



MEP SYSTEM INSTALLATION RELATED REWORK CAUSES AND IMPACT ON PROJECT PERFORMANCE; A CASE STUDY OF RIYADH METRO PROJECT SAUDI ARABIAN

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Abstract

Mechanical, Electrical and Plumbing (MEP) system is lifeblood of a building which enhances building quality and functionality. For instance, you are in the most magnificent building of a city, if the air conditioning and lights are taken away you will be left in a dark and a suffocated shell. The application of modern building services has increased installation complexities in construction projects. Consequently, rework during the installation phase has become common and acceptable practice in the construction industry. At MEP system installation phase wrong execution of any activity at the very first attempt causes quality deviations, cost overruns and time delay. The main aim of this research is to investigate occurrence of reworks in MEP installation phase and to identify their impact on project performance. This case study included three main transfer stations of Riyadh Metro Project (RMP) in Saudi Arabia. The questionnaire survey was conducted using probability sampling technique, randomly 130 experienced construction professionals (project managers, site engineers, supervisors, field engineers, quality control and project control engineers) from client, consultant, contractor and sub-contractors. The data analysis was conducted in SPSS (Statistical Package of Social Sciences) and finally, the research result revealed some potential causes of rework which impact the project performance. The causes of reworks such as; improved coordination between design and construction, allocation of qualified MEP engineers, deploying of skilled workers, use of approved design at installation stage and timely submission of inspection requests to the engineer were presented high rank by the construction experts. The research concluded potential triggers of rework as a pathway to guide MEP engineers and construction professionals to enhance performance of forthcoming building projects.

Keywords: Rework, construction, Mechanical, Electrical and Plumbing (MEP), project performance, metro projects.

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1. Introduction

In the world of construction MEP stands for Mechanical, Electrical and Plumbing [1]. MEP system is also known as Building Services System (BSS) it turns the building from empty rooms into comfortable spaces that will be friendly and liveable for the residents. In building projects the MEP system plays a significant role as the blood, nerves and digestive system in the human body [2]. In mega building projects MEP system installation takes 40-50% of total construction time [3]. Moreover, the time required to complete MEP testing in industrial building reached to 26 % of project total duration [4]. In modern building projects the cost of MEP has reached to 25-40% of the project total cost [5]. The percentage of cost and time is increasing frequently due to advancements in building technology and services.

MEP system is complex in design and requires specialities for design and installation at site to avoid reworks. Fixing of defective components which discovered during testing results 12% cost of respective system installation [6]. Usually, in design stage architecture and structure drawings are developed first and due to deficiency of MEP knowledge structure engineers and architects left limited space for MEP equipment and services [7]. Rework is one of the main reasons for time and cost overruns that impact the project success.

Therefore, the Engineering Procurement and Construction (EPC) industry facing challenges in delivering building projects on time and within a budget [8]. The performance of construction projects can be elevated with the implementation of rework moderation strategies [9]. Considering the necessity for construction professionals to mitigate reworks by transformation of tacit information from the construction field to the body of

knowledge. The current study has been carried out to demonstrate the possibility of reducing reworks resulting from MEP installation during the construction phase of the RMP. A case study conducted in three main stations 1A1, 1B3 and 1F7 of line-1 in RMP.

2. Literature Review

In 21st century buildings are becoming more complex and the complication rising each year due to new technologies and increasing demands of building owners [10]. The MEP system become an essential discipline in construction projects. MEP system consists of several sub-systems integrated together which alters the building into a comfortable, friendly and safe place for its residents [11].

2.1 Application of MEP system in construction projects

The construction industry is divided into five different divisions. This distinction is based on the nature and application of project [12]. The five common divisions of construction projects are:

- i. Residential Building Construction
- ii. Commercial Building Construction
- iii. Infrastructure and heavy construction
- iv. Industrial Building Construction
- v. Institutional Building Construction

Every building consists of MEP services and without it the building is like a human without skeleton system. Whether in a multi-story building, healthcare facility, institutional building, or a metro station the MEP system transforms buildings from empty rooms into comfortable space [13]. MEP system is mandatory in residential, commercial, industrial and institutional buildings, in modern building projects MEP system make them more attractive living spaces for building residents [14]. The fundamental application of MEP sub-

systems in buildings project are air conditioning, water supply, power supply, lighting, fire protection and alarm, drainage and sewage services and building management system etc. [2].

2.2 Review of MEP system in Riyadh metro stations

According to General Authority for Statistics (2018) Riyadh is the biggest city in Saudi Arabia and one of the largest cities in the Middle East with a population of around 7.6 million and expected to grow up to 10 million by the year 2025. Considering the growth in population and traffic Saudi Arabian government has invested more than 26 billion US\$ to build the largest urban transit system in capital city of Riyadh. The metro project is under construction since from April 2014 and is expected to be operational in the coming

years [15] the revised plan for completion is in 2024.

The experts in public transportation around the world are interested to improve the service quality of transportation [16]. In contrast to conventional building projects, the design life of RMP assumed as 100 years and accordingly the metro stations are fully furnished with modern MEP system to accommodate the future population. The research area included three main transfer stations of line 1 at RMP named 1A1, 1B3 and 1F7. Typical scope of the MEP services is almost uniform in main stations but some of the sub-systems differ conditionally due to limitations of the space in false ceiling; such as ducts, pipes and equipment clearance in iconic stations. Figure 2.1 shows the MEP sub-systems classification applied in main stations of RMP.

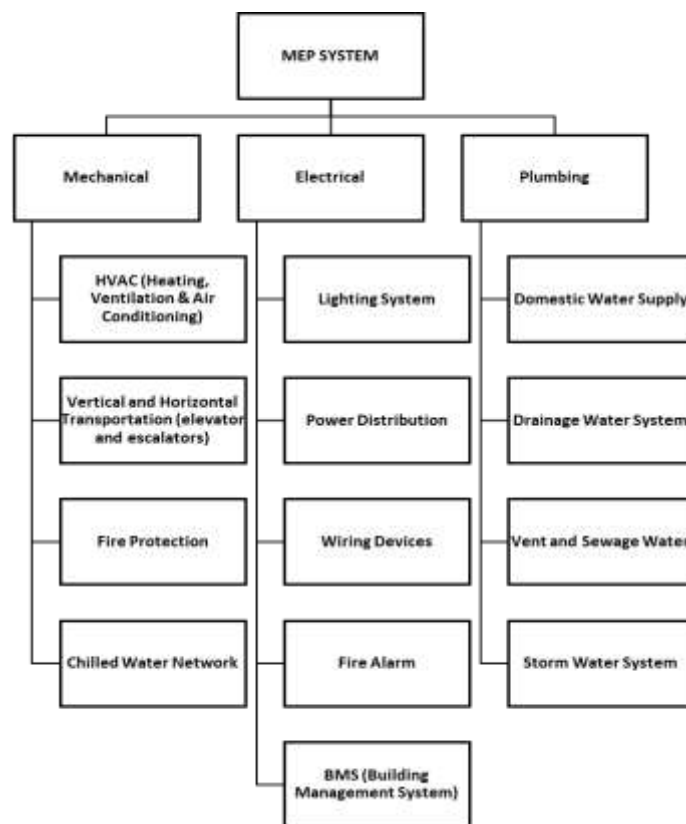


Figure 2.1: Classification of MEP system and sub-systems

2.2.1 Mechanical System

Mechanical is considered as the heart of MEP system. In mega project mechanical

system reached up to 60% of total MEP scope. One of the fundamental part of mechanical is HVAC (Heating ventilation

Air Conditioning) accountable for controlling indoor environment [17]. Buildings use many types of mechanical sub-systems but major part of mechanical work in residential and commercial buildings deal with HVAC. The space heating, ventilation and air conditioning systems maintains desired environmental conditions inside buildings.

Building temperature, humidity and ventilation control systems are designed and installed by mechanical engineers. In metro stations of RMP every floor holds mechanical rooms and shafts which are designated for equipment such as FCU (Fan Coil Units), AHU's (Air Handling Unit), Pumps, elevators, escalators and mechanical piping. The chillers are installed in cooling yard on roof levels of stations kept open to sky as per recommendation of manufacturer to enhance efficiency of the plant. The exposed to public parts of mechanical in stations are fire hose cabinet, sprinklers, grills and diffusers [4].

2.2.2 Electrical System

Electrical is also one of the core segments of MEP engineering. Electric current is essential for building services like blood for the human body [2]. The main equipment of electrical system in buildings are panels, containments (conduits, cable trays and ladders), lighting fixtures, switches and sockets, power distribution boards, wiring devices and earthing protection[18]. The large scale and mega projects like metro stations mostly designed and installed according to international electrical codes and standards to meet customer satisfaction [19].

In RMP the design and installation of electrical systems applied based on local and international codes as per employer requirements. The electrical devices installed in metro stations for smooth operation of the facility [20] the electrical system consists of various logical equipment connected by various size

cables and wires for flow of current and feed lights and equipment for successive operation of rapid transit.

2.2.3 Plumbing System

In buildings projects plumbing system is responsible for distribution, storage and pumping cold and hot water from reservoirs to plumbing fixtures through pipes [21]. According to research buildings consume 25% of global water and 40% of global resources [22]. Thus plumbing system for effective management of water in buildings is an important sub-system of MEP to reduce global waste and increase recycling to achieve UN sustainable development goals (SDG).

In DUS (Deep Underground Station) plumbing becomes more challenging especially when it comes to drain and supply water from 45m deep underground platforms and pits of train tunnels. Building sewerage consists of plumbing fixtures; soil, waste and vent pipes with combination of floor drains, scupper drains and cleanout plugs on floor and roof for collection of storm water by horizontal and riser pipes. The local building codes (or Saudi Building Codes) provided specifications for design and installation of plumbing system according to weather parameters of Riyadh city.

2.3 MEP system associated reworks in construction

Due to several challenges the building construction sector is facing poor performance in terms of schedule, cost and quality [23]. During construction several problems in MEP system installation affect project performance. Many MEP services in building projects passes from concrete shafts or fit-in ceilings and shafts space kept by architectural and structural designs. Hence spaces are often restricted in size due to a lack of MEP system awareness by various disciplines.

The limited spaces cause MEP system installation and testing issues. The involvement of MEP engineers in early design may prevent such issues and will allow smooth installation of system in the facility during the life cycle of the project [10]. Various factors have the potential to interrupt construction site work progress and to impact workers productivity but rework impact project performance with high magnitude [24].

Most building projects are exposed to high risk due to structural complexity and application of latest MEP systems. The complication of work due to HVAC, fire alarm, drainage, elevators, fire protection and clean agents, power and lighting in rooms as per client increasing with time. Many mitigation strategies were explored for smooth construction to avoid reworks which will manage costs over runs and time delay issues in projects [25].

Building information modelling (BIM) has found one of the approaches which have demonstrated its advantages in improving mechanical, electrical and plumbing (MEP) layout in the design stage. Unfortunately, BIM applications normally stop prior to construction stage and MEP layout design may no longer fit properly during the installation process when there are as-built deviations between structures and MEP installation while execution at field [26].

Large scale construction projects still have issues for supporting cooperative construction management due to generation gap between construction industry and modern technology which cause issues for installation of services and affect the project management at site [27].

2.3.1 Rework identification

Rework is one of the most common problems in construction. The rework definition has been elaborated by many researchers such as; “non-conformance”, “deviation” and “quality failure”. Rework is unnecessary effort of re-doing a process

or activity which incorrectly completed for the first time [28]. According to the Construction Industry Institute (CII 2001) rework is described as activity at site that performed more than once or an activity that eliminate the earlier installation in the field [29].

According to International Journal of Sustainable Construction Engineering & Technology (IJSCT) published by Universiti Tun Hussein Onn Malaysia (UTHM) rework is process in which an item get approve as per requirements by additional efforts after completion more than once due to non-conformance with quality standards [30]. Rework is modifying the product according to the customer or engineer's specifications when the product or service does not meet customer requirements. Therefore, the rework contributes to waste and value losses in building design and construction [29].

2.3.2 Causes of rework

The construction industry in general is still struggling with inefficiency issues in the implementation of its construction procedures. Rework and causes differ in construction due to unique nature of each project's budget, schedule and availability of resources [31]. Rework can mainly result from four primary sources like error, omission, change and damage during the design and construction [29]. Some of the factors related to reworks identified by researchers during installation of the MEP system are listed below:

- i. Inadequate experience of MEP system installation
- ii. Poor coordination between design and construction
- iii. Lack of coordination between interlinked disciplines
- iv. Delay in approval of design
- v. Material size and delivery issues
- vi. Change of site condition

- vii. Failure in installation and construction supervision
- viii. MEP installation damaged by civil works
- ix. Cash flow issues in the project
- x. Lack of workmanship
- xi. Disregard the sequence of construction

Several issues become root cause of reworks in construction stage of projects [32]. Any rework cause arises at initiation phase will continues through project stages until it reaches to final testing [33]. The cause and effect (Fishbone) diagram in Figure 2.2 shown the common rework causes.

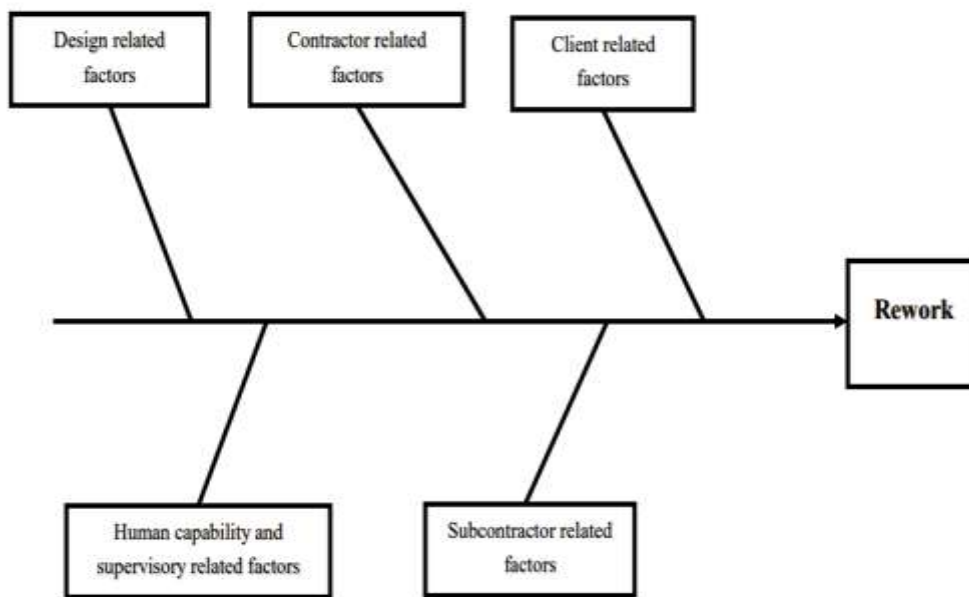


Figure 2.2: Fishbone diagram of rework root causes [33]

Moreover, some frequent rework causes observed during installation of the MEP system in Riyadh metro stations were; work resume prior to the approved drawings, shortage of skilled workers and qualified MEP engineers, failure to protect the completed works, delays in submission of inspection requests for work approval, change in design due to clashing with MEP services installation, lack of collaboration between equipment manufacturer and design selection, insufficient MEP qualified managers and engineers, communication and coordination issues among various disciplines, construction planning issues and unfeasible site condition for installation of MEP system.

To maintain the project acceptable performance it is not only be constructed as per specified quality but also to be delivered within specific time and cost [33] which can be achieved by lowering the causes of reworks by identifying them in the initial stage.

2.4 Impact of reworks on project performance

Rework is a global problem in construction industry. To conquer this matter a collective effort from construction professionals from industry is required to mitigate its adverse consequences [34]. Rework in construction projects has both direct and indirect impacts on project performance [33]. The rework accounted for around 4.4% percent of the overall

project cost and required an additional 7% of total project time [35]. In addition, the direct effects in terms of time, cost and quality on specific activities, the rework occurrences often have indirect effects such as stress, loss of trust, low profit and de-motivation on individual or group.

2.4.1 Impact of rework on cost

Several studies have investigated the cost of rework in the construction industry. According to Construction Industry Institute CII (2015) rework accounts for up to 20% of project total cost. The rework for industrial, residential and commercial buildings range from 2% to 6% from the contract value [36] also the major factors contributing to project cost overruns is rework [37]. The cost overrun is a regular incident associated with almost every type of construction project [33].

In construction the costs reduction which involve during the design and planning stage prior to the project execution. There is a strong positive and significant relationship between the cost of rework and the project cost and has substantial relationships between the costs of rework and project completion time [38]. Research conducted in Pakistan explored that average cost of rework in building project reached up to 5% of the contracts total cost [39]. Moreover, a study conducted on building projects in Malaysia revealed that the cost of rework normal ranged from 3-6% of the project cost and the performance impact due to rework reached from 5-10% for mega projects in Malaysian construction industry [40].

2.4.2 Impact of rework on time

Productivity of construction projects is regarded as one of the frequently discussed topics in construction industry [24]. Hence, time delay in construction industry is an old issue that impact the image of whole industry [41]. The construction industry is struggling with project management issues and the most notable

of which are schedule delays which can be caused by number of variables including reworks [42]. Rework leads to a significant delay in project time according to a study by considering random projects executed in the last 20 years most of the project were delivered late, means schedule delays occurred in all projects [43].

The research published in IJSCET published in UTHM Malaysia time and cost overrun are linked which causing time delay issues in most circumstances [44]. Another study found out that rework increases the cost by 3-5% and schedule delay by 10–70% for different work categories for a residential and commercial project in Saudi Arabia [45]. MEP system installation rework begins during the execution stage of building projects and if not swiftly corrected may progress to the testing stage and finally it will impact the project delivery schedule.

2.4.3 Impact of rework on quality

Reworks and quality performance has a cooperative relationship. Poor quality occurs in more than 80% of building projects [46]. Effective quality significantly increases the project performance and aids in completion the project on time and equally effect the budget which is directly related to rework at project site. According to International Federation of Consulting Engineers (IFCE) any lack of quality in construction is arrive due to poor or non-sustainable workmanship later this creates reworks in the project.

Researcher asserted that to improve quality there is a need to understand the root causes of reworks. The basic reason for its existence or the set of conditions that stimulate its occurrence [33]. Several studies have consistently established that design and engineering stage of a project rework or quality issues emerge and impact project performance [47]. MEP system is a dynamic system which continuously operate after installation if

reworks have identified in design and installation stage the project quality failure will also impact the maintenance performance in life cycle of project.

3. Research Methodology

The quantitative technique was applied in this research which comprised distributing well-structured self-explanatory questionnaires to the respondents. To obtain significant result of the questionnaire was forwarded to construction professionals from client, consultant and contractor companies working in RMP. Total 130 respondents were selected and feedback was received from 102 respondents.

In first stage the literature review conducted about MEP system in building projects and metro stations to identify the research gap. In second stage, implemented quantitative approach, a questionnaire design was developed to achieve the research objectives. In third stage, pilot study was carried out to check the feasibility and clarity of questionnaire by taking open suggestions from construction professionals prior to final

field survey. In fourth stage, after pilot test final survey was conducted for data collection. Furthermore, in the fourth stage, rework causes during the installation of the MEP were categorised into three sub-groups according to project management triangle i.e., quality, cost and time and feedback was analysed in SPSS V-26. In the fifth stage research results were revealed according to the objectives. Finally, in sixth stage conclusions were drawn and suggestions for MEP engineers and construction professionals were given to improve the performance of in upcoming projects.

3.1 Questionnaire Design

The questionnaire design composed of two main parts. The first part intended to collect general information about the respondent's qualification level, field of specialization, the nature of their company, project subsection, and work experience. The second part include three subsections about the causes of reworks during installation of MEP system in metro stations. The subsections identify the causes of rework and its impact on quality, cost and time based on a five-point Likert scale as shown in Table 3.1.

Table 3.1: Five Point Likert scale [38]

| Numerical Value | Response Category (Scale) |
|-----------------|---------------------------|
| 1 | Very Low Impact |
| 2 | Low Impact |
| 3 | Medium Impact |
| 4 | High Impact |
| 5 | Very High Impact |

The reliability test was conducted on final questionnaires using Cronbach's alpha method [29]. Higher the alpha values are more desirable (range from 0 to 1) if the value reached greater than 0.70 considered as a reliable measure [43]. After

conducting the reliability test for the questionnaire in SPSS the Cronbach's alpha (α) value evaluated $\alpha = 0.91$, which was an excellent reliability scale. The reliability test result is shown in Table 3.2.

Table 3.2: Reliability Test of Questionnaire (SPSS- V26)

| Cronbach's Alpha | No of Items |
|------------------|-------------|
|------------------|-------------|

| | |
|------|----|
| 0.91 | 45 |
|------|----|

3.2 Population and sampling

Sampling is the process of choosing a sample from the defined population [48]. The sample size for this study was

calculated 130 which was derived by using area population formula. The confidence level considered as 95% shown in below equation (Mc Naughton & Cowell, 2018):

$$S = \frac{X^2 NP (1 - P)}{d^2 (N - 1) + X^2 P (1 - P)}$$

Where:

S = sample size from the finite population (Method: probability random sample)

X = based on a confidence level of 1.96 for 95% confidence was used for this study

d = Precision desired, expressed as a decimal (i.e., 0.05 for 5% used for this study)

P = Estimated variance in Population as a decimal (i.e., 0.5 for this study)

N= total number of populations (N= 195 for this study)

$$S = \frac{(1.96)^2 \times 195 \times 0.5 (1-0.5)}{(0.05)^2 \times (195-1) + (1.96)^2 \times 0.5 (1-0.5)} \approx 130$$

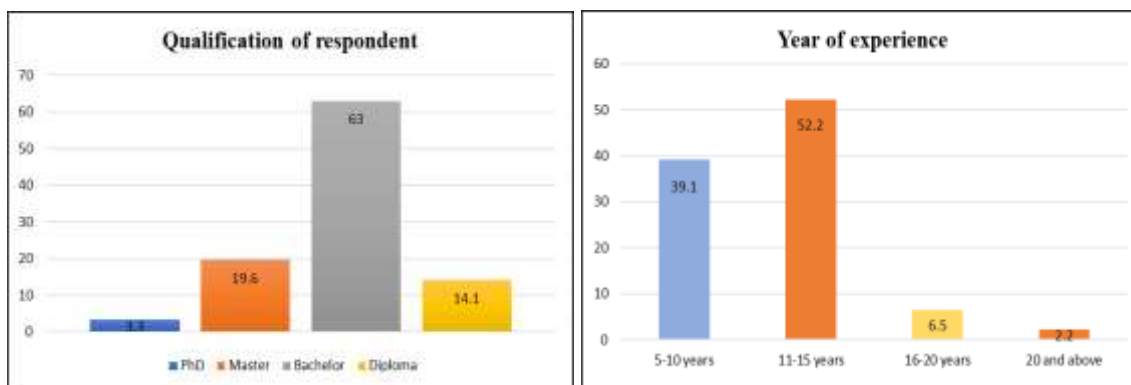
4. Results & Discussions

The research revealed the objectives by identifying the potential causes of reworks associated with MEP system installation and their impact on overall project performance.

acceptability of the research results. As per selected sample total 130 questionnaire survey forms were distributed to construction professionals working in three main stations of RMP and 102 feedback were received. The Figure 4.1 shows demographic information of respondents from clients, consultants, contractors and subcontractor companies employed in main stations of RMP.

4.1 Demographics of Respondent's

The demographics of the respondents is an important factor for the accuracy and



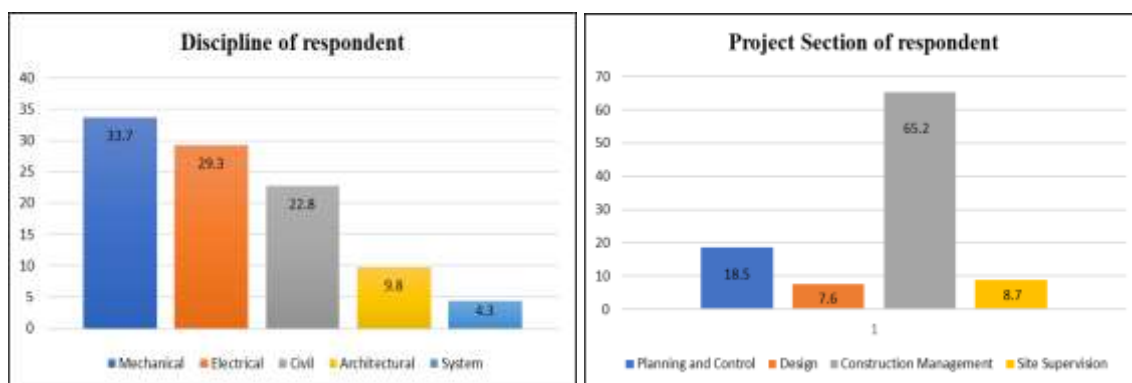


Figure 4.1: Demographic information of respondents

4.2 MEP system associated rework impact on project

This section elucidates the result obtained after analysis of questionnaire in SPSS V26 as specified in the research methodology. The rework causes and impact on project performance during the installation of the MEP system in metro stations were further classified into quality, time (or schedule), and cost. Each group had a unique self-explanatory

rework causes identified in installation of MEP system which influence and impact the project's overall performance.

4.2.1 Rework impact on project quality

This section comprises of 15 rework causes observed during the installation of the MEP system in Riyadh Metro transfer stations; the results of rework impact on project quality is illustrated in Table 4.1

Table 4.1: Rework causes and impact on Project Quality

| S/ No. | Cause of Rework | Mean | Std. Deviation | Impact Level |
|--------|---------------------------------------------------------------------------|------|----------------|--------------|
| 1. | Non-compliance with specifications and standards | 4.10 | 0.76 | High |
| 2. | Poor coordination between the design and construction team | 4.04 | 0.81 | High |
| 3. | Poor workmanship | 4.02 | 0.59 | High |
| 4. | Lack of knowledge and experience of project staff | 3.94 | 0.83 | Medium |
| 5. | Poor communication among different project stakeholders | 3.91 | 0.86 | Medium |
| 6. | Shortage of skilled workers | 3.79 | 0.65 | Medium |
| 7. | Work resume prior to the approved drawings | 3.78 | 0.92 | Medium |
| 8. | Fast-tracking and crushing of activities due to limited time | 3.71 | 0.61 | Medium |
| 9. | Negligence in taking clearance from Civil/ Arch before MEP installation | 3.68 | 1.02 | Medium |
| 10. | Use of low-grade construction materials | 3.58 | 0.92 | Medium |
| 11. | Lack of collaboration between equipment manufacturer and design selection | 3.51 | 0.95 | Medium |

| | | | | |
|-----|---------------------------------------------------------------|------|------|--------|
| 12. | Over-design results in quality issues | 3.48 | 0.85 | Medium |
| 13. | Failure to protect the completed works | 3.23 | 0.83 | Medium |
| 14. | Delays in submission of inspection requests for work approval | 3.17 | 1.13 | Medium |
| 15. | Disregarding the sequence of construction | 3.10 | 0.68 | Medium |

The results in Table 4.7 revealed that 3 causes of reworks, “Non-compliance with specifications and standards”, “Poor coordination between the design and construction team” and “poor workmanship” were given high impact on project quality by the respondents with a mean value greater than 4. Moreover, remaining causes of rework had a medium

impact on project quality with mean scale value greater than 3.

4.2.2 Rework impact on project cost

This section is composed of 15 rework factors that influence cost performance during the installation of the MEP system in Riyadh Metro transfer stations; the results of rework impact on project cost are demonstrated in Table 4.2 below:

Table 4.2: Rework causes and impact on Project Cost

| S/ No. | Cause of Rework | Mean | Std. Deviation | Impact Level |
|--------|-----------------------------------------------------------------|------|----------------|--------------|
| 1. | Poor cost estimation for construction work package | 4.09 | .346 | High |
| 2. | Change in design on client request after work completion | 4.03 | 1.03 | High |
| 3. | Incomplete design during installation works at the site | 4.01 | .744 | High |
| 4. | Change in design due to clashing with MEP services installation | 3.80 | .986 | Medium |
| 5. | Concrete chipping due to equipment size issues | 3.60 | .610 | Medium |
| 6. | Conflict of interest between project stakeholders | 3.52 | .762 | Medium |
| 7. | Missing openings for piping and HVAC duct in floor/walls | 3.50 | 1.01 | Medium |
| 8. | Unfeasible site condition for installation of MEP system | 3.46 | 1.02 | Medium |
| 9. | MEP material costs escalated in the market | 3.45 | .732 | Medium |
| 10. | Changes asked by the Engineer for quality control | 3.43 | .730 | Medium |
| 11. | Overdesign due to lack of construction experience | 3.15 | 1.04 | Medium |
| 12. | Repair of damage caused by another subcontractor | 3.11 | .958 | Medium |
| 13. | Fast-tracking of activities for schedule compression | 2.65 | .965 | Low |

| | | | | |
|-----|-------------------------------------------------------------------|------|------|-----|
| 14. | Cost variation requested by the contractor due to Site limitation | 2.57 | 1.00 | Low |
| 15. | Conflicts within the project team members | 2.47 | .777 | Low |

The respondents agreed on 2 causes of reworks “Poor cost estimation for construction work package”, “Change in design on client request after work completion” and “Incomplete design during installation works at the site” has a high impact on project cost with mean scale greater than 4 and rest causes have medium and low impact.

4.2.3 Rework impact on project time

According to the construction professionals employed in RMP, this group comprises 15 rework causes related to MEP installation in metro stations and its impact on project time. The results of rework impact on project schedule or time are demonstrated in Table 4.3 below:

Table 4.3: MEP system installation-related reworks impact on Time

| S/ No. | Cause of Rework | Mean | Std. Deviation | Impact Level |
|--------|----------------------------------------------------------------------|------|----------------|--------------|
| 1. | Payment issues or delays in monthly progress claims | 4.08 | .968 | High |
| 2. | Delay in submission of shop drawings for review/ approval | 4.01 | .977 | High |
| 3. | Delay in delivery of the materials by supplier | 3.95 | .572 | Medium |
| 4. | Poor coordination between design and construction | 3.82 | .585 | Medium |
| 5. | Inefficient selection of the subcontractor | 3.78 | .723 | Medium |
| 6. | Effect of uncontrolled causes such as pandemic conditions | 3.77 | .961 | Medium |
| 7. | Failure in project construction planning (construction stage) | 3.64 | .688 | Medium |
| 8. | Strikes by workers due to wages and payments | 3.59 | .914 | Medium |
| 9. | Shortage of skilled labour required to complete tasks | 3.55 | .731 | Medium |
| 10. | Logical dependencies in phase of MEP installations | 3.44 | .856 | Medium |
| 11. | Area not released by Civil/ Arch for MEP installation | 3.39 | 1.27 | Medium |
| 12. | A lengthy procedure of change requests and approvals | 3.11 | .887 | Medium |
| 13. | Lack of using advanced construction equipment | 2.92 | .683 | Low |
| 14. | Acts of God/Force Major i.e., weather conditions, summer, storm etc. | 2.86 | 1.11 | Low |
| 15. | Poor site conditions, such as water, electricity and food | 2.72 | .927 | Low |

The respondents agreed on 2 causes of reworks “Payment issues or delays in monthly progress claims” (4.08) and “Delay in submission of shop drawings for review/ approval” (4.01) has a high impact on project time delay with mean scale greater than 4 and rest causes have medium and low impact.

4.2.4 Overall Impact on Project Performance

The respondents agreed on the rework “impact on quality” during the installation

of the MEP system in metro stations is extreme with a mean value of 3.45 and was ranked first. The “impact on time” with a mean of 3.37 was ranked as the second, “impact on cost” with mean 3.28 was ranked as third cause to impact overall project performance. The figure 4.2 represents the graphical version of reworks impact on project performance of project (quality, time cost and scope).

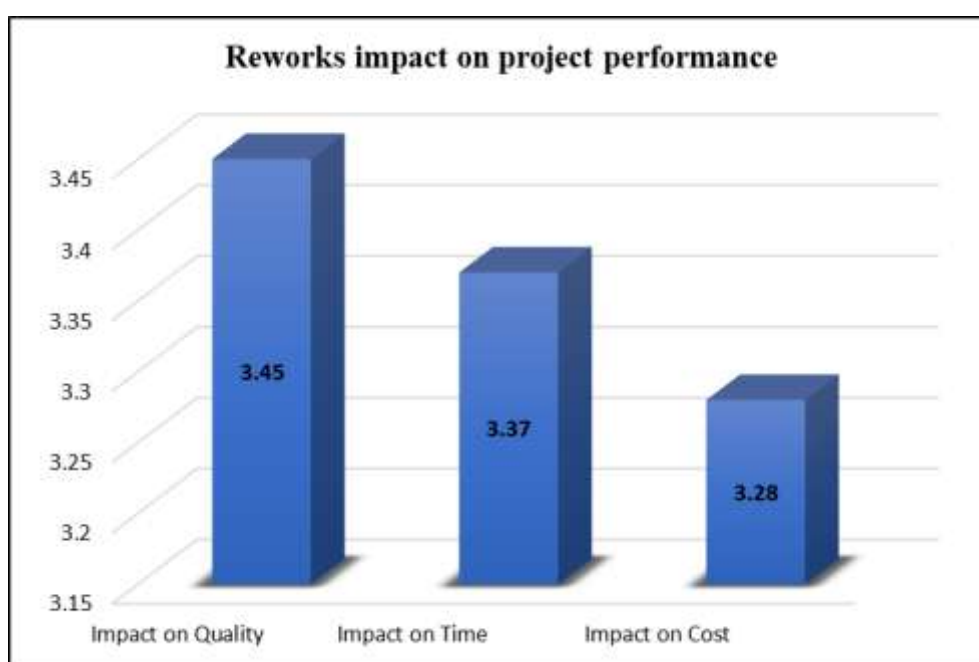


Figure 4.2: Reworks impact on project performance

The respondents agreed on the rework “impact on quality” during the installation of the MEP system in metro stations to be extreme as compared to its “impact on time” and “impact on cost”. Therefore the reworks in overall affect the project performance.

5. Conclusion And Recommendations

The first objective of this research revealed causes of rework in installation of MEP system in main stations at RMP. The second objective of this research revealed the impact of reworks on project

performance. According to construction professionals, payment issues or delays in monthly progress claims and delays in submission of shop drawings for review/ approval are the high potential rework root causes with a high impact on time delay issues in project.

The study evident that overall rework impact in MEP installation at metro stations ranked the “impact on quality” as first, “impact on time” as second and “impact on cost” as last. The result also provides some effective policies for MEP engineers and construction professionals to install MEP systems effectively in

coordination with civil and architecture works. Finally, the research advises recommendations listed below to improve overall performance of the project:

- i. It was evident from the findings that non-compliance with specifications and standards causes reworks in MEP system installation. Therefore, site engineers are advised to follow the project specifications and relevant international standards to mitigate rework.
- ii. The respondents suggested to improve coordination and communication between construction and design to avoid reworks. Relevant technical coordinator contributes in reducing the conflict and rework issues in project.
- iii. Companies are advised to hire qualified and experienced MEP engineers as building services are more technical in depth. Therefore, only experienced engineers and workers should execute work.
- iv. In modern projects MEP system cost reached up to 20-30 % of the project total cost and more than 25% of projects overall duration; therefore, to avoid reworks and improve projects performance the Client, Consultant and Contractor companies are advised to deploy MEP construction managers in hierarchy to lead respective MEP engineers/staff.
- v. Construction professionals agreed that incomplete design during installation works at project site initiate reworks. This can be avoided by providing an approved drawing construction team.
- vi. Respondents agreed that delays in the submission of inspection and testing for the Consultant /Engineer impact rework. Hence, the contractor may submit on-time submit inspection request to the engineer.
- vii. Most Site engineers agreed that the structure wall, floor, false ceilings and roof openings for services, i.e., pipes, ducts and containment, were missed due to poor coordination. Therefore, during civil

works taking MEP clearance may prevent reworks.

- viii. Most Mechanical and Electrical engineers agreed to verify manufacturer recommendations prior to installation of MEP equipment (i.e., chiller, pump, panels etc).

Rework has been established as a major factor for construction project quality, cost and time overruns. Therefore, project participants should be alert in addition, have good foresight in identifying rework triggers and mitigate them before impact rise in installation of the MEP system in construction projects.

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