900,090.000	100,090.00	5.5	The location of the project and the scope of work changes 4 times
21	Construction of 2x20Mva33/11K	1,661,631.000	1,428,053.780	233,577.22	-14.1	

	V Primary Substation					
22	Const. of Primary substations of 2x20Mva and 33/11KV distribution station	1,068,000.00	1,136,000.000	68,000.00	6.3	Additional works
23	Const. of distribution substations for central highway	1,633,000.00	1,574,000.00	- 59,000.00	-3.6	The location of the project and the scope of work changes 2 times
24	Construction of overfly U-turn	2,100,000.00	2,293,000.00	193,000.00	9.2	Same additional work done for Clint it is not included in scope of work
25	Const. of Primary substations and service building to local Hospital	1,999,000.00	1,895,659.00	- 103,341.00	-5.2	The location of the project and the scope of work changes 2 times
26	Construction of Grid power network and associated civil works	430,610.511	506,600.600	75,990.089	17.6	The location of the project and the scope of work changes 2 times
27	Construction of Grid power and distribution Station	1,102,000.00	1,300,000.00	198,000.00	18	Non availability of the as build drawing and existing service data.
28	Refurbishment of existing power workshops	43,686.579	39,518.565	- 4,160.00	-9.5	Changing the location of the project
29	Upgrading of 125MVA Grid power station	181,000.00	221,000.00	40,000.00	22	Additional works and scope changing
30	Upgrading of service facilities at interior area	1,260,000.00	1,460,000.00	200,000.00	15.9	Additional works for extra services.
31	Refurbishment of highway	604,800.00	537,433.00	-67,367.00	-11.1	Reducing the scope of work
32	Construction of	258,300.00	309,600.000	51,300.00	19.9	Scope changing's

	Generator, transformer and Repairing Work shop					and changes of the project location during the construction stage
33	Construction of Offices and staff accommodations with internal roads and service facilities	1,350,000.0	1,350,000.00	0	0	
34	Upgrading 33/11KV substation	715,156.200	656,063.000	-59,093.200	-8.3	reducing scope of work
35	Construction of medical facilities with internal roads and power substations	5,480,000.00	7,400,000.00	1,920,000.00	35	The location of the project and the scope of work changes 2 times after the awarding the tender.
36	Construction of 2X20MVA33/11 KV Primary Substation	6,430,000.00	7,368,000.00	938,000.00	14.9	The location of the project and the scope of work changes 2 times after the awarding the tender.
37	Upgrading of existing service roads and junctions	272,636.00	241,879.00	-30,757.00	-11.2	Reducing scope of work
38	Under grounding power cables and accessories works	1,275,674.00	1,641,618.00	365,971.00	28.7	Additional works of services and civil
39	Construction of bridge and junction road	58,000,000.00	59,000,000.00	1,000,000.00	1.7	Additional works
Total cost (R.O)		**517,728,672.66**	692,841,514.99	175,112,842.300	25	

Case studies

Among the 39 projects studied, four cases were selected to typically represent the different types of projects constructed in Oman. The case studies total preliminary cost estimate, detailed cost estimate (just before tendering), contracts' value, and actual construction cost were R.O. 29,500,000.000 (USD 76,700,000.00), R.O. 98,800,000.000 (USD 256,880,000.00), R.O. 128,750,000.000 (USD 334,750,000.00), and R.O. 139,840,000 (USD 363,584,000.00), respectively. The cost overrun was R.O. 11,090,000 (USD 28,834,000) which is 8.61 per cent of the contract values. The total delay period was 638 days which represents a time overrun of 37.3 per cent of the total contract time.

A. Case study 1: Construction of a buidling complex

The original project scope of work constitutes construction of government office complex for 750 employees in a multi-story structure building of a total gross floor area of 17,000 square meters, service compound, a guard house compound wall, and service roads, and 337 asphalted and shaded car park lots within the compound wall. The project went through four stages: feasibility study stage, concept and design stage, tender stage, and construction stage. The owner participated in all stages of design and construction. The original project objectives and criteria given to the consultant are shown in Table 2. The planned budget sum for the said services was set to be Rial Omani R.O. 5 million (USD 13 million) including design and construction works. The design cost of the project was R.O. 164,000 (USD 426,400.00) which is 3.28 percent of the planned budget sum. The initial requirements were reviewed by the consultant and a conceptual design formulated and approved by the client to proceed with detailed design within the planned budget sum. During the detailed design stage, the client ordered additional space requirements. The detailed cost estimate of the project at the end of the design stage reached R.O. 10 million which is 100 per cent larger than the planned budget at the preliminary design stage. The construction work was awarded to the lowest bidder and a contract was signed with a value of R.O. 14,100,000.00 (USD 36,660,000) including R.O. 535,000.00 as contingencies for a construction period of 390 days.

Table 2. Project objectives and criteria (Case study 1)

(a) Objective
1. Construct a multi-story building to accommodate 750 staff. 2. Construct shaded car park for staff and public uses. 3. Provide easy and quick communication and IT services for staff and public. 4. Maintain high security service in the building. 5. Stay with reasonable agreed budget. 6. Make consensus between the basic requirements and secondary requirements.
(b) Desired criteria
1. Materials to be properly selected with high quality. 2. The building external view to be Oman's building styles. 3. The design should allow for future expansion. 4. The internal service roads to be as per Omani standards and specifications.

This contract value is larger than the initial and pre-tender estimated costs by about 282 and 141 percent respectively. In addition, the consultant supervision services were increased by 1.125 percent due to change in construction period agreed upon during the time of tendering stage. During the construction, fifteen change orders were issued to the contractor with additional cost of R.O. 3,100,000 (USD 8,060,000), which is 22 per cent of the original contract value (486.4% larger than the contingency value). Figure 1 shows the changes in the project budget during the design and construction stages. There was no time overrun due to the change orders. The variations were classified into two groups; client-related and consultant-related. The first group included the variations issued due to additional requirements and changes in design. The second group was mostly design errors and missing items in the tender documents. Figure 2 shows causes and percentages of change order values. It is clear that most of the change orders (96.6 %) were instructed by the client, which indicates unclear vision of requirements before and during design stages. The cost overrun started immediately after the preliminary design was approved. Usually, after this stage, the users start to realize and begin to be more involved in the project which lead to change orders. During construction, the structure and space dimensions are visualized and new changes are ordered. This scenario is repeated almost in all governmental building projects. The clear reason for this, is the lack of communication between the users and people conducting the feasibility study and consultant during the preliminary design stage. Another reason for this scenario is the long time lag between the feasibility study and design stages which leads to change of requirements due to growth or advances of technology. The actual cost of case 1 project was 344 percent larger than the initial allocated budget. In Oman, such problems are tackled either by requesting additional funds from the ministry of finance or by transferring money from other projects within the organization. The first solution is time consuming and usually causes an additional delay to the project, while the second solution leads to reduction in the scope of other projects or postponing them until additional funds areallocated. This shows how cost overrun could disrupt an owner's plans and confuses the management of the project. In addition, the situation may become more complicated if the owner could not secure additional funds as the project may be suspended for unknown period. Since there was no function analysis carried out before or during design, function's cost analysis was carried out using the actual cost taken from the project recodes. The project was divided into different functions and function's cost analysis was carried out based on the construction cost of each function. The project components were categorized as basic and secondary functions. The basic function of this project is to accommodate staff (usable space) where the secondary functions are the functions support the occurrences of the basic functions (control environment, connect services, transfer and generate power, enclose space, prepare site etc.). The actual cost of the basic function components was R.O. 6,900,725.173 which is 48.95 per cent of the total cost of the project as shown in Figure 3. The ratio of the basic function cost to the secondary functions cost was 0.96. This indicates that the basic functions cost are almost equal to the secondary functions cost. Commonly, if the planned basic functions cost are more or equal to the planned secondary functions cost, and the same was found using the actual cost without any cost overrun the project can be considered as an ideal (Assaf, 2000). However, due to absence of planned function analysis and because of the occurrence of cost overruns during the design and the construction stages, it cannot be argued that the existing ideality was planned and implemented by careful setting of the requirements and balancing between the basic and secondary functions. It is clear that this project has undergone many changes which resulted in huge cost overrun compared to the originally planned budget but the result was a balanced project with fulfillment of basic and secondary functions. However, it was not clear how the agent managed to secure additional funds and whether other projects were affected by this project cost overrun or not

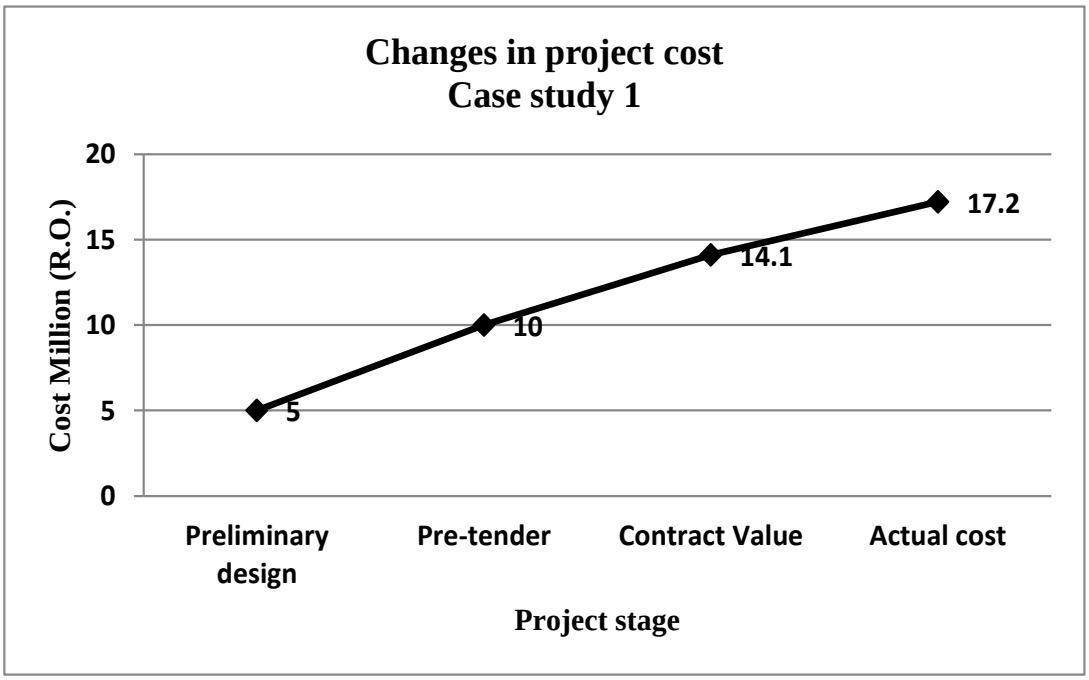

Figure 1: Changes in project budget (Case study 1)

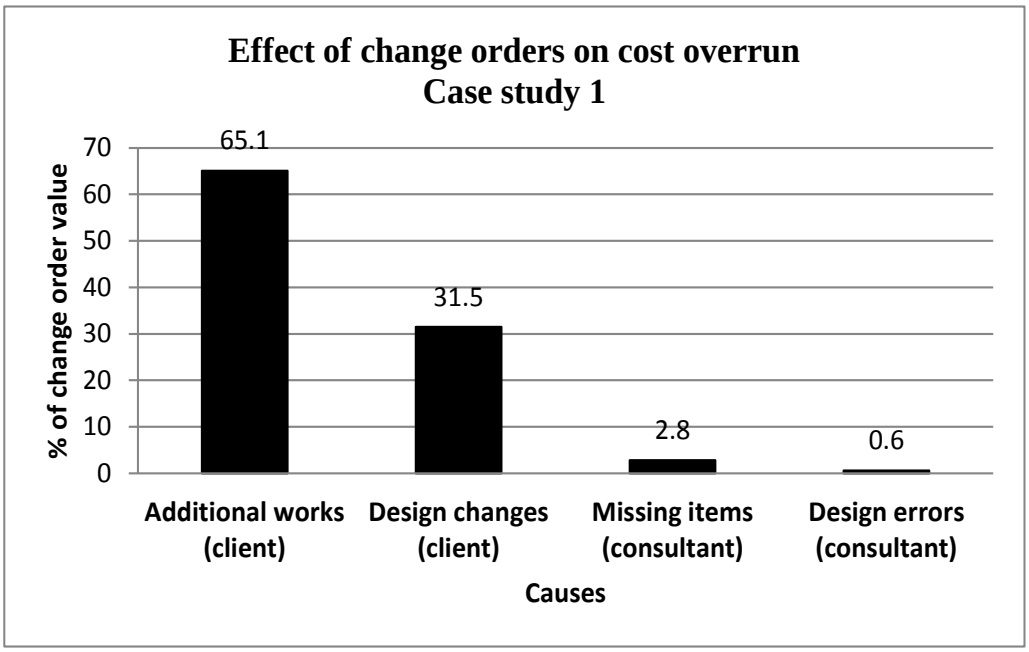

Figure 2: Percentage of change order values (Case study 1)

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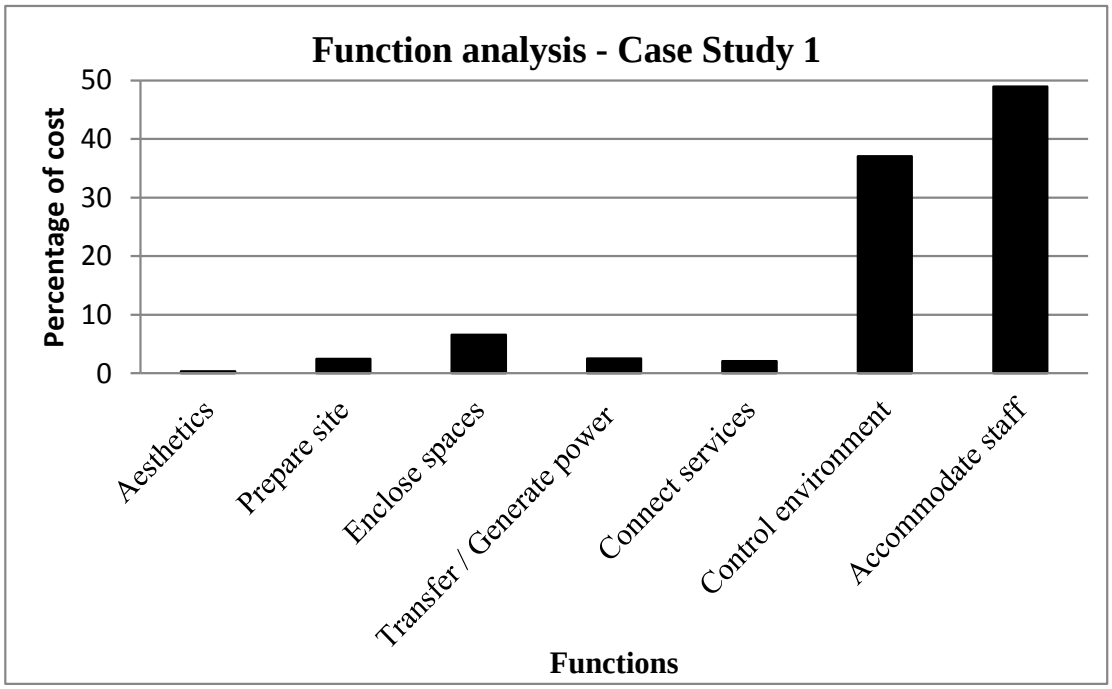

Figure 3: Percentage of basic and secondary functions cost (case study 1)

B. Case study no.2: Construction of container terminal in a seaport

The project scope consists of construction of two container berths, a new rubble mound breakwater, dredging of the harbor basin and channel, and land reclamation by hydraulic methods to handle largest container vessels. Table 3 shows the basic requirements of the project. International consultant carried out the feasibility study and based on that R.O. 20 million (USD 52 million) allocated as a conceptual budget for design and construction. The project was awarded to an international consultant for design for a period of 13 weeks excluding the time required for client approvals. The requirements were recorded and discussed several times before the preliminary design approval with agreed above budget. New requirements to the conceptual proposal were added to relocate some existing services at the detail design stage. The estimated detailed cost of the project just before tendering stage was R.O 81.8 million (USD 212.7 million) which is 409 per cent larger than the conceptual budget. Several technical queries raised by the bidders during the tender stage. Most of them were pointing to a lack in specifications, undefined scope of some items and design issues. The queries were not addressed properly in the project tender document. The construction work was awarded to the lowest bidders for R.O. 103,700,000 (USD 269,620,000) for a construction period of 540 days. The cost was larger than the conceptual cost and pre-tender cost for about 418 per cent and 141 per cent respectively. Twenty change orders were issued to the contractor amounting to R.O. 6,700,000.00 (USD 17,420,000.00) which is 6.46 per cent of the original contract value and larger than the contingency by 133.5 per cent. The time overrun was 38.89 per cent. The variations were issued to cover undefined items in tender documents, design errors, scope changes and additional works. Figure 4 shows the budget growth of the project from the concept to construction. Figure 5 shows that the changes in the scope caused the largest amount of variations (60.2%), followed by client additional requirements (31.3%). Most of the scope changes were due unclear vision during the feasibility study. Based on the function analysis, the basic and secondary functions costs were identified as shown in Figure 6. The cost of the basic functions was 19.7 per

cent of the total actual construction cost. The ratio of the basic functions to the secondary functions costs was 0.24. This ratio indicates that there is no harmony in costs between the basic functions and secondary functions. There was certain amount of money invested in secondary functions and resulted in low worth to the basic-functions. It is clear from the above discussion that the objectives of the project were not studied carefully during the feasibility and design stages. The consequences of the pitfalls resulted in large number of modifications to the design. In addition, the client new requirements contributed to the growth of the cost overrun. Further, the project contained secondary functions that could be avoided or reduced if proper planning and function analysis were carried out at the feasibility and design stages. The client managed to finance the project until completion by transferring money from different planned projects.

Table 3. Objectives of the project (Case study 2)

1. Construct a container terminal to handle container vessels of length 16.5-18.5 m
2. Construct two berths to increase the terminal cargo capacity up to 4.5 million tons annually.
3. Construct a breakwater system.
4. Upgrade the existing services area to align with the development.
5. Provide easy and quick services for vessels.
6. Stay with reasonable budget.
7. Make consensus between the existing services and new required services.

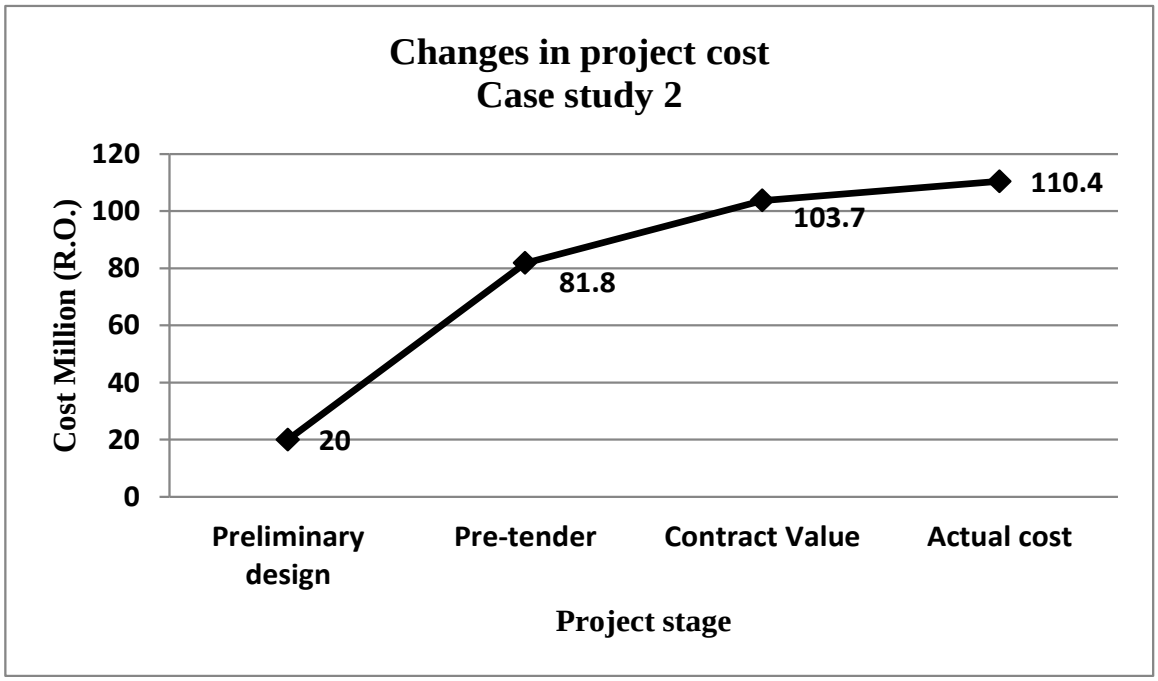

Figure 4: Changes in project budget (Case study 2)

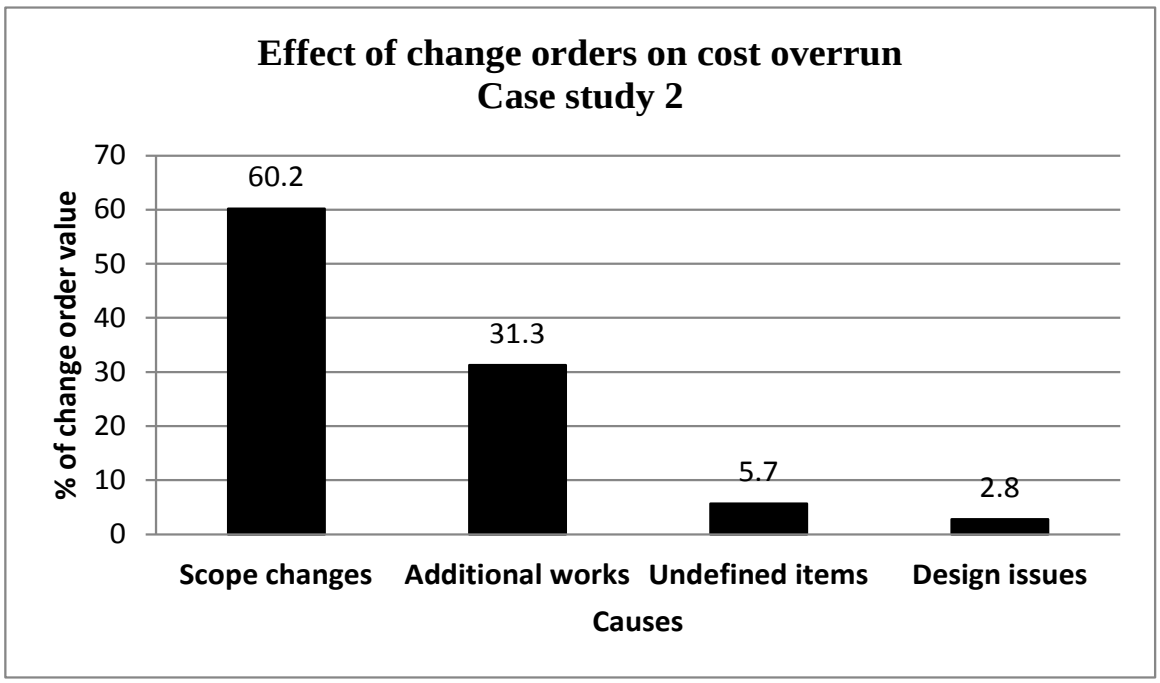

Figure 5: Percentage of change order values (Case study 2)

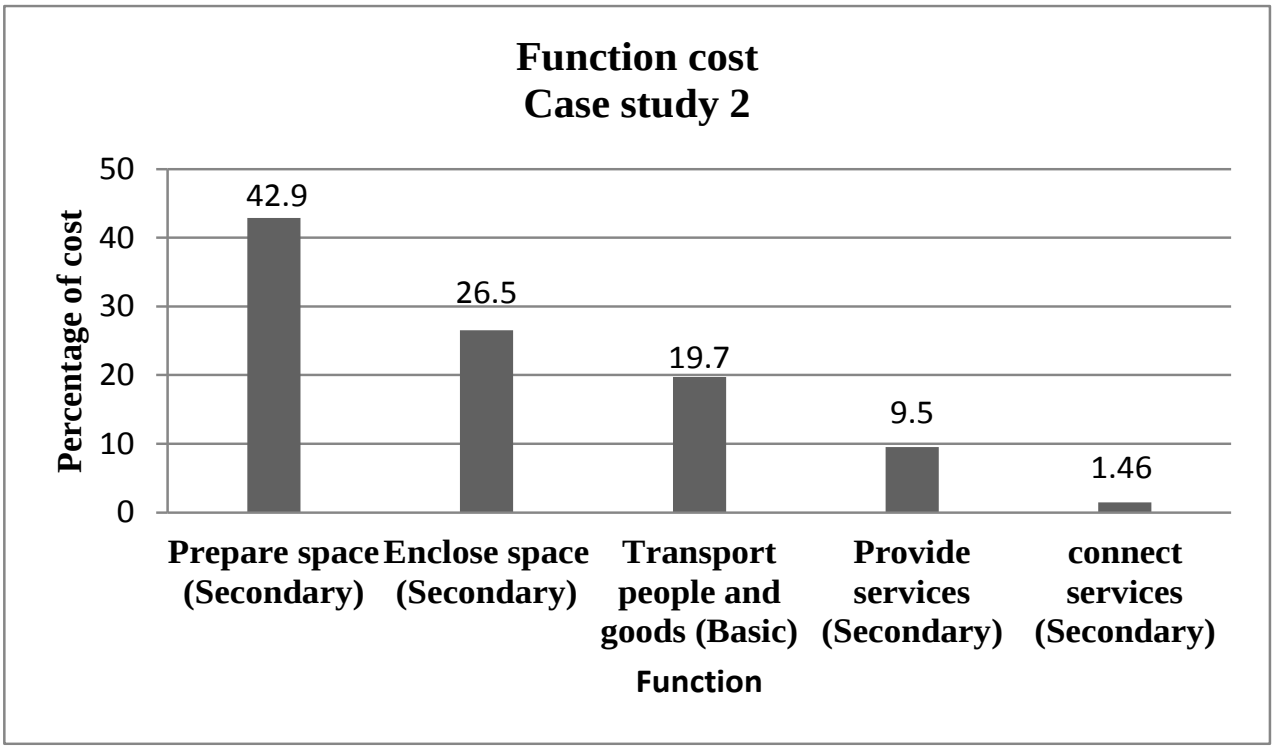

Figure 6: Percentage of functions cost (Case study 2)

C. Case study no.3: Construction of internal roads

This case study represents a construction of 6 km service roads connecting to an expressway. Table 4 shows the design objectives of the project. The project life cycle was consisted of: feasibility and concept stage, design and tender stage, and construction stage. Based on the feasibility study a conceptual budget of R.O. 1.5 million (USD 3.9 million) was reserved for this project. During the detail design, the client asked for additional requirements and changed some design concepts. The design was carried out in a hurry to meet dead line made by the client. The pressure on the designer to complete the design did not allow proper surveying of the existing underground services in the project lines. The detailed cost estimation of the project just before tendering was R.O. 2 million (USD 5.2 million). The construction work was awarded to the lowest bidder for an amount of R.O. 2,850,000.00 (USD 7,410,000) for a construction period of 360 days. The contract value was larger than the initial and detailed estimate by 190 per cent and 143 per cent respectively. During construction, thirty seven change orders were issued causing the project actual cost to reach about R.O. 3,140,000.00 (USD 8,146,000.000) with a 68.06 per cent construction time overrun. Figure 7 shows the growth of the project budget. As a result of budget adjustment, two planned projects of similar size were delayed. 77.7 per cent of the change orders were due to diversion of existing services, and scope and design changes, while the remaining 22.3 per cent were due to additional works. The basic function of the project as per the function analysis is to provide access to the expressway. The secondary functions included; separate traffic, add lanes, provide services, right of way impact, establish footprint and clear site. The cost of the basic function was 16.4 per cent of the total functions cost (Figure 8). The ratio of

the basic functions cost to the secondary functions cost was 0.19. There are disproportional amount of costs being spend for secondary functions and resulted in less worth to basic functions. This case presents various factors contributed in causing cost and time overruns. The factors are: the unclear client requirements during the feasibility study; design errors due to shortage of time, lack of knowledge of existing underground services, and improper study of the designer works submitted to client for approval. The project was in short of fund, cash flow control; and inadequate site survey.

Table 4. Objectives of the project (Case study 3)

• Mass earthworks. • Construction of 6 km of internal asphalt roads to connect with expressway. • Construction of roundabouts, crush barrier, traffic signs, street lighting, ripraps, box and pipe culverts, road marking etc. • Construction of parking areas and small power substations to serve the road.

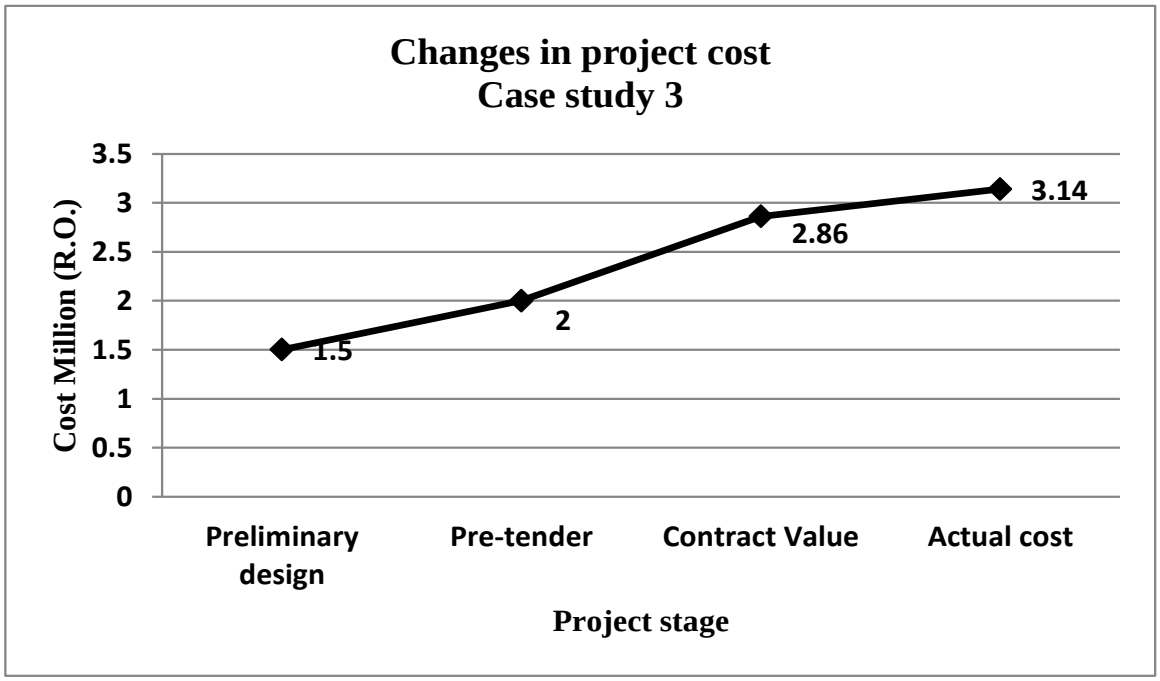

Figure 7: Changes in project budget (Case study 3)

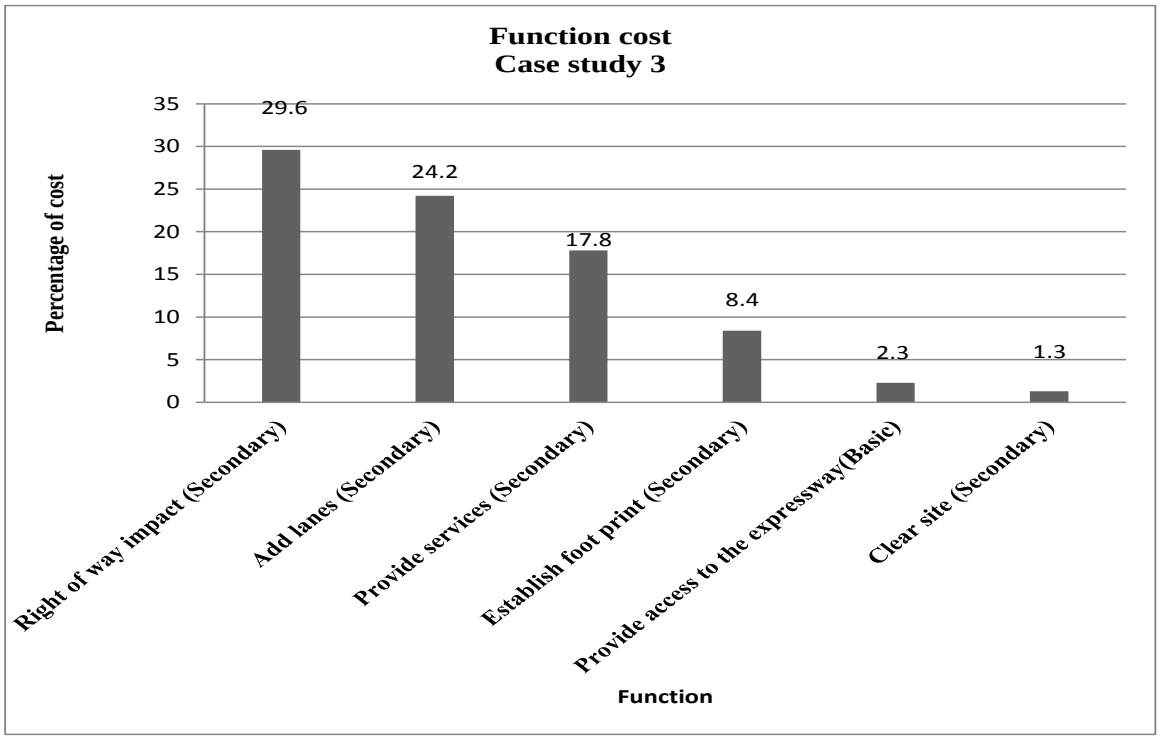

Figure 8: Percentage of functions cost (Case study 3)

D. ***Case study no.4: Fast ferry service project***

The project comprised of construction of fast ferry service facilities. The scope of work included the construction of berthing facilities, link bridges, pontoons, mooring piles, water and sewage networks, custom and immigration buildings, diversion of existing waste and cleans water networks, and internal asphalt roads. The project went through feasibility study stage, concept and design stage, tenders stage, and construction and maintenance stage. Based on experience in previous similar projects and the consultant knowledge, a conceptual budget of R.O. 3,000,000.00 (USD 7.8 million) was allocated for the construction of this project. During the detail design stage, new requirements and services to the concept proposal were added. The detailed cost estimate of the project just before tendering for construction was R.O. 5 million (USD 13 million). The project was awarded to the lowest bidder for R.O. 8,100,000 (USD 21,060,000) including a contingency value of R.O 343,626.228 (USD 893,428.19). The construction period was 420 days. Thirty two change orders were issued to the contractor during the construction stage. The actual cost of the project reached R.O. 9,100,000.000 (USD 23,660.000). This is 303.3 per cent larger than the conceptual cost, 182 per cent larger than the detailed cost estimate just before tendering and 11.3 percent than the contract value. The variations cost was R.O. 1,000,000.00 (USD 2,600,000.00) which is 12.35 per cent of the original contract and larger than the contingency amount for 191.01 per cent. Figure 9 shows the budget growth of the project. The construction time overrun is 21.43 per cent. The changes were classified into two groups. The first group included variations issued due to technical design issues and undefined items in the scope of work. The second group included the variations issued due to additional requirements and changing of project scope of work. The additional works amounted to 48 per cent of the total change order values followed by the scope changes for about 42 per cent. The variations due to design issues and undefined items in the scope of work were 6.7 per cent and 3.3 per cent respectively. Figure 10 shows the

causes of change orders. The project was time overrun for 180 days which is 66.7 per cent of the original planned construction period of 270 days. Based on the function analysis shown in Figure 11, the basic function was to transport people and goods. The secondary functions of the project were to connect and upgrade services, enclose space and prepare site. The cost of the basic function was 26.2 per cent of the project actual cost. The ratio of the basic function to the secondary functions was 0.35.5. This ratio indicates that there is no consensus in costs between the basic functions and secondary functions. The investment in the secondary functions resulted in low worth to basic functions. This reduces the value of the project. It is clear from the four case studies discussed above as shown in Table 5 that the average percentage of scope changes and additional works dominated the causes of change orders issued representing 52.9 and 41.7 per cent respectively. Table 6 shows assessment made at different stages of the projects lives using data collected from records and face to face meetings. It is clear that no project has undergone function analysis, risk analysis, concept analysis, or cost comparison, during feasibility or design stages. 50 per cent of the projects were not included in a strategic plan but were executed as a reaction to immediate need. In all of the four cases studied, there were unplanned requirements introduced during the design stage, mostly by the client, which resulted in cost overruns. The cost overrun started at the design sage and continued until the completion of construction. The average percentage of the budget increase at the design stages was 257.6 per cent whereas in the construction stage, it was 11.4 per cent.

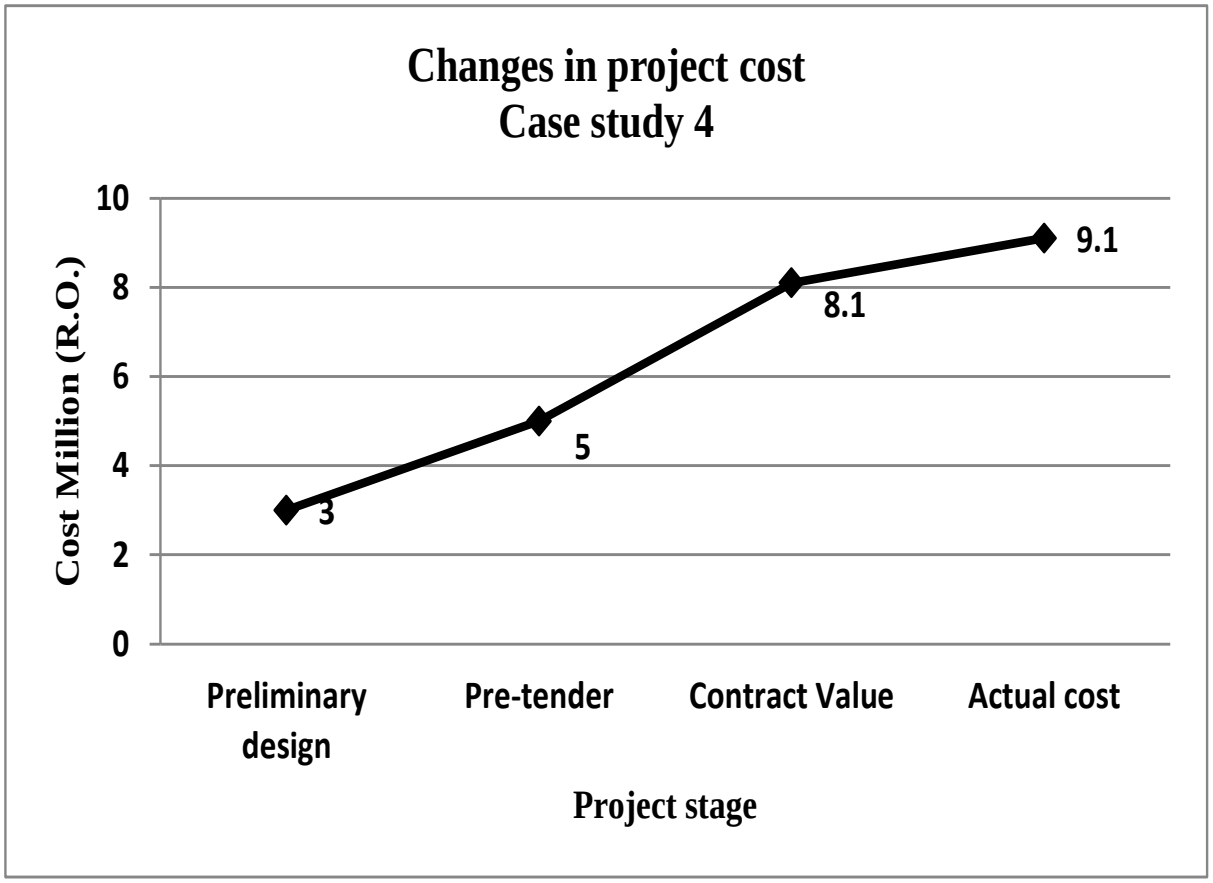

Figure 9: Changes in project budget (Case study 4)

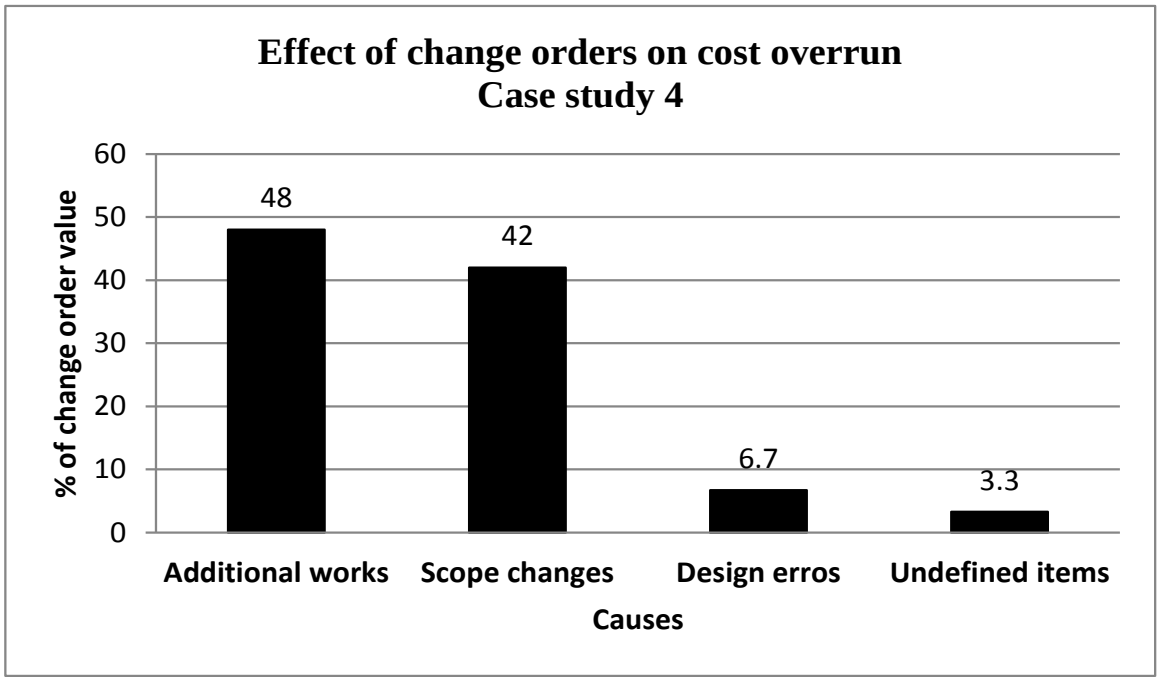

Figure 10: Percentage of change order values (Case study 4)

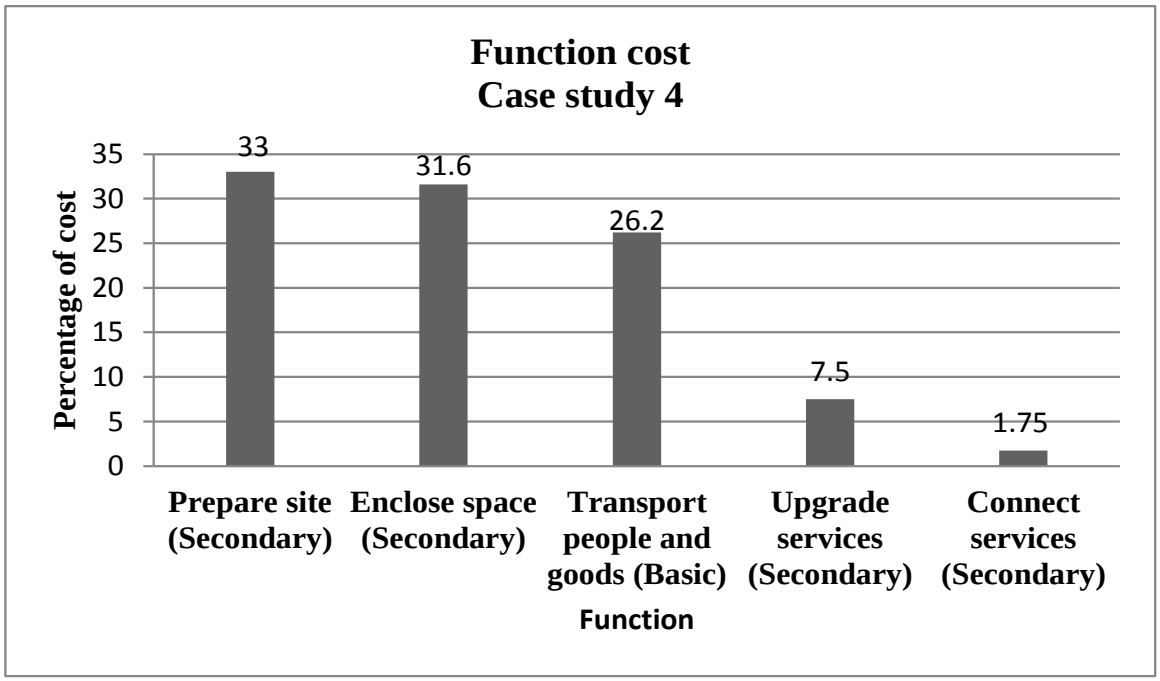

Figure 11: Percentage of functions cost (Case study 4)

Table 5: Values of causes as percentages of contract values of the case studies

Case study No.	Scope changes (%)	Additional works (%)	Undefined items (%)	Design issues (%)
1	31.5	65.1	2.8	0.6
2	60.2	31.3	5.7	2.8
3	77.7	22.3	0	0
4	42	48	3.3	6.7
Average	52.9	41.7	2.95	2.5

Table 6: Case studies life cycle and task assessment carried out at each stage

Cases	Pre-design				Design stage									Tender stage			Construction			
Case study 1	•	•	•	•	•	•		•		•		•		•	•			•	•	•
Case study 2	•	•	•	•	•			•		•		•		•	•		•	•	•	•
Case study 3		•	•	•	•			•		•		•		•	•		•	•	•	•
Case study 4		•		•	•			•		•		•		•	•		•	•	•	•
	Strategic plan	Feasibility study	Conceptual cost estimate	Requirment setting	Requirment analysis	Performance criteria setting	Function setting	Concept selection	Concept analysis	Preliminary cost estimate	Cost comparison	Detailed design	Financial Risk analysis	Bill of Quantities	Detailed cost estimate	Pre-tender analysis	Final financial risk analysis	Scope review	Variation occurance & analysis	Cost overrun	Time overrun
	Pre-breife		Breife		Conceptual design							Detailed design			Tender			Construction			

The face to face meetings also showed that, the lack of or improper information, at three stages of the project life cycle, augmented the problem. The first one is when the client transfers his requirement and project objectives to the consultant to start the design, the second is at end of the design when the consultant presents the tender document to bidders to cast their prices and the last one is when the contractor is awarded the project with unclear items. The first one may allow the consultant to establish his own prospective. The second one causes misunderstanding of the bidder especially if his queries during tendering where not addressed properly. The third one may cause losses to either party, the client or the contractor, due to ambiguities occurred during tendering and may lead to dispute and cost and time overruns. This emphasizes the importance of starting the project design with clear objectives and implementing that in the design. This requires proper study of the client's needs and reviewing it carefully before the design starts. The available budget should be decomposed to basic and secondary functions and make sure to strike a balance between these functions. Table 7 shows percentages of budget increase, time overrun and ratio s of basic to secondary functions.

Table 7: percentages of the budget changes

Case No.	Conceptual cost (R.O.)	Actual cost (R.O.)	Percentage of the cost increase	Time delay (days)	Ratio of the basic function to secondary functions
1.	5,000,000.00	17,200,000.00	244.0	-	0.96
2	20,000,000.00	110,400,000.00	452.0	210	0.24
3	1,500,000.00	3,140,000.00	109.3	248	0.19
4	3,000,000.00	9,100,000.00	203.3	180	0.35
Average			252.15	212.67	0.435

IV. CONCLUDING REMARKS

Based on the analysis of the collected data of 39 projects and the 35 face-to-face discussions made with project managers with emphasize on the four study cases, the following remarks are withdrawn:

- 82 per cent of the studied projects suffered cost overrun with an average of 34.5 percent of the contract values.
- The percentages of positive minimum and maximum cost overruns were 6.5 and 360 respectively.
- With exception to one project, all the projects had contract values less than or equal to R.O. 104,000,000.000 (USD 270,400,000.000).
- The infrastructure and building projects experienced larger cost overrun than the power station projects.
- Changes of scope of works and additional works ordered by the client were found to be the major causes of cost overrun while design errors, change of project location, changes in specification etc. were also found to cause cost overruns but with less extent.
- The average cost overrun of the four case studies was 12.8 per cent of the original contract values and the time overrun was 37.3 per cent of the original total contract time.

- The average percentage of scope changes and additional works, in the four cases studied, dominated the causes of change orders issued representing 52.9 and 41.7 per cent respectively.
- None of studied cases undergone function analysis, risk analysis, concept analysis, or cost comparison, during feasibility or design stages and 50 per cent of the projects were not included in a strategic plan but were executed as a reaction to immediate need.
- The average percentage of the budget increase at the design stages was 257.6 per cent whereas in the construction stage, it was 11.4 per cent.
- Lack of or improper information at different stages of the project worsened the problem.
- 104 change orders were issued during the construction of the four case studies with an average of 26 change order per project. No relation trend was found between the percentages of cost overrun and the number of change order.
- It is essential to study the client needs in detail based on clear strategic plans and implement a proper system for function and cost analysis during the design stage. A function-value analysis will help visualizing the cost of basic and secondary functions.
- The average time overrun for the four case studies was found to 159.5 days/project.
- With exception to one project of the four case studies, the ratio of the basic functions to the secondary functions was found inappropriate with ratios 0.96, 0.24, 0.19, and 0.35 for cases 1, 2, 3 and 4 respectively.
- Most of the changes in the project budget occur during the design stage and therefore is essential to improve the design system and integrate cost control with function performance measurement.

V. REFERENCES

Acharya N. K., Lee Y. D., Im, H. M. (2006), Conflicting Factors in Construction Projects: Korean Perspective. "Journal of Engineering Construction and Architectural Management", 13(6), 543–566.

Akpan, O. P., Igwe, O. (2001), Methodology for Determining Price Variation in Project Execution. "Construction Engineering and Management", ASC, 127(5), 367– 373.

Al-Momani A.H. (2000), Construction delay: A Quantitative Analysis. "International Journal of Project Management" , 18(1), 51–59.

Alnuaimi A. S., Taha R. A., Al-Mohsin M. and Al-Harthi A. (2010), Causes, Effects, Benefits and Remedies of Change Orders on Construction of Public Projects in Oman. "Construction Engineering and Management", ASC, 136 (4), 615 – 622.

Arun, C., and Rao, B. N. (2007), Knowledge Based Decision Support Tool for Duration and Cost Overrun Analysis of Highway Construction projects. "Journal Institution of Engineers India", Part ME Division, 88, 27–33.

Kaming, P., Olomlaiye, P., Holt, G., and Harris, F. (1997), Factors Influencing Construction Time and Cost Overruns on High-Rise Projects in Indonesia. "Construction Management and Economy", 15, 83–94.

Lee J. K. (2008), Cost Overrun and Cause in Korean Social Overhead Capital Projects: Roads, rails, Airports and Ports. Journal of Urban Planning and Development , 134, 59–62.

Perkins, R. A. (2007), Sources of Changes in Design/ Build Contracts for A Governmental Owner. "Management of Engineering and Technology", 5(9), 2148–2153.

Wu C., Hsieh T. and Cheng W. (2005), Statistical Analysis of Causes for Design Change in Highway Construction in Taiwan. "International Journal of Project Management", 23, 554–563.
Al-Zadjali, Z. (2010), A Study on the Causes of Cost Overrun in Telecommunications Projects in the Sultanate of Oman. Msc. Thesis. Department of Electrical and Computer Engineering, College of Engineering Sultan Qaboos University.
Al-Ruqaishi, M. (2011), Causes of Project Schedule Overruns in Oil and Gas Industry in Oman. Msc Thesis. Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University.
Alghaity, R. (2003), Construction Claims in Oman. Msc Thesis. Department of Civil Engineering, School of Engineering, University of Birmingham.
Ambusaidy, S. (2005), Project Risk Management in the Omani Construction Industry. Msc Thesis. School of Mechanical, Aerospace and Civill Engineering, University of Manchester.
Assaf S., Jannadi O. A., and Al-Tamimi A. (2000), Computerized System for Application of Value Engineering Methodology. "Journal of Computing in Civil Engineering", ASCE 14, 206-214.