Performance Evaluation of Maintenance contractor, A case study of Elevator.

FINAL YEAR PROJECT UG2018

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ABSTRACT

The major goal of this project is to do research into elevator maintenance issues. This study covers the evolution of elevators, including their history, definitions, and commonly used elevator concepts. Elevators are currently an important part of thousands of people's daily lives, and they will play a big role in the future of urbanization as population density rises and real estate prices fall. Elevators not only provide convenient vertical mobility, but they also play a significant role in providing accessibility for individuals with disabilities, thus their safe and reliable operation is critical. This thesis examines elevator maintenance and safety practices across the country, as well as a study of several elevator-related mishaps in order to recommend safety measures. Modern elevators are very safe in general, but poorly maintained systems, passenger safety vulnerabilities, incomprehensive work instructions, negligence and lack of proper safety protocols still cause several accidents every year. The engineering parameters related to elevator safety such as rated load, rated velocity, brakes, and safety gears are also explored, and a brief study is done about elevator maintenance.

DEDICATION

We are dedicating our efforts to our Supervisor and our families for always being there for us to help.

ACKNOWLEDGEMENT

We would like to thank Dr. Umer Zubair for his advice, mentorship, assistance, and continued support while working on this thesis. His constant support helped us to reach our destination. He helped us in reading different RFPs and finding factors from them. In addition, we are indebted to NUST and particularly the NUST Institute of Civil Engineering (NICE) for helping us in our project. The experience here was very great and they taught us most of the things we learned and wrote in this report. We couldn't complete this thesis without the information provided by respondents. Special Thanks to Dr. Umer Zubair for helping us proofread and finalized this final draft.

LIST OF ACRONYMS

LIM	Linear Induction Motor
RFP	Request For proposal
RII	Relative Importance Index
SD	Standard Deviation
AM	Arithmetic Mean

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CHAPTER 1

1.1 INTRODUCTION

1.1.1History:

Elevators have long been thought of as a mode of vertical transportation. In his book Elevator Mechanical Design, Lubomir Janovsky defines an elevator as "a permanent lifting equipment serving two or more landing levels, including a car for transportation of passengers and/or other loads, running at least partially between rigid guides either vertical or inclined by less than 15 degrees, running at least partially among rigid guides either vertical or inclined by less than 15 degrees." (L. Janovsky, Elevator Mechanical Design, 2nd ed. Ellis Horwood Limited, 1993.)

There are currently prototype elevators that can travel both horizontally and vertically. Despite the fact that most of them are not commercially produced, owing to a lack of compliance with specific safety laws around the world, recent technological advancements have allowed engineers to broaden the definition of elevators. ThyssenKrupp, for example, has recently developed MULTI, a new rope-free elevator system that can travel vertically as well as sideways. (Thyssenkrupp Elevator AG, MULTI, [Online], Available: https://multi.thyssenkrupp-elevator.com/)

The following definition of Elevator is the easiest approach to avoid confusion when defining an elevator for literary purposes.

Permanent hoisting and lowering mechanism with a car or platform moving vertically in guides and serving two or more levels of a structure is referred to as an elevator. Conveyors, tiering or piling machines, material hoists, skip or furnace hoists, wharf ramps, lift bridges, car lifts, and dumpers are not included in this definition. (Occupational Safety and Health Administration (OSHA), Code of Federal Regulations, U.S. General Services Administration, National Archives and Records Service, Office of the Federal Register, 31 December 2008, [Online], Available:

https://play.google.com/store/books/details?id=NiUsk12npwC&source=ge-web-app,)

Elevators will surely play a significant role in the development of technology and urbanization in the future. In Pakistan, the scarcity of real estate land for an expanding population density is already visible, indicating that buildings will likely grow vertically rather than spread horizontally in the future. As a result, elevators as a mode of transportation will become as common in the future as automobiles are today. As we try to maintain the safety standards for a constantly expanding technology, this also means that elevator design, manufacturing, and maintenance require rigorous engineering.

Even though elevators are a common sight in Pakistan, there is a scarcity of knowledge on how they work and how to ensure their safety. This is due to a lack of correct documentation and agencies' reluctance to share information about how they work and how to ensure their safety. Elevator breakdowns and damages are still regular, and while serious injuries are uncommon, elevator mishaps can be frightening and serve as a reminder of how important elevator safety and maintenance are. Elevators have become quite safe thanks to modern technology, however, there are still some ancient buildings with antique elevators that must be maintained. While we convert to contemporary elevators, we must continue to maintain and manufacture parts for these older elevators. As a result, publications and documentation of design specifications and elevator maintenance standards are necessary for various agencies to have over time.

1.1.2Design Development of Elevators

Manually operated windlasses, animal-powered hoists, shaft ways discovered in ancient Roman ruins, and other vertical movement systems based on the simple machine - the pulley - were the earliest versions of elevators. It's even possible to argue that elevators were discovered at the same time as pulleys. Baskets dragged by a pulley and rope, propelled by a windlass and labor, are still used to vertically move people in hilly terrain such as Tibet.

Because the rope was made of fiber and there was no fail-safe mechanism in case the rope broke, steam-driven hoists were largely utilized for material transportation in the early nineteenth century and were disastrous when used for people.(G.R. Strakosch, The Vertical Transportation Handbook, 3rd ed. John Wiley & Sons, Inc., 1998).

Modern elevators are more or less defined by a system that prevents the carriage from falling if the linkage or lifting means fail. When Elisha Graves Otis was working in a factory in 1853, he wondered how he could clean up the place better by shifting the old debris to the upper levels of the facility. When the strain on the hoisting rope was removed, his safety system caused a pair of spring-loaded dogs to engage the cog design of the guide rails. (Elevators Market, The Essentials of Elevatoring: Elevators History, [Online],10 June 2018, Available: https://elevatorsmarket.com/the-essentials-ofelevatoring/, Accessed: 4 February 2019).

Despite the increased safety of elevators, the public did not begin to accept and order elevators for passenger use until 1857. In that year, the first elevator was installed in the New York store of E.V. Haughwout & Co. This elevator travelled.5 stories at a remarkable 40 feet per minute speed (fpm). (G.R. Strakosch, The Vertical Transportation Handbook, 3rd ed. John Wiley & Sons, Inc., 1998).

Improved wire rope became more widely accessible during the next few years, while steam motive power for hoisting made rapid progress. The public began to embrace and approve of architectural ideas, and this revolution in the elevator industry spurred an extraordinary demand for the "downtown" area, resulting in skyscraper cities like Manhattan, Hong Kong, and Dubai. The first elevator in Pakistan was erected in 1930 at Karachi's City Railway Station, and it is still in use today. (https://duncanpk.com/#:~:text=The%20first%20lift%20installed%20in,which%20is%20still%20in%20operation.)

The traction elevator was first commercially introduced in 1903. The friction between the grooves in the machine drive sheave and the hoist ropes imparts lifting force to the hoist ropes in a traction elevator. The ropes connect the carriage to the counterweight by wrapping around the machine drive sheave in grooves. Due to the weight of the car and counterbalance, the ropes are guaranteed to sit in the groove. The traction elevator overcomes the disadvantages of drum and hydraulic machinery, allowing skyscrapers with 100 or more stories to be built. Different varieties of traction elevators and modern hydraulic elevators are currently in use around the world, contributing to urbanization by permitting efficient movement in tall buildings.

Elevators, as we can see from their history, are a technology in a continually evolving business, where changes in technology, current construction rules, market demands, and technological innovation occur on a regular basis. ThyssenKrupp Elevators launched the twin elevators in 2003, which were the first to run two cars in a single shaft. The higher car could go to all of the floors except the lowest, while the lower car could go to all of the floors except the highest. This was a revolution in the elevator industry since it drastically cut wait times in high-traffic and high-rise buildings by using computer programming to manage cars in order to efficiently flow traffic in tall buildings.

1.1.3 Classification of Elevators

Elevators can be classed depending on a variety of qualities, but the design concepts and component manufacturers are dependent on the drive system. Elevators are classified into three categories based on how they are powered. (L. Janovsky, Elevator Mechanical Design, 2nd ed. Ellis Horwood Limited, 1993.)

1. Electric elevators

2. Hydraulic elevators

3. Pneumatic elevators

1.1.3.1 Electric Elevators

Electric elevators can be further classified into three types:

A. Traction drive (geared or gearless)

B. Positive drive or drum drive

C. Linear Induction Motor (LIM) drive

Traction elevators elevate cars by employing ropes that pass over a wheel and an electric motor at the top of the hoistway. A counterweight is used to balance the car's (and passengers') weight, reducing the amount of work the motor has to do, resulting in a more efficient elevator operation.

The suspensions on a positive drive elevator are similar to chain or rope, however, the drive method is ineffective owing to friction. Drum drive elevators, for example, use rolling steel ropes attached to the drum to propel the elevator carriage around the drum. Except for a few low-rise freight elevators, these were the older types of elevators that are no longer in service. Because of multiple cases of ultimate limit switch failures, these elevators can be regarded as the most dangerous.

Linear Induction Motor (LIM) drive is commonly considered the elevator of the future while winding drum elevators are a thing of the past. The linear motor generates the driving force that easily operates on the carriage in LIM drive (or the counterweight).

The system's reliability and efficiency are improved without the requirement for a machine room because no transformation mechanism is required. Over the previous few decades, various businesses have built several design prototypes of linear induction motor drive elevator systems. With some type of magnetic levitation, LIM drive elevators could be tethered or ropeless.

1.1.3.2 Hydraulic Elevators

Plunger-driven hydraulic elevators have a piston beneath the elevator that propels the car up. Oil (hydraulic fluid) is forced into the piston by an electric motor. Unlike traction elevators, the machine room is positioned close to the elevator shaft on the lowest floor. Hydraulic elevators have traditionally had a sheave that extends below the pit floor, but in recent decades, hole-less and roped hydraulic elevators have become more popular. Many of them use telescoping pistons to accommodate the hydraulic system without or with a small hole below the elevator pit's bottom. Hydraulic elevators are typically less expensive to install and maintain, but they are not suitable for high-rise structures. (Archtoolbox, Elevator Types, [Online] Available: https://www.archtoolbox.com/materials-systems/verticalcirculation/elevatortypes.html)

1.1.3.3 Pneumatic Elevator

The carriage of a pneumatic or vacuum elevator is moved up or down by air suction, which is caused by a difference in air pressures above and below the carriage. On the top of the elevator, turbines are used as exhausts. Pneumatic elevators are commonly utilized in multi-story residential buildings.

There are several other types of elevators that have been developed by various companies but have yet to be commercialized due to their respective limitations, most notably a failure to meet current safety codes, but which have used innovative technological design methods and could be a part of the future of vertical transportation. (Pneumatic Vacuum Elevators, LLC., Principles and Components, [Online], Available: https://www.vacuumelevators.com/principles-components/, Accessed 17 February 2019)

1.1.4Frequently used electric elevator parts:

Understanding typical elevator components are necessary before delving deeper into the intricacies of an elevator. While any elevator has many components, and there are many distinct types of elevators, the basic components of an electric elevator are explained below.

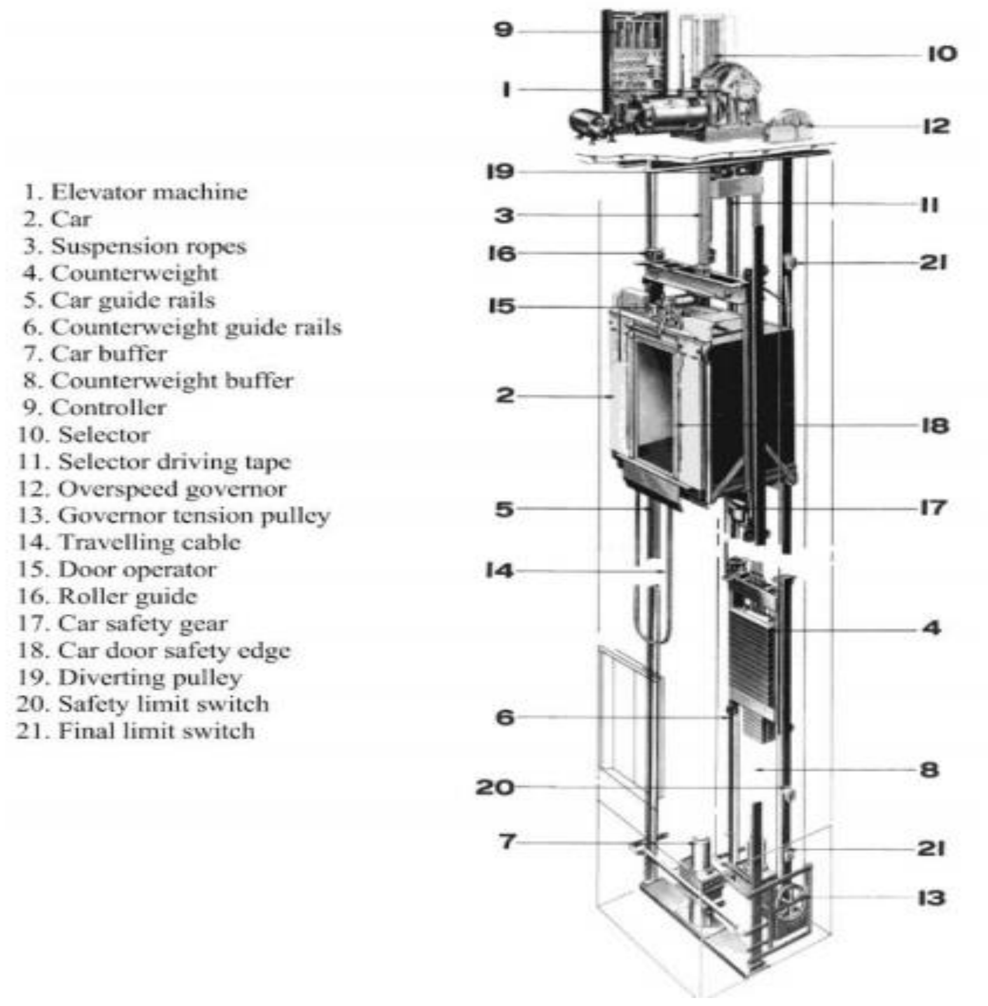

Figure 1: A typical passenger elevator (Picture courtesy of Otis Elevator)

Source(s): (L. Janovsky, Elevator Mechanical Design, Picture Courtesy of Otis Elevator, 2nd ed. Ellis Horwood Limited, 1993.)

1. Suspension
   The steel wire ropes or chains used to suspend cars and counterweights are referred to as suspension. Suspension ropes are crucial for carriage safety because they are what hangs the carriage. They must be chosen carefully, have a long life, and be maintained and replaced on a regular basis. When choosing suspension ropes, the factor of safety can be computed using the rated load, the mass of the car and the counterweight, the height of travel, the rated speed, the roping factor, and whether or not compensating cables are used.

The factor of safety is given by,

f = $minimum\ breaking\ load\ of\ the\ rope/maximum\ static\ force\ in\ the\ rope$ = $(n \times N)/F$

where n is the number of ropes,

N is the minimum breaking load of one rope and F is the maximum tensile force in the elevator ropes. It is calculated with the stationary carriage on the lowest floor with the rated load.

2. Driving machine
   The word "drive machine" is a broad term that refers to an elevator's driving mechanism. In a traction elevator, for example, it would refer to the power unit, which includes the electric motor, gears, brake, sheave, drum or chain sprockets, and so on.
3. Car
   The term "car" refers to the section of the journey that the majority of passengers take. The carriage is the vehicle that transports passengers and/or cargo. It refers to the entire framework, which includes the sling, metal framework linking to the 19 suspensions, the platform floor, and the automobile enclosure in technical terms. The car is also equipped with suspension, guiding rails, safety equipment, a car door, and a door operator.
4. Counterweight

In an elevator, the counterweight balances the weight of the car and the load. To move the car between floors, the counterweight is tipped in the appropriate direction. This also reduces the amount of work the motor has to accomplish.

5. Hoistway or Elevator Well
   The elevator is installed and the car moves in this tubular space that extends from the pit floor to the roof. The vehicle, counterweight, guide rails, buffers, landing doors, and other items are normally housed in this compartment.
6. Safety gear
   In the event that the suspension fails, the safety gear is a mechanical device designed to stop the automobile and/or counterweight and keep it in place. When the elevator car's speed exceeds the rated value, the safety gear activates in addition to the over-speed governor.
7. Buffers
   To accumulate or disperse the kinetic 20 energy of the car and counterweight, buffers are installed at the bottom of the hoistway, past the lowest point where the car and counterweight are generally expected to go. They come in a variety of shapes and sizes, including spring, oil, and polyurethane.
8. Electrical components
   Lighting, safety features, displays, digital door operators, and other electrical components, as well as electrical safety, are all employed in elevators.
9. Control systems
   The control system is a processing unit that performs diagnostics, analyses traffic, and controls elevator functionality in general. It is normally located in the control room or the machine room if there is one. The 32-bit microprocessor controller, for example, may make thousands of decisions every second.
10. Door Operator

When the elevator reaches the destination floors, this section of the elevator regulates the door opening and closing. In modern elevators, they are frequently equipped with a sensor to prevent people and things from becoming trapped between the door and the vehicle, and they should only open when the car is stationary on a specific floor. In ten years, a typical door operator is anticipated to operate 1.75 million times. Door operators are responsible for around 80% of all elevator difficulties, and they have been linked to multiple elevator-related accidents. As a result, it's critical that they're well-maintained over time. Traditional door operators are far less safe than current digital door operators.

1.1.5Research Objectives:

This research is geared towards the following objectives.

. Understanding various parts of an Elevator

. Identifying the defects which could occur in an elevator

. Finding ways to stop the occurrence of defects

. Improving the client’s capabilities to evaluate elevator maintenance contractors.

1.1.6Methodology:

Our research involved studying the varying problems related to elevator maintenance by reading different RFPs. We studied different contracts and did surveys to identify the major issues related to the evaluation of elevator maintenance contractors. We identified the most important issues and did surveys to make a final questionnaire that would help a client to evaluate the elevator maintenance contractor. We divided the questionnaire into 3 parts involving the parts of elevator and punctuality of contractor etc.

1.1.7Conclusion:

Our aim is to introduce a way in which it would be easy for a client to evaluate the maintenance contractor of an elevator and whether he knows about all the parts of the elevator or not. Whether he is coming on time or not. Considering all these things we made a questionnaire and completed our research.

CHAPTER 2

1.2 LITERATURE REVIEW

1.2.1 Introduction:

Research articles regarding previous studies on maintenance projects in general were read and different factors ranked in them regarding their criticality and importance were extracted from them. Since these articles were on generic maintenance projects i.e. maintenance of a building' HVAC system or maintenance of a hospital building etc. so they did not include factors concerning the technical aspects of elevator maintenance. For those factors we read Request for proposal (RFPs) regarding elevator maintenance projects.

Work from some **Research articles** has been shown here:

Data was collected using an instrument based on the SERVQUAL technique. The comparison of the clients' expected and perceived service quality levels was used to determine service quality. Few the contractors meet clients' expectations in all areas, according to the data, while the majority fall short of clients' goals in all dimensions. Factors that were rendered important are Tangibles, Reliability, Responsiveness, Assurance, and Empathy. **(Sambo Zulu & Nicholas Chileshe, 2014)**

Nik Elyna Myeda, Syahrul Nizam Kamaruzzaman, and Michael Pitt carried research in **2011.** The goal of this study was to identify the most important areas of performance measurement for office building maintenance management in order to improve maintenance service delivery. This study provided a performance measuring system that has been shown to be practical and appropriate for assessing the effectiveness of office building maintenance services. Key factors extracted were satisfying the Employee's needs, equipment, cost, Task Efficiency, and Quality.

A model was used to evaluate contractor by **Maria Creuza Borges de Araújo,Luciana Hazin Alencar, and Caroline M. Miranda Mota** in **2016**. The suggested model employs the ELECTRE TRI technique to categories building contractors based on their performance. As a result, ELECTRE TRI assigned contractors in three classes expressed both hopeful and pessimistic perspectives.

Those classes were good, moderate and bad. Key factors used were Relations, Management, Quality, Personnel, Time, and Financial.

1.2.2 Research Paper Analysis

Here are some factors mentioned by different research articles that have impact on performance evaluation of maintenance contractor.

Table 1: Critical Factors mentioned in research Articles

Sr. No.	Factors	Reference
1	Tangibles	(Sambo Zulu & Nicholas Chileshe, 2014), (Gladys Kim Wan Siu , Adrian Bridge & Martin Skitmore, 2010), (Anthony W.Y. Lai and W.M. Lai, 2013)
2	Reliability	(Sambo Zulu & Nicholas Chileshe, 2014), (Gladys Kim Wan Siu , Adrian Bridge & Martin Skitmore, 2010), (Anthony W.Y. Lai and W.M. Lai, 2013)
3	Responsiveness	(Sambo Zulu & Nicholas Chileshe, 2014), (Gladys Kim Wan Siu , Adrian Bridge & Martin Skitmore, 2010), (Anthony W.Y. Lai and W.M. Lai, 2013)
4	Assurance	(Sambo Zulu & Nicholas Chileshe, 2014), (Gladys Kim Wan Siu , Adrian Bridge & Martin Skitmore, 2010), (Anthony W.Y. Lai and W.M. Lai, 2013)
5	Empathy	(Sambo Zulu & Nicholas Chileshe, 2014), (Gladys Kim Wan Siu , Adrian Bridge & Martin Skitmore, 2010), (Anthony W.Y. Lai and W.M. Lai, 2013)
6	quality	(Christopher C. Obiajunwa, 2012), (Maria Creuza Borges de Araújo,Luciana Hazin Alencar, Caroline M. Miranda Mota, 2016)
7	Safety	(IGAL M. SHOHET, SAREL LAVY-LEIBOVICH, DANY BAR-ON, 2010), (Christopher C. Obiajunwa, 2012)
8	cost	(Christopher C. Obiajunwa, 2012), (Nik Elyna Myeda, Syahrul Nizam Kamaruzzaman, Michael Pitt, 2011), (IGAL M. SHOHET, SAREL LAVY-LEIBOVICH, DANY BAR-ON, 2010)
9	CustUmer satisfaction	(Abdullateef Olanrewaju,Wong Wai Fang,Seong Yeow Tan, 2018), (Nik Elyna Myeda, Syahrul Nizam Kamaruzzaman, Michael Pitt, 2011)

10	Time	(Maria Creuza Borges de Araújo,Luciana Hazin Alencar, Caroline M. Miranda Mota, 2016), (Christopher C. Obiajunwa, 2012)

1.2.2.1 Tangibles:

Physical facilities, equipment, employees, and communication materials' appearance are termed as tangibles. Such as:

- **Modern equipment**
- **Visually appealing physical facilities**
- **Clean look**
- **Appropriate size in relation to the task at hand**
- **Work presentation standards, both verbally and in writing**

1.2.2.2 Reliability:

The ability to provide the promised service with consistency and accuracy. i.e.

- Will complete a task by a specified deadline
- Demonstrate genuine interest in resolving problems
- Delivers the service on time
- Completes the job correctly the first time
- Would build a long-term relationship

1.2.2.3 Responsiveness:

Willingness to assist custUmers and give quick service. i.e.

- Informs clients when services will be provided
- Provides fast service to us
- Responds to client requests
- Willing to Assist Clients

1.2.2.4 Assurance:

Employees' capacity to inspire trust and confidence by their knowledge and civility. It includes:

- **Employees' behaviours instil confidence in clients**
- **Clients feel safe in their transactions**
- **Employees are always nice to us**
- **Employees have the knowledge to respond to inquiries**
- **The work is done by skilled employees**
- **Good site supervision of projects**

1.2.2.5 Empathy:

A company's caring, individualized attention to its clients. Such as"

- Operating at times that are convenient for clients
- Provide specialized attention to clients
- Recognize clients' specific demands
- Recognize the clients' organization

1.2.2.6 Quality:

At its most basic level, quality refers to a project's completion within the scope of work's established parameters. This document acts as a collection of project guardrails based on the owner's expectations, and it explains how to carry out the project to these standards.

1.2.2.7 Safety:

Safety aims to ensure that a construction site or the construction industry as a whole does not provide an immediate hazard to the general public or construction employees, as well as ensuring that the finished product meets mandated safety requirements.

1.2.2.8 Cost:

Construction project for their success really depends upon budget being executed as efficiently as possible. So in this regard, it is important for a contractor to take care of costs being in the range as mentioned in tender. Even if changes have been made by client in the scope budget should be in feasible range.

1.2.2.9 Customer satisfaction:

Client satisfaction is defined as how successfully a contractor satisfies the custUmer's expectations. When choosing a contractor, the consumer sets expectations for what will happen as a result of that activity.

1.2.2.10 Time:

Because contractors are given a legally binding contract, failure to adhere to its terms and deadlines can result in a partial loss of monetary payment or even cancellation of the contract, time management is critical to their profitability.

1.2.3RFPs Analysis

1.2.3.1 ABOUT RFPs

We read about 80 RFPs that were about the projects of elevator maintenance in different areas of the world mostly after 2010. As per standard RFP they contained scope of project and all other aspects to be covered by contractors in their tenders. Different factors from these RFPs regarding the technical aspects of elevator maintenance and managerial aspects of contractors were extracted.

1.2.3.2 Factors from RFPs:

Here are some factors mentioned by different RFPs that have impact on performance evaluation of maintenance contractor.

1.2.3.3 Grouping of Factors

These factors extracted from RFPs have been classified into three groups depending upon their i.e. whether they are related to technical aspects or they are related to managerial aspects. Following are the three groups:

- Call Backs/ Responsiveness
- Equipment Performance
- Duties and responsibilities during maintenance

Table 2: Factors mentioned in RFPs

Table 2.1: Factors related to Call backs\ Responsiveness

SR. NO.	CODE	FACTOR	REFERENCE (RFP)
1	CB1	Responds promptly to rectify eficiencies identified by the client	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
2	CB2	Responds promptly to elevator	(Elevator Preventative Maintenance and Repair Services,

		malfunction/passenger entrapment	Purchasing,Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
3	CB3	Responds promptly to non-emergency callbacks	(Elevator Inspection and Maintenance Services, Muscogee County School District Columbus, Georgia, 2019)

Table 2.2: Factors related to Equipment Performance:

As to ensure working of all Parts of elevator, Contractor shall inspect, adjust, and lubricate as needed on a regular and systematic basis, and, if conditions warrant, recommend repairs or replacement of the equipment including the following mentioned in table.

SR. NO.	CODE	COMPONENTS	REFERENCE (RFP)
1	EQ1	Controller	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
2	EQ2	Landing door hardware	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
3	EQ3	Hoist Motor and Generator	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
4	EQ4	Machine including worms, gears, bearings, brake, and sheaves	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
5	EQ5	Door Operator System	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)

6	EQ6	Car and Counterweight Guide Shoes	(Elevator Preventative Maintenance and Repair Services, Purchasing,Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
7	EQ7	Power unit and hydraulic system components	(Elevator Inspection and Maintenance Services, Muscogee County School District Columbus, Georgia, 2019)
8	EQ8	Governor	(Elevator Inspection and Maintenance Services, Muscogee County School District Columbus, Georgia, 2019)
9	EQ9	Car and Hall Signal and Operating Devices	(Elevator Preventative Maintenance and Repair Services, Purchasing,Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
10	EQ10	Switches, cams, and sheaves in the hoistway	(Elevator Preventative Maintenance and Repair Services, Purchasing,Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
11	EQ11	Car and counterweight guard rails	(Elevator Inspection and Maintenance Services, Muscogee County School District Columbus, Georgia, 2019)
12	EQ12	Hoist and Governor Ropes	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
13	EQ13	Car, hoist way, and machine room wiring including traveling cables	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)

Table 2.3. Factors related to Duties and Responsibilities during Maintenance

SR. NO.	CODE	Factors	REFERENCE (RFP)
1	DM1	Diligently maintains logbook indicating PM performed, callbacks, and repairs	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
2	DM2	Adequately furnishes all material, labour, and supplies	(Elevator Inspection and Maintenance Services, Muscogee County School District Columbus, Georgia, 2019)
3	DM3	Uses high-quality replacement parts, lubrication, and hydraulic fluid	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
4	DM4	Designates experienced and qualified maintenance staff	(Elevator Preventative Maintenance and Repair Services, Purchasing, Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
5	DM5	Keep the client's representative well-informed about the PM, visits, and failures	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
6	DM6	Provides periodic written reports indicating PM tasks, callbacks, repairs, failures, downtime, and testing results	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
7	DM7	Provides periodic	(Elevator Preventative Maintenance and Repair Services, Purchasing, Department 2020 Labieux Road Nanaimo, BC V9T 6J9, 2019)
8	DM8	Diligently equipment testing at client's specified intervals	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator

			Maintenance, CITY OF SCHENECTADY, 2017)
9	DM9	Maintain cleanliness of machine room, hoistways, car tops, pits, and site	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)
10	DM10	Maintains a comprehensive spare parts inventory	(MUNICIPAL HOUSING AUTHORITY OF THE CITY OF SCHENECTADY Elevator Maintenance, CITY OF SCHENECTADY, 2017)
11	DM11	Maintains specified rated speed, acceleration, and retardation rates	(Elevator Maintenance and Repair Services City of Dublin, 100 Civic Plaza City of Dublin, CA 94568, 2019)

NOTE:

Factors mentioned above have great role in defining the performance of a contractor doing maintenance of elevation. So if a client is to keep an independent check on the performance of a contractor, he can make these factors standard for him regarding not only managerial but also technical aspects of elevator maintenance.

Call backs and Duties and responsibilities during maintenance groups of factors are self –explanatory while the different parts of elevator in Equipment performance category are not known to everyone. So their pictures are shown below:

1.2.3.4 Different Parts of Elevator:

1.2.3.4.1 ELEVATOR CONTROLLER:

An elevator controller is a mechanism for manually or automatically controlling elevators. Only the motor requires 3-phase power supply, which is normally tuned down to between 12V and 24V by the controller.

Figure 2: Elevator Controller

1.2.3.4.2 LANDING DOOR HARDWARE:

The elevator landing door device, often known as the elevator header, is the door that passengers view from outside the elevator.

Figure 3: Landing Door Hardware

1.2.3.4.3 HOIST MOTOR:

A geared or winding drum elevator houses the hoist motor. It connects to the brake drum and turns the elevator drive sheave with a spiral worm gear that meshes with the machine's ring gear.

Figure 4: Hoist Motor

1.2.3.4.4 MACHINE:

A pulley is a simple contraption that lifts huge things by combining a rope or cable with a wheel and axle. In modern elevators, huge metal cable pulleys are used. The cable is wrapped around the wheel and axle's groove. The cable is pulled by an electric motor, which lifts the car between levels.

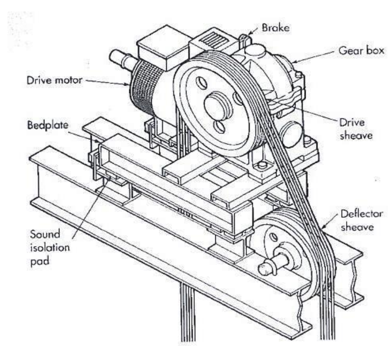

Figure 5: Machine

1.2.3.4.5 CAR AND COUNTERWEIGHT GUIDE SHOES:

Four sets of guide shoes are fitted on both sides of the upper beam and under the safety gear seat at the bottom of the vehicle in each elevator car; four sets of counterweight guide shoes are installed on the bottom and upper section of the counterweight beam in each elevator car.

Figure 6: Car and Counterweight Guide Shoes

1.2.3.4.6 HYDRAULIC ELEVATOR POWER UNIT:

On all types of hydraulic elevators, an elevator power unit is a necessary component. A power unit accomplishes two important tasks: it raises the piston (elevator jack) and allows oil to return to the elevator's tank as a vehicle descends.

Figure 7: Hydraulic Elevator Power Unit

1.2.3.4.7 GOVERNOR:

An overspeed governor is a device on an elevator that functions as a brake if the elevator exceeds its rated speed. In traction elevators and ropes hydraulic elevators, this component must be installed.

Figure 8: Governor

CHAPTER 3

1.3 METHODOLOGY

1.3.1General Background:

The lack of any elevator maintenance contractor's evaluation model causes some severe conservation of elevators related to maintenance and safety. This research aims to provide a framework for consultants to evaluate contractors. It is going to solve many preservation and maintenance-related issues in elevators. The Framework contains all the critical factors involved in the safety and maintenance of elevators. All the elements were extracted through the literature review earlier. Questioner about these factors was created and circulated among experts, and the final model was created based on the results.

1.3.2Project Timeline:

The timeline for the project was as per the following:

Sr. No	**Objective**	**Dates**
1	Topic Finalization	15-Sep-2021 To 14-Nov-2021
2	Literature Review	15-Oct-2021 To 18-Nov-2021
3	Developing Methodology	15-Nov-2021 To 22-Dec-2021
4	Developing Questionnaires	23-Dec-2021 To 27-Jan-2022
5	Collection Data	28-Jan-2022 To 24-Feb-2022
6	Processing Data	25-Feb-2022 To 17-Mar-2022

7	Final Model	18-Mar-2022 To 14-Apr-2022

Table 3: Project Timeline

1.3.3Flow Chart of Work:

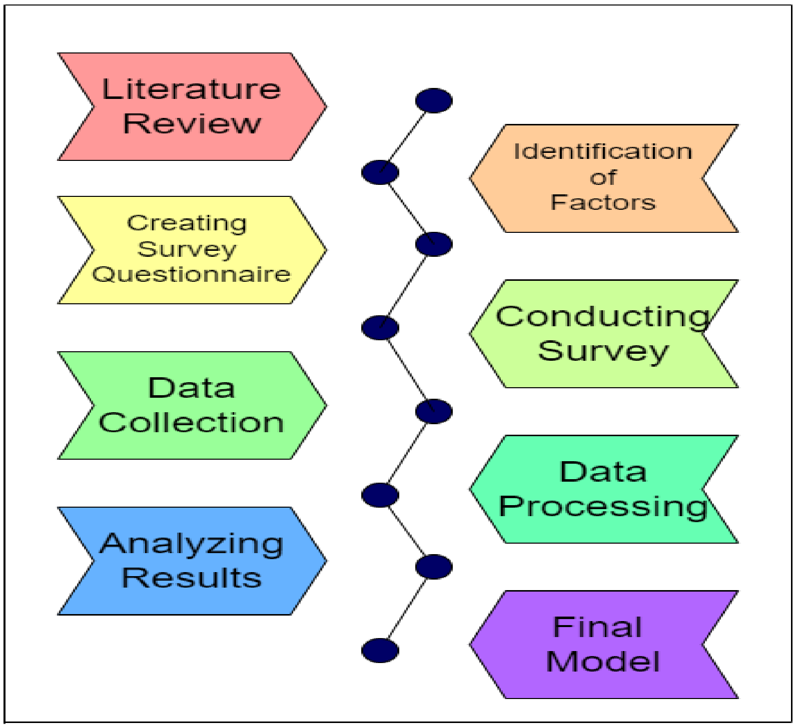

Figure 9: Flow Chart of Work

1.3.4Creating Survey Framework.

1.3.4.1 Extracting of factors:

The literature review was done earlier. The factors were determined from the RFPs related to the elevator maintenance contracts. All the factors and their relative occurrence were determined. A table of the most occurring factor and their frequency was developed.

1.3.4.2 Shortlisting of factors:

The number of factors was determined through the literature review. Factors were then shortlisted on the bases of their relative occurrence. All the critical factors having an occurrence percentage of more the 40% (occurs in more than 40% of contracts) were shortlisted.

1.3.4.3 Categorization of Critical Factors**:**

All the shortlisted factors were then categorized concerning their relative classes and roles. Three Categorized were formed according to the factors.

1.3.4.3.1 Call-Back:

Call back concerning how the contractor responds to calling them in emergency and non-emergency situations.

1.3.4.3.2 Equipment performance:

This category involves all the factors related to equipment and its performance. It deals with how contractors handle and maintain different critical factors in an elevator and show the relative importance of different pieces of equipment in elevators.

1.3.4.3.3 Duties and Responsibilities:

The category involves factors concerning how a good contractor performs its duties and responsibilities.

Section B – Callbacks

On the scale of '**0-5',** rate the following factors in terms of their importance to evaluate the performance of elevator maintenance contractor whereas ('0 – not applicable', '1 – slightly important', '2 – fairly important', '3 –important', '4 – very important' and '5 – extremely important')

SECTION B		**RESPONSIVENESS**	
NO.	**Code**	**FACTOR**	**Importance**
1	CB1	Responds promptly to elevator malfunction/passenger entrapment	0 1 2 3 4 5

2	CB2	Responds promptly to non-emergency callbacks	0 1 2 3 4 5
3	CB3	Responds promptly to rectify deficiencies identified by the client	0 1 2 3 4 5

Other critical components and ratings (optional):_______________________________

Section C – Equipment Performance

On the scale of ‘**0-5’,** rate the following components in terms of their criticality to effect the performance of elevator maintenance contractor whereas ('0 – not applicable', '1 – slightly critical', '2 – fairly critical', '3 – critical', '4 – very critical' and '5 – extremely critical')

NO.	**Code**	**Components**	**Criticality**
1	EQ1	Controller	0 1 2 3 4 5
2	EQ2	Landing door hardware	0 1 2 3 4 5
3	EQ3	Hoist Motor and Generator	0 1 2 3 4 5
4	EQ4	Machine including worms, gears, bearings, brake, and sheaves	0 1 2 3 4 5
5	EQ5	Door Operator System	0 1 2 3 4 5
6	EQ6	Car and Counterweight Guide Shoes	0 1 2 3 4 5
7	EQ7	Power unit and hydraulic system components	0 1 2 3 4 5
8	EQ8	Governor	0 1 2 3 4 5
9	EQ9	Car and Hall Signal and Operating Devices	0 1 2 3 4 5
10	EQ10	Switches, cams, and sheaves in the hoist way	0 1 2 3 4 5

11	EQ11	Car and counterweight guard rails	0	1	2	3	4	5
12	EQ12	Hoist and Governor Ropes	0	1	2	3	4	5
13	EQ13	Car, hoist way, and machine room wiring including traveling cables	0	1	2	3	4	5

Other factors and ratings
(optional):____

Section D – Duties and Responsibilities during Maintenance

Please rate the significance of the following factors on a scale of 0-5 ('0 – not applicable', '1 – slightly significant', '2 – fairly significant ', '3 – significant ', '4 – very significant ' and '5 – extremely significant).

NO.	**Code**	**Components**	**Criticality**					
1	EQ1	Diligently maintains logbook indicating PM performed, callbacks, and repairs	0	1	2	3	4	5
2	EQ2	Adequately furnishes all material, labour, and supplies	0	1	2	3	4	5
3	EQ3	Uses high-quality replacement parts, lubrication, and hydraulic fluid	0	1	2	3	4	5
4	EQ4	Designates experienced and qualified maintenance staff	0	1	2	3	4	5
5	EQ5	Keep the client's representative well-informed about the PM, visits, and failures	0	1	2	3	4	5
6	EQ6	Provides periodic written reports indicating PM tasks, callbacks, repairs, failures, downtime, and testing results	0	1	2	3	4	5
7	EQ7	Provides periodic	0	1	2	3	4	5

8	EQ8	Diligently equipment testing at client's specified intervals	0	1	2	3	4	5
9	EQ9	Maintain cleanliness of machine room, hoist ways, car tops, pits, and site	0	1	2	3	4	5
10	EQ10	Maintains a comprehensive spare parts inventory	0	1	2	3	4	5

Other factors and ratings
(optional):_______________________________________

Table 4: Categorization of Factors

1.3.4.4 Creating Framework:

After the categorization of factors, each factor was given a rating from 1 to 5 as per the following:

•1 for slightly significant.
•2 for fairly significant
•3 for significant
•4 for very significant
•5 for extremely significant

1.3.4.5 Creating Survey Form

A Google survey form was created from the factors extracted.
Factors were given importance from 1 to 5, as explained earlier.

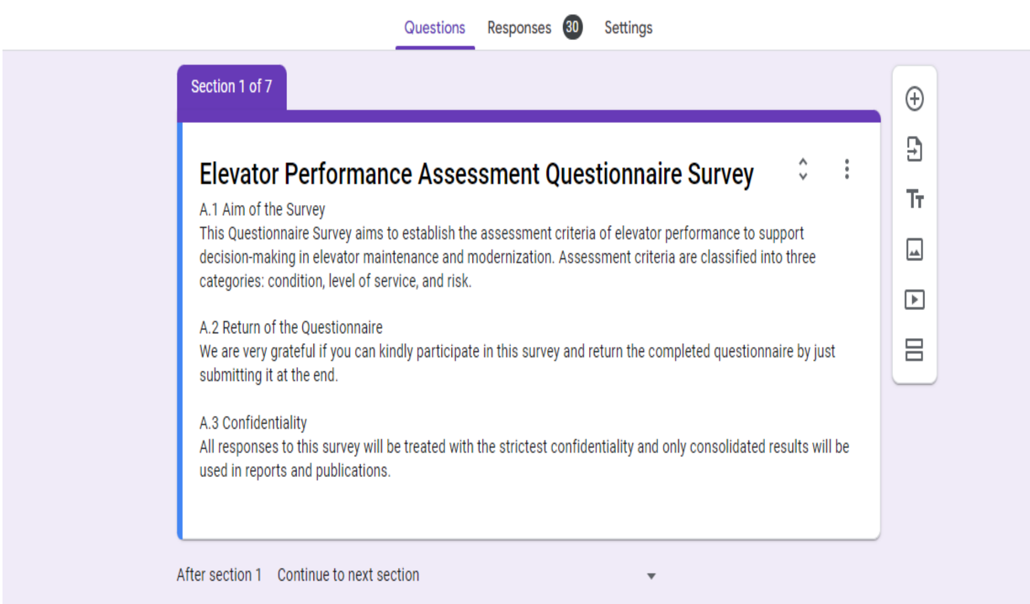

Figure 10: Creating Survey Form

1.3.5 Conducting Survey.

1.3.5.1 Selection of Survey Audience:

Our target audience for the survey was elevator maintenance consultants throughout the world. 20% of our target audience was from Pakistan and the rest throughout the world to make our research acceptable globally.

1.3.5.2 Selection of medium to communicate:

Two types of medium were selected to communicate with the targeted audience.

1) Visiting Experts: site visits were done to the experts within our reach in Islamabad. They filled out the survey form, and interviews were done with them related to our research.
2) Online Platform: Most of our target audience was abroad and out of our physical reach. So help of some online professional platforms was taken for surveying both local and international elevator maintenance consultants. The primary tool used for this survey was LinkedIn. Almost 90% of our responses are through LinkedIn. We approached different experts and conducted surveys with them. Other online platforms like Upwork, Facebook, and WhatsApp were used to approach our targeted audience.

1.3.6Data Acquisition

1.3.6.1 Collection of Data:

Data was collected in the form of a spreadsheet with all experts' responses. Data contains the relative importance of all the factors on a scale of 1 to 5.

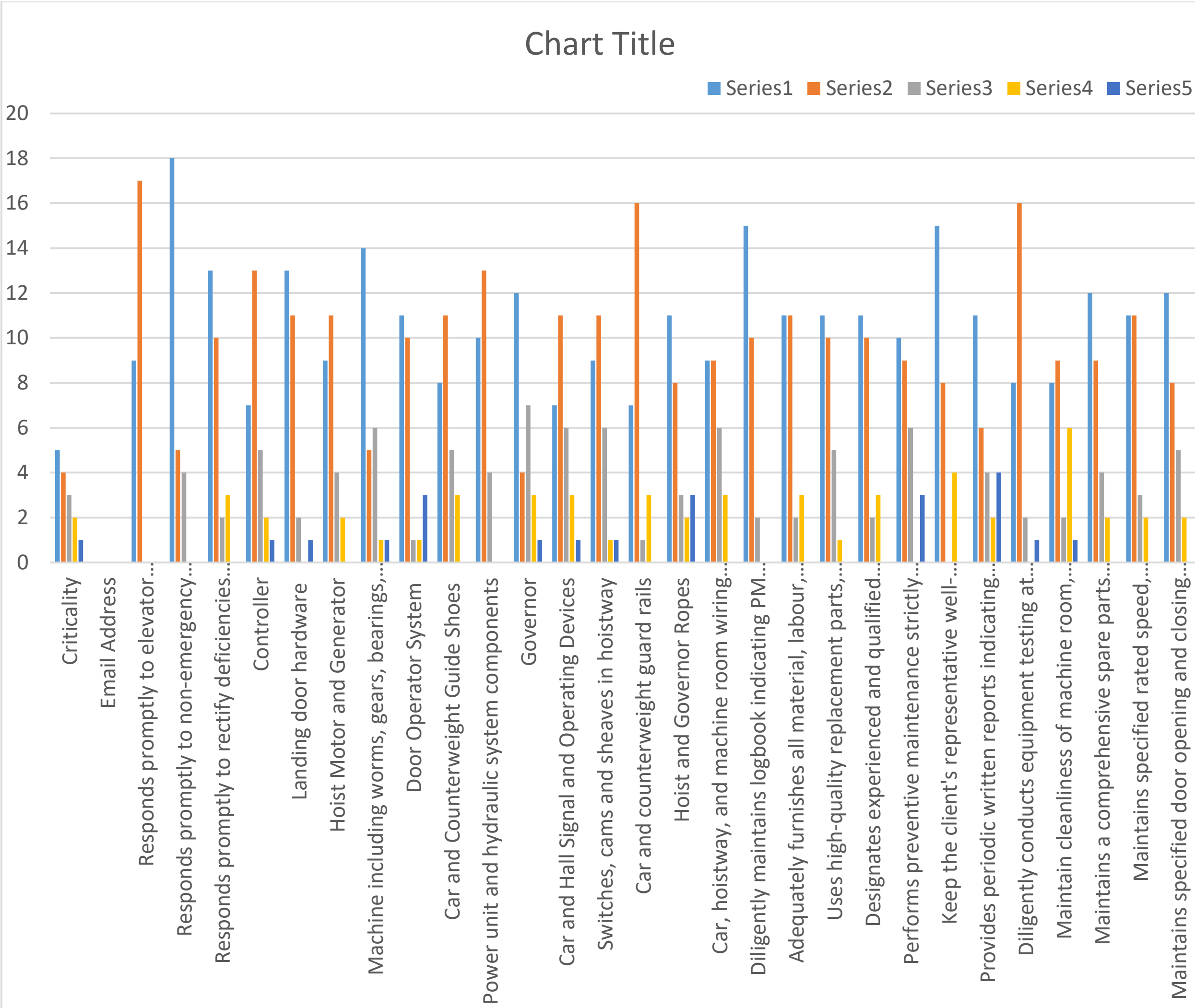

Figure 11: Data Collection

1.3.6.2 Data Verification/Filtration:

Verification/filtration of data was done as needed. Finally, all the responses were verified. Unsuitable responses, i.e., responses from contractors and other not technical people, were filtered out. Relevant and essential data was then extracted through it.

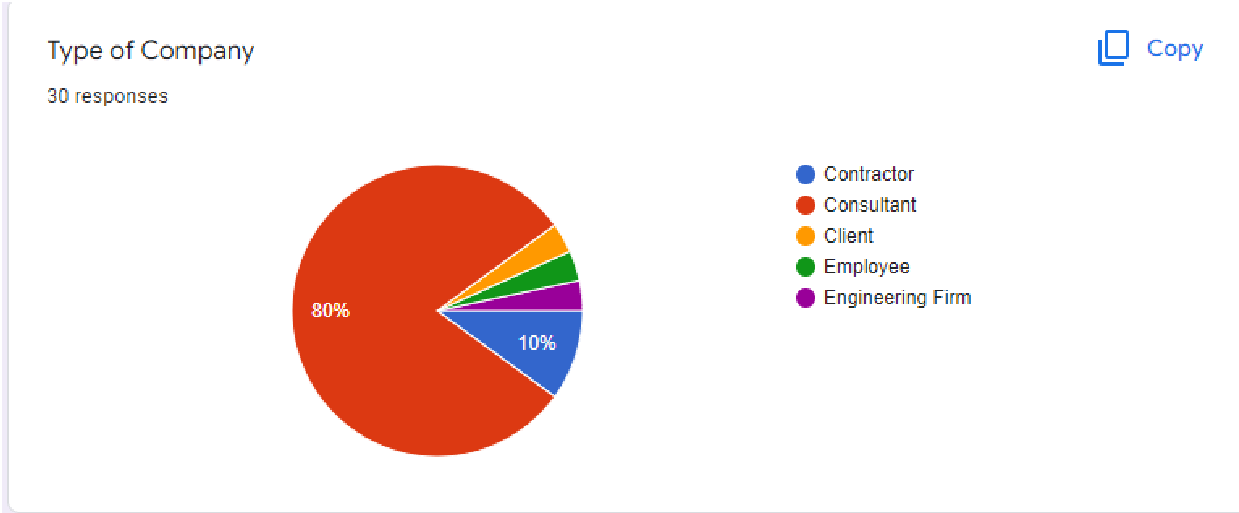

Figure 12: Data Verification

1.3.6.3 Type of Data:

As the data was acquired from a Google survey form, data was in the form of numbers, i.e., Numerical data. Factors were rated from 1 to 5 as per their importance and seriousness concerning maintenance and safety of the elevator.

CHAPTER 4

1.4 ANALYZING OF DATA

1.4.1Initial Data:

Initially, the data was in the form of numbers from 1 to 5, showing the relative importance of factors in their categories.
This data was extracted directly from the spreadsheet of all the responses we got online and through field visits. This Raw data was needed to analyze and process to make a beneficial outcome.

1.4.2Survey Respondent:

Respondents of the survey were from throughout the globe. 12% of responses were from UAE, 9% from Saudi Arabia and Bangladesh, and the rest from Nigeria, Spain, the USA, Norway, Etc. Only 20% of responses were from Pakistan rest were from other countries.

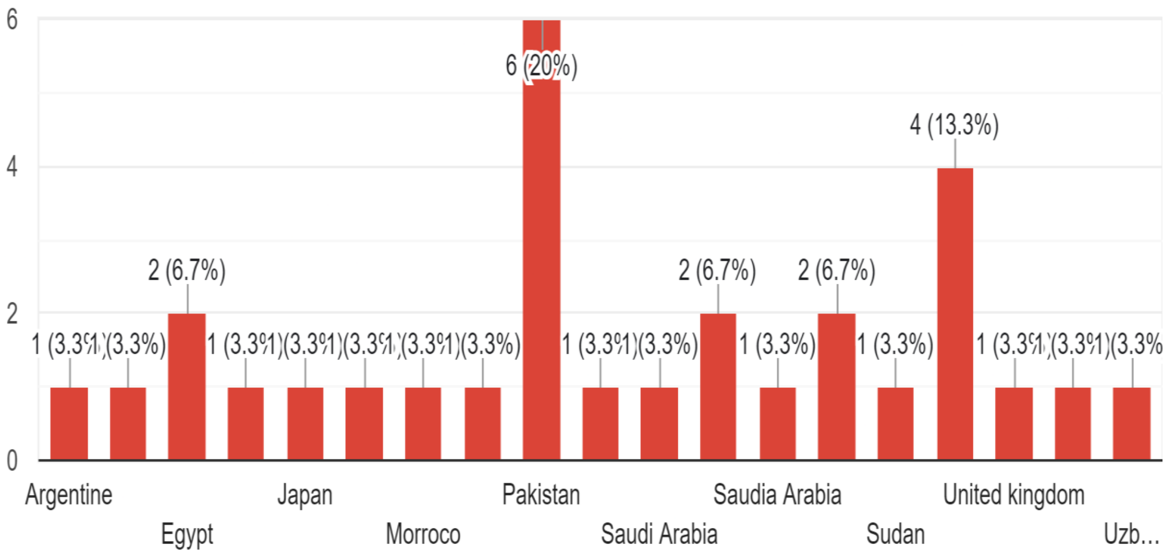

Figure 13: Survey Respondent

1.4.3Data Process:

All the required data was gathered and processed to get the required results. Data was in the form of numbers. Different statistics tools were used to get our final Framework. Tools used in analytics are discussed:

1.4.3.1 Relative Importance Index:

The Relative Importance Index (RII) determines the relative importance of the quality factors involved. The points of the Likert scale are equal to the value of W, with weighting given to each factor by the respondent. The Relative Importance Index (RII) was calculated using an equation.
Where:

$$RII = \frac{\sum W}{A * N}$$

Figure 14: RII Formula

W: Weighting given to each factor by the respondent
A: the highest weight in the research
N: Total number of respondents
Reason to use:
Different factors will have different Relative Importance Index (RII), which is used to rank them. The importance of each factor is based on the higher value of the Relative Importance Index (RII) obtained from the equation above. As to determine the relative importance of each factor, RII was taken.

1.4.3.2 Median:

The Median is the middle number in a sorted list of numbers. The Median can be used to determine an approximate average or mean but is not confused with the actual mean. To determine the median value in a sequence of numbers, the numbers must first be sorted, or arranged, in value order from lowest to highest or highest to lowest.

- If there is an odd amount of numbers, the median value is the number that is in the middle, with the same amount of numbers below and above.
- If there is an even amount of numbers in the list, the middle pair must be determined, added together, and divided by two to find the median value.

Reason to use:
As the Median gives an approximate middle value from the sample of different values, the Median was taken to sort out our data and present a single value of each factor.

1.4.3.3 Standard Deviation:

The standard deviation is a statistic that measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance. The standard deviation is calculated as the square root of variance by determining each data point's deviation relative to the mean.
If the data points are further from the mean, there is a higher deviation within the data set; thus, the more spread out the data, the higher the standard deviation and wise versa
formula,

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{n-1}}$$

where:

x_i = Value of the i^{th} point in the data set

$\overline{x}$ = The mean value of the data set

n = The number of data points in the data

Figure 15: SD Formula

Reason to use:
As SD provides how much data is dispersed from the mean, the determined dispersion in our result and accuracy of our result SD was taken.

1.4.3.4 Arithmetic Mean:

In statistics, the **Arithmetic Mean (AM)**, or called average, is the ratio of the sum of all observations to the total number of observations.
If these n observations have corresponding frequencies, the arithmetic mean is computed using the formula

x = $\sum_{i=1}^{n} b_i = \frac{b_1+b_2+b_3+....+b_n}{n}$

Figure 16: AM Formula

and using Sigma notation =

where N = f1+ f2 + ……….+ fn.

The above formula can also be used to find the weighted arithmetic mean by taking f1, f2,…., fn as the weights of x1, x2,….., xn.

Reason to use:

As our data contains numerical data ranging from 1 to 5. All individual respondents gave each factor a separate rating. So to produce a final model, each factor must be given a single value signifying its relative importance. So the mean of Each factor was taken. As mean is one of the most knowledgeable and used statistical analyses for this purpose.

1.4.4Use of Arithmetic tools and techniques on responses:

1.4.4.1 Relative Importance Index:

We get the RII of the factors by the sum of the product of rating times its frequency divided by the product of maximum rating (here its value is 5) times the number of respondents and then arranged according to the descending order of the RII of the factors as shown in the table given below. This table is arranged according to the descending order of the RII of the factors.

1.4.4.2 Median

We get the Median of the factors by the first making the order of factors in ascending the take the middle rating (If there is an odd amount of numbers) or take an average of two middle ratings (If there is an even amount of numbers) and then arranged according to the descending order of the Median of the factors as shown in the table given below. This table is arranged according to the descending order of the Median of the factors.

1.4.4.3 Standard Deviation

We get the Standard Deviation of the factors by taking the square root of the variances and then arranged according to the descending order of the Standard Deviation of the factors as shown in the table given below. This table is arranged according to the descending order of the Standard deviation of the factors.

1.4.4.4 Arithmetic Mean

We get the mean of the factors by the sum of the rating assigned by respondents to the factors divided by the number of respondents as shown in the table given below. This table is arranged according to the descending order of the Mean of the factors.

Section B – Callbacks

SECTION B		RESPONSIVENESS			
NO.	**FACTOR**	**Mean**	**RII**	**Median**	**Standard Deviation**
2	Responds promptly to elevator malfunction/passenger entrapment	4.519	0.903 7	5	0.753
1	Responds promptly to rectify deficiencies identified by the client	4.22	0.837	4	0.8006
3	Responds promptly to non-emergency callbacks	4.1	0.867	4	0.989

Section C – Equipment Performance

NO.	Components	Mean	RII	Median	Standard Deviation
2	Landing door hardware	4.3	0.859	4	0.912
4	Machine including worms, gears, bearings, brake, and sheaves	4.2	0.82	4	0.96
7	Power unit and hydraulic system components	4.2	0.84	4	0.7
10	Switches, cams, and sheaves in the hoistway	4.04	0.815	4	0.854
11	Car and counterweight guard rails	4	0.8	4	0.877
1	Controller	3.96	0.793	4	0.808
3	Hoist Motor and Generator	3.96	0.777	4	0.98
5	Door Operator System	3.9	0.763	4	1.299

6	Car and Counterweight Guide Shoes	3.9	0.778	4	0.917
8	**Governor**	3.9	0.77	4	1.23
13	Car, hoistway, and machine room wiring including traveling cables	3.9	0.8	5	1
12	Hoist and Governor Ropes	3.81	0.76	4	1.36
9	Car and Hall Signal and Operating Devices	3.8	0.8	4	1

Section D – Duties and Responsibilities during Maintenance

NO.	Components	Mean	RII	Median	Standard Deviation
1	Diligently maintains logbook indicating PM performed, callbacks, and repairs	4.5	0.895	4	0.643
6	Provides periodic written reports indicating PM tasks, callbacks, repairs, failures, downtime, and testing results	4.3	0.85	4	1.06
3	Uses high-quality replacement parts, lubrication, and hydraulic fluid	4.15	0.83	4	0.86
11	Maintains specified rated speed, acceleration, and retardation rates	4.15	0.829	4	0.907
12	Maintains specified door opening and closing times	4.11	0.822	4	0.895
2	Adequately furnishes all material, labour, and supplies	4.1	0.8	4	1
8	Diligently equipment testing at client's specified intervals	4.1	0.8	4	0.8
10	Maintains a comprehensive spare parts inventory	4.1	0.826	4	0.95
4	Designates experienced and qualified maintenance staff	4	0.793	4	0.997
5	Keep the client's representative well-informed about the PM, visits, and failures	3.9	0.79	5	1.14
9	Maintain cleanliness of machine room, hoistways, car tops, pits, and site	3.78	0.7	4	1.15
7	Provides periodic	3.7	0.7	4	1.5

Table 5: Model for performance Evaluation of Maintenance Contractor of Elevators

1.4.5Discussion

The above model shows that for the category of callbacks, the factor “Responds promptly to elevator malfunction/passenger entrapment” has A. Mean value of 4.519 (greatest in its category), means it is the most important factor among the other 2 factors. Similarly, the factor “Responds promptly to rectify deficiencies identified by the client” has A. Mean value of 4.22 (middle in its category), means it is lesser important than the first factor and greater important than the third one. The third factor “Responds promptly to non-emergency callbacks” is lesser important than the other 2 factors.

In the same way, for the category of Equipment performance, the factor “Landing door hardware” has A. Mean value of 4.3 (greatest in its category), means it is the most important factor among other factors. Like-wise the factor “Machine including worms, gears, bearings, brake, and sheaves” has A. Mean value of 4.2, means it is lesser important than the first factor and more important than all other factors. In this category, the mean value of the factor “Car and counterweight guardrails” is 4, which is almost the average rated factor in this category. “Hoist end Governor ropes” and “Car and Hall Signal and Operating Devices” are the factors that have the least importance in this category. Their mean values are 3.81 and 3.80 respectively.

With same concept, we can interpolate that the factor ”Diligently maintains logbook indicating PM performed, callbacks, and repairs” has highest value in its category of “Duties and responsibilities during maintenance” so the importance. In this category, the factors “Adequately furnishes all material, labor and supplies”, “Diligently equipment testing at client’s specified intervals” and “Maintains a comprehensive spare parts inventory” have an average Importance in this category and their mean values are 4.1 each. The least important factor in this category is “Provides periodic”. This factor has a value of 3.7.

CHAPTER 5

1.5 CONCLUSION

1.5.1Conclusion:

The theme of this project is about helping clients and consultants to evaluate the contractor with respect to his performance in the Maintenance of elevators. This research will help in ensuring the safety of the public. Dangerous and costly repairs can be greatly avoided with it as well. The literature review was carried out to find the factors, then suitable factors were selected using different filters and limits for this purpose. It was then followed by a questionnaire which was conducted and responded to many consultants and clients from Pakistan and all over the world, including the US, UK, European countries, middle east countries, and many more. Those responses were groomed using different analytical tools and techniques to give us a framework that is capable of achieving our objectives and goals.

1.5.2Limitations:

There are a few limitations that are worthy to mention. First of all, our responses are about 30. Our results could have been more accurate if we had gotten more responses. The reason for fewer responses could be the low number of clients and consultants in the market. Secondly, many of them did not reply back due to their lack of seriousness towards our research.

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Survey Questionnaire

ELEVATOR PERFORMANCE ASSESSMENT
QUESTIONNAIRE SURVEY

Section A – Introduction to the Questionnaire Survey

A.1 Aim of the Survey

This Questionnaire Survey aims to establish the assessment criteria of elevator performance to support decision-making in elevator maintenance and modernization. Assessment criteria are classified into three categories: condition, level of service, and risk.

A.2 Return of the Questionnaire

We are very grateful if you can kindly participate in this survey and return the completed questionnaire by email to Mpanhwar.bece18@nice.nust.edu.pk or by post to Umar Zubair, School of Civil and Environmental Engineering, National University of Science and Technology, H12, Islamabad, Pakistan

A.3 Confidentiality

All responses to this survey will be treated with the strictest confidentiality and only consolidated results will be used in reports and publications.

Section B – Callbacks

On the scale of '**0-5',** rate the following factors in terms of their importance to evaluate the performance of elevator maintenance contractor whereas ('0 – not applicable', '1 – slightly important', '2 – fairly important', '3 –important', '4 – very important' and '5 – extremely important')

SECTION B	**RESPONSIVENESS**							
NO.	**Code**	**FACTOR**	**Importance**					
1	CB1	Responds promptly to elevator malfunction/passenger entrapment	0	1	2	3	4	5
2	CB2	Responds promptly to non-emergency callbacks	0	1	2	3	4	5
3	CB3	Responds promptly to rectify deficiencies identified by the client	0	1	2	3	4	5

Other critical components and ratings (optional):___________________________

Section C – Equipment Performance

On the scale of '**0-5',** rate the following components in terms of their criticality to effect the performance of elevator maintenance contractor whereas ('0 – not applicable', '1 – slightly critical', '2 – fairly critical', '3 – critical', '4 – very critical' and '5 – extremely critical')

NO.	**Code**	**Components**	**Criticality**
1	EQ1	Controller	0 1 2 3 4 5
2	EQ2	Landing door hardware	0 1 2 3 4 5
3	EQ3	Hoist Motor and Generator	0 1 2 3 4 5
4	EQ4	Machine including worms, gears, bearings, brake, and sheaves	0 1 2 3 4 5
5	EQ5	Door Operator System	0 1 2 3 4 5
6	EQ6	Car and Counterweight Guide Shoes	0 1 2 3 4 5
7	EQ7	Power unit and hydraulic system components	0 1 2 3 4 5
8	EQ8	**Governor**	0 1 2 3 4 5
9	EQ9	Car and Hall Signal and Operating Devices	0 1 2 3 4 5
10	EQ10	Switches, cams, and sheaves in the hoistway	0 1 2 3 4 5
11	EQ11	Car and counterweight guard rails	0 1 2 3 4 5
12	EQ12	Hoist and Governor Ropes	0 1 2 3 4 5
13	EQ13	Car, hoistway, and machine room wiring including traveling cables	0 1 2 3 4 5

Other factors and ratings (optional):_______________________________________

Section D – Duties and Responsibilities during Maintenance

Please rate the significance of the following factors on a scale of 0-5 ('0 – not applicable', '1 – slightly significant', '2 – fairly significant ', '3 – significant ', '4 – very significant ' and '5 – extremely significant).

NO.	Code	Components	Criticality
1	EQ1	**Diligently maintains logbook indicating PM performed, callbacks, and repairs**	0 1 2 3 4 5
2	EQ2	Adequately furnishes all material, labour, and supplies	0 1 2 3 4 5
3	EQ3	Uses high-quality replacement parts, lubrication, and hydraulic fluid	0 1 2 3 4 5
4	EQ4	Designates experienced and qualified maintenance staff	0 1 2 3 4 5
5	EQ5	Keep the client's representative well-informed about the PM, visits, and failures	0 1 2 3 4 5
6	EQ6	Provides periodic written reports indicating PM tasks, callbacks, repairs, failures, downtime, and testing results	0 1 2 3 4 5
7	EQ7	Provides periodic	0 1 2 3 4 5
8	EQ8	Diligently equipment testing at client's specified intervals	0 1 2 3 4 5
9	EQ9	Maintain cleanliness of machine room, hoistways, car tops, pits, and site	0 1 2 3 4 5
10	EQ10	Maintains a comprehensive spare parts inventory	0 1 2 3 4 5

Other factors and ratings (optional):____

***** END OF THE QUESTIONNAIRE *****

Thank you for your kind support and valuable contribution to this questionnaire survey!