Development of Performance Management Dashboard (PMDs) for Construction Industry

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THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS thesis written by Mr Qasim Jilani Farooqi, Registration No 00000318658, of School of Civil and Environmental Engineering (SCEE) has been vetted by undersigned, found complete in all respects as per NUST Statutes/ Regulations/ MS policy, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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I, Qasim Jilani Farooqi hereby state that my MS Thesis titled “Development of Performance Management Dashboards (PMDs) for Construction Industry” is my own work and has not been submitted previously by me for taking any degree from this National University of Sciences and Technology (NUST) or anywhere else in the country/ world.

At any time if my statement is found to be incorrect even after I graduate, the university has the right to withdraw my MS Degree.

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Date: ______________________________________

This thesis is dedicated to my loving family, affectionate friends, my honorable teachers & supportive colleagues.

ABSTRACT

The construction industry is one of the significant contributors to economic growth and development of any country. Dejectedly, construction industry is facing inconsistency and inefficiency in projects owing to its complex nature. Construction industry has focused a little on employment of automation and information technology (IT) to overcome this complexity. Application of modern visualization tools can make efficient information management and information-based decision making besides augmenting productivity. Besides this, variety of success factors, other than time, cost and quality, are not being used to curb this complexity. The pivot point in this research is to develop a properly planned dashboard to visualize variety of critical success factors regarding construction projects. Factors contributing success on any construction project and underlying metrics were identified through extensive literature review & scrutinized using questionnaire survey involving construction professionals. Exploratory Factor Analysis (EFA) was utilized to group together factors. The groups of factors were linked to a properly planned OBS and exceptions were planned for each underlying metric. Concept of management by exception (MBE) was used to increase overall efficacy of developed dashboard. The user interface for dashboard was developed after incorporating several visualization techniques. Construction professionals were involved to validate the dashboard design to improve usability for end level construction professionals.

Keywords: Management, Dashboard, Exploratory Factor Analysis

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

AOR	Area of Reference
CSF	Critical Success Factor
EFA	Exploratory Factor Analysis
KMO Test	Kaiser-Meyer-Olkin
MBE	Management by Exception
OBS	Organizational Breakdown Structure
PMBOK	Project Management Body of Knowledge
PMU	Project Management Unit
RII	Relative Index of Importance

CHAPTER 1: INTRODUCTION

Construction industry plays a vital role in economic advancement and development of any country (Kopsida & Vela, 2015). However, research depicts performance inconsistency and inefficiency of construction projects, and this trend is growing rapidly. Construction industry has always considered cost and time, with little focus on quality, as measure to judge performance of construction industry(J. F. Y. Yeung et al., 2013).

Construction industry is considered efficient and consistent if the projects are finished on time within stipulated budget. Unfortunately, 90% of construction projects face time and cost overruns besides other problems (Moon et al., 2018). Industries other than construction industry, consider several Critical Success Factors to assess their performance. Research shows that construction industry has not considered any CSFs other than cost & time to measure its performance. Construction industry immensely depends on golden triangle rule of considering cost, time and quality for performance measurement.

Moreover, use of technology in other industries have proved wonders in improving performance of those industries. Employing technology in different industries has induced many improvements like cost efficiency, timely information distribution, fast track decision making, ease of doing work, better product quality, lesser production time, lesser wastage, and many others (Yap et al., 2021). Despite increased interest in improving efficiency of construction industry, work regarding use of technology in construction industry is not up to the mark.

Visualization of project information in a timely manner for management to make fast decisions is one of the key areas which needs to be worked on, to bring improvement in the construction industry. In this regard, other industries have benefited a lot by using progress monitoring & decision support dashboards. Visualization platforms, if employed in construction project monitoring & control process can be useful in improving overall efficacy of construction industry.

1.1 Construction Project Monitoring & Control

Construction project monitoring and control consists of several activities including identifying and reporting project status, detect deviations from project plans, comparing project status with project plans, analyzing areas of defect, and implementing corrective actions (Tengan & Aigbavboa, 2021). Basically, project monitoring and control is all about processes that ensure the project objectives are achievement. A monitoring policy that specifies what, how, where, when, and by whom to monitor is necessary, as are control policies that specify what, how, where, when, and by whom to intervene and correct (Divakar & Subramanian, 2009).

Effective progress monitoring is comprehended as a vital component for projects to be completed on schedule and within budget. Increase in complexity and interdependency of activities in construction projects has increased challenges in monitoring process (Kopsida & Brilakis, 2020). Various factors including task, location of task, sequence of execution, required resources, etc. Change frequently in construction projects. This makes it one of the difficult and demanding job for management to track and monitor progress on any construction project. Besides this, technology is scarcely employed in construction project monitoring which adds to complex nature of process.

Timely reception of actual information on regular intervals is essential for project control ensuring increase in efficiency of the construction project. Information inflow at regular intervals is helpful in identifying problems at an early stage, preventing foreseeable delays in case of interlinked tasks, and taking on time decisions to rectify the issues (Few, 2007). Moreover, filtering useful information without undermining the reliability and correct nature of information is vital for project control activities. Hence, efficient on-site data collection, timely data analysis and information transfer in a well interpreted way are major concerns for construction organizations.

Despite the importance of information systems, the construction industry does not have efficient information technology systems compared to other industries. This causes huge hindrance in data reception & analysis besides providing easy to understand information to managers (Wu et al., 2021). Data analysis and information flow is critical as managers spend 30 – 50% of their time in recording and analyzing data due to the manual nature of monitoring and controlling methods and thus, they are distracted from other important tasks.

The means of representing discrepancies in any key performance index is major factor to facilitate decision making for corrective actions. Platforms for visualization of reports, returns and analytical results, etc enhance decision making ability of managers. Research shows that descriptive and explanative tasks consume about 35% and 42% of time in meetings and only 12% and 11% of the time evaluation and decision making is done respectively (Wu et al., 2021). This delay in evaluation and decision making are caused by the lack of adequate means to visualize and represent information extracted after data collection and analysis.

Apropos, there is need for development of progress monitoring & problem-solving platforms for construction industry. These platforms will help in well-coordinated and efficient project control by providing efficient and timely data visualization. This will help reduce time for decision making, control actions and dealing with exceptions in a reduced time and under controlled costs.

1.2 Research Gap

Researchers have worked on importance and usage of Performance Management Dashboards. Research in recent years has focused on acceptance of performance management dashboards by professionals, need of dashboards and dashboards as a tool to increase efficiency (debusk et al., 2003). Unfortunately, areas like impact of dashboards on project management, faster decision making, one window access to projects' performance, better communication, real time tracking of business situation, receipt of updated reports of projects and use of dashboard as immediate problem-solving tool is not prime focus of researchers (Few, 2007).

Research shows that construction industry lacks a properly planned visualization platform. When it comes to developing visualization platform, there are two main components that need to be focused i.e., Functional Features and Visual Features (Verbert et al., 2014). Functional component is relates to the part which decides what functions can be performed. Contrary to this, visual component refers to how the data will be actually visualized i.e., what type of tool/ software is used for visualization, how effectively data is presented to the user, factors effecting perception of users, etc.

Besides this, the level of control allowed to every hierarchical level still needs to be planned. The decision hierarchy matrix needs to be developed to show which hierarchical level can make decisions up to what extent, about what problems and what problems they cannot interfere in. This needs planning for exceptions and developing multi-level information access criterion. Management by exception (MBE) concept must be used to increase efficiency of decision-making process (Judd et al., 2019). In this way, top management may not be indulged in every problem that arises and majority of problems may be dealt with at lower hierarchical levels.

Another area requiring attention is filtering the inflowing data and allowing only useful information to pass through. Construction industry, as mentioned earlier, produce a large amount of data and obviously all of it is not required while making decisions(Lee & Pena-Mora, 2016). Manual shortlisting of the useful data and selecting what information to pass through can increase inefficiency due to human interference. Moreover, it is a hectic and time-consuming effort which will hinder the fast-decision-making process. Without suitable planning, information may not be utilized properly, and efficacy of decision-making process may be affected.

Moreover, the critical success factors that must be visually available on the dashboard are not researched on, leaving a gap in this field. Mostly, the golden triangle rule is applied to measure and manage progress and success of construction projects and industry. But research has shown that cost, time and quality are not the only considerable factors and other factors affecting success of construction projects must be considered to keep up with ever growing challenges of industry (Durdyev et al., 2017). Other factors besides cost, time and quality, if considered and dealt with properly can increase success percentage of construction industry to great extent.

This research focuses on development of Problem-Solving Visualization Platform using concepts of Management by Exception (MBE). The platform once developed will help management of any construction organization to make project related decisions and select best possible solutions for the specific problem. Moreover, it will help management to be apprised in real time with progress on projects and all arising problems within the organization.

1.3 Problem Statement

Construction industry depends on large amount of information for all its processes. Extracting useful information from humungous stature of data and presenting it to management in an easy-to-understand way is a challenge (El-Mashaleh et al., 2017). Unfortunately, construction industry has not made full use of information technology and lacks platform for effective reception & visualization of information (Kopsida & Vela, 2015). Problems like sluggish decision-making process, error prone & ambiguous information besides loss of information during transfer are caused by absence of data transferring & filtering mechanism and properly planned information visualization methods (Ma et al., 2020). This suspends managers' capability to identify deficiencies in an early stage, prevent potential upcoming delays in case of interlinked tasks, and make timely decisions for corrective actions (You & Wu, 2019). Additionally, professionals with less experience and lower stakes in performance of projects are assigned responsibility to handle multidimensional problems. A platform which can filter useful information for multi-level decision making process is absent. This cause abrupt decision making which worsen the problem instead of solving it.

1.4 Research Question

The research gap and problems identified in earlier paragraphs can be solved by organizing and displaying project success parameters in a manner that gives an exhaustive yet concise snapshot of project performance & shortcomings for timely decision making. The following questions will drive this research to achieve the final goal: -

- What are the parameters that define success or failure in construction industry and how are they measured?
- How should the data be organized and displayed to support decision making process?

1.5 Objectives

Construction industry being one of the largest industries has a major contribution in country's economic growth. Construction industry currently handles deals with data in bulk which will increase manifolds as use of technologies is increased. This huge influx of data is a headache for construction management professionals. A fully automated platform supported by suitable decision support systems for presenting information enabling effective decision making is a viable option to improve this situation. Development of problem-solving platform will go through following research objectives: -

1.5.1 To identify project parameters critical in determining the success of a project

Construction Projects generate data in millions of bytes, but all this data is not useful when it comes to project monitoring and control. Updated and accurate information is required to take time bound decisions for streamlining the project performance in construction industry. For this to be achieved, all project data necessary for decision making must be known, so that no information gets ignored by management while making decisions and planning the way forward for the project. To induce proper planning and meeting this objective, extensive literature review is required. Identification of project data necessary for timely decision-making necessary to avoid project failure must be the first step towards development of problem-solving platform.

1.5.2 Developing Visualization Platform for Effective Management through Exception

Top Management in any construction organization has to deal with variety of complex tasks. From planning to execution and from monitoring & control to project closure, management have immense busy schedules. Involving in every bit of variety of projects is not possible. This is where management by exception (MBE) comes into play. In this step framework for visualization based problem-solving platform enabling MBE will be developed for effective management of problems that arise on minute-to-minute basis.

1.5.3 Validation of Developed Platform using Expert Opinion

Validation of the approach applied for the research and its findings is a necessary part in any research endeavor. Validation is done to make sure that every stage of the selected research approach strictly complies with the highest standards of quality. Validity is the standard by which the planning, carrying out, and evaluation of research are judged. In this step developed dashboard will be presented to experienced construction professionals and their expert opinion will be utilized for the validation purpose.

1.6 Organization of Thesis

This thesis consists of five chapters with chapter 1 presenting an introduction to development of problem-solving platform, chapter 2 covers literature review. Chapter 3 explains detailed methodology used in the research and chapter 4 describes results and analysis. The final chapter presents the recommendations, conclusions and related future research that can be based upon this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Managing Performance of Construction Project

Managing performance in any project is the process of aligning project goals and objectives to organizational goals, while keeping in view the individual and departmental goals. Project performance shall not be limited to task execution rather it should be considered as a bigger picture (J. F. Yeung et al., 2009). The performance management schema includes three steps, i.e., a) linking projects to strategic goals of any organization, b) tracking the performance of your projects over time and c) reviewing projects till completion with intentions of making improvements in future.

Construction projects are executed in dynamic environment. The nature of construction industry is always characterized by uncertainties in budgets, less use of technology, time constraints, communication gaps and numerous other factors (Ullah et al., 2016). Due to this complex, dynamic and uncertain nature of construction projects, the project teams face immense challenge to keep project performance issues under control (Toor & Ogunlana, 2010). Use of technologies for performing different types of construction activities have helped project team to overcome these challenges but there is still room available for improvement.

2.2 Project Performance Issues

In past, construction projects were linked with three constraints mainly i.e., time, cost and quality. Construction professionals have been noticed many times mentioning that the project was delivered on time, within budget and at the required quality (Lempinen, 2012). By now the project managers and project sponsors just do not believe it anymore.

Development of numerous factors for measuring performance in other industries has caused a decline in confidence on golden triangle rule which is widely being used in construction industry. Construction professionals now feel the need to employ variety of performance measuring factors.

Many project managers falsely believe that monitoring and control are one and the same thing and that the monitoring revolves around budgets and plans. Monitoring reports are for project managers and sponsor to have summary details on what has been achieved in the project (Nassar & abourizk, 2014). Basically, the reports deal with history of project, no matter how recent it is. On the other hand, control is acting in response to these reports. Control includes what a team has learnt from past and how will they respond to any problem that arises.

Project progress monitoring in past had to deal with basically three factors or constraints as mentioned earlier. But as the complexity and dynamic nature of construction industry increased, the project managers have noticed the fact that many other factors need to be considered in order to improve and increase efficacy of construction industry as the complex nature of industry has amplified (Ullah et al., 2016). If we look at the problems or hindrances a project team has to face in today's dynamic construction industry, we find that there are a lot of points to ponder upon.

One of the problems mostly faced by project team and managers is scope creep. As defined by PMBOK, increase in scope of work without consideration of its effect on time, costs, resources and increase without taking all stakeholders in consideration is scope creep. Basically, scope creep relates to increase in project's requirements over project lifecycle (Doloi et al., 2012). This means the project which started with simple one deliverable now becomes five or six deliverable projects. Besides this, extra time and cost for the deliverables are not under consideration.

Effective communication in the project management is extremely important for a successful project. Project managers need to have timely and transparent method of communication to ensure that all stakeholders are involved in the process (Majrouhi Sardroud, 2015). Deloitte states that 32 percent of construction professionals believe that communication is the biggest issue of the project management. Project managers often rely on various collaborative and project management software available in market to ensure that everyone stays updated (Saad ul Haq, 2013). These software help project managers to some extent but cannot cover all areas of complex construction industry.

One of the most important prerequisites for a successful completion of a project is the clarity of its goals and objectives. When this is lacking, a number of project challenges arise. According to a survey, a lack of planning and clearly defined project objectives causes 39% of projects to fail (Lamptey & Fayek, 2012). Once the project plan is not clear and communicated to every team member the project will be easily manageable for managers and achieving planned goals will be easier. Besides this, a project with poor plan will be difficult to execute in addition to poor monitoring of goals, as a thing not planned cannot be tracked or monitored to that extent.

Budgeting issues are one of the biggest hurdles in effective project management. A study in 2017 revealed that 49.5 % of managers consider costs as the biggest project management challenge they face (Chan et al., 2018). By efficient cost management, a manager can avoid various common complications a project may face and strive for better and quicker results. It is necessary to adopt a proper budgeting procedure and make realistic assumptions to avoid cost overruns. Planning the project scope must be done keeping in mind the budget in hand. Else, budget limitations could threaten the very success of a poorly budgeted project.

A chain is as strong as its weakest link and in the case of project teams, performance highly depends on their individual skill levels. As a project manager, you can create the most ideal environment but if the team does not possess the necessary skills to tackle the problem at hand, your project is bound to fail (Unegbu et al., 2022). This is a huge project management problem that can only be solved with proper experience and foresight. Project managers pre-assess the skill set of current available resources and determine the need for additional staff and skillset.

Having the foresight to identify potential 'what if' scenarios and making up contingency plans is an important aspect of project management. Projects rarely go exactly as planned because there are so many variables that can create unlimited possibilities (Toor & Ogunlana, 2010). It is the job of every project manager to come up with alternate plans that the team may adopt if the project begins to spiral out of control. Having a proper risk management system helps in identifying the types of risks and mitigating them. Unfortunately, there is lack of risk mitigation system in construction industry.

When each member of a project team assumes responsibility and works to carry out their specific task, the team as a whole performs well. An entire project can fail if team members lack accountability. Effective project managers delegate tasks to team members and guide them towards the shared objective of finishing their project on time (Dave et al., 2016). Having a platform or a project tool that allows responsibilities to be assigned and tracked is key to fostering accountability. Additionally, having regular check-ins within the team also fosters accountability. This area is not focused on by project managers and causes serious performance issues.

Project managers must make sure that all project stakeholders are in agreement and have a clear understanding of the project. It's crucial to take into account customer feedback and keep them informed at every level of the project because an uninvolved client might lead to significant issues in the project's final stages (Windapo & Qamata, 2015). Project managers should conduct regular meetings with client and other stakeholders so they can actively participate in shaping the project and providing feedback. Further, project managers should keep all internal and external stakeholders in the loop right from the project planning stage. Scheduling regular meetings with all stakeholders and addressing their concerns are important to improve performance on projects.

Having an impossible deadline is another project management challenge that can severely affect the quality of the end product. Any effective project manager knows the capability of the project team and negotiates the project timeline by prioritizing deadlines and project tasks (Ali Musarat et al., 2018). A good project performance management technique is to decide timeline of projects collectively by taking inputs from all stakeholders. This task is required to be completed during the planning phase of the project. Further, frequent monitoring of deadlines by the project manager is a must.

These mentioned problems are what seems to be basic in nature and their scale may seem smaller but once these problems start to grow there is no stopping that. These and many other issues not discussed here can be rectified by use of automated monitoring and control systems. The problems if treated on earlier stages can help successful, in time, on budget completion of construction projects and desired results can be achieved for any organization.

2.3 Critical Success Factors (CSFs) & Metrics

Researchers are now emphasizing the need of identifying Critical Success Factors (CSFs) to measure success in construction projects. On the other hand, there is a group of researchers who do not believe in this notion (Tengan & Aigbavboa, 2021). They claim that there is unique set of Critical Success Factors (CSFs) for each project which are not transferable to any other project. This disagreement is based upon perception of project success. Users or end customers are more interested in whether the project goals were achieved or not, whereas the parties involved in construction phase of any project are interested in knowing what they are getting out of the project (Banihashemi et al., 2017).

The success of construction projects depends on a number of elements, including those relating to people, projects, project management, and the external environment, etc. Different performance indicators can be considered to measure success in any project (Williams, 2015). These performance metrics are constructed using a variety of criteria, including time, cost, client satisfaction, quality, client changes, company performance, health and safety, and others. Cost, time and quality are factors that are in use since long but they are becoming obsolete now as project managers need variety of critical success factors to measure performance on projects.

Different CSFs are developed by researchers which help in measuring and monitoring success of any project and organization. CSFs are often referred as success indicators as measuring success reveals performance of any project team (Kiani Mavi & Standing, 2018). Success is basically defined as the degree to which goals and objectives of any organization have been achieved. Success can be viewed from different perspectives and every individual in organization may have different perspective of success. This makes success intangible and make success measurement a critical activity (Kiani Mavi & Standing, 2018). Similar phenomena is faced by construction organizations as client, consultant and contractor have different perspectives when it comes to success of any project. Measuring performance includes quantification of efficiency and effectiveness of actions. A performance measurement system is a useful tool when it enables assessment, provides useful information and detect problems and provide judgment on certain predetermined criteria. For the above-mentioned reasons and discussions, this research focuses on identification of CSFs in order to measure success. The 37 CSFs relating to construction industry were identified after a thorough and extensive literature review. Table 2.1 contains the identified CSFs and their sources.

Metrics are distinct from CSFs in that they only keep track on the progress of a certain business process. Metrics are different factors or variables that define result/ value of any CSF. Metrics are just a system of measuring CSFs. So, we can say that several metrics group together to give a collective result to any CSF. That result will suggest weather any business is going in correct direction or not, based on that specific CSF under consideration. Basically, the CSFs are a tool for top management to track performance, organizational goals and objectives while metrics are several values calculated on the base of data provided by the operational staff. As mentioned earlier the CSFs for performance management and monitoring of construction projects were identified after extensive literature review. After that related metrics for each CSF were identified and shortlisted.

Table 2.1: List of Critical Success Factors related to Construction Industry

	Research Paper Code	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25
Ser	Key Performance Indicators (KPIs)/ Project Performance Measures	Unegbu 2020	Jeffrey 2020	Anwar 2019	Reza 2018	Banihashemi 2017	Williams 2016	Sibiya 2015	Ramlee 2015	Gunduz 2015	Tarhini 2015	Costantino 2015	Harris 2014	Ameyaw 2014	Gudienė 2013	Akintoye 2013	Mbugua 2013	Saqib 2010	Chua 2010	Toor 2009	Chan 2009	Shams 2008	Aksorn 2008	Egbu 2007	Chen 2007	Chiang 2007
1	Scheduling	✓			✓		✓	✓	✓	✓	✓		✓			✓	✓	✓			✓		✓	✓	✓	
2	Profitability	✓																								✓
3	Project Planning & Control	✓	✓			✓	✓											✓			✓		✓			
4	Resource Management	✓	✓	✓		✓			✓	✓	✓	✓	✓		✓				✓						✓	
5	Risk Management	✓				✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓			✓			✓		
6	Quality Assurance	✓		✓	✓		✓	✓	✓	✓			✓				✓	✓	✓	✓						
7	Client Satisfaction	✓	✓	✓			✓	✓			✓									✓	✓				✓	
8	Safety Management	✓		✓			✓	✓		✓		✓					✓				✓		✓		✓	
9	Time Predictability	✓	✓															✓			✓				✓	
10	Productivity	✓		✓																				✓		✓
11	Cost Predictability	✓	✓			✓	✓		✓				✓	✓	✓	✓		✓	✓	✓	✓					
12	Procurement Management	✓	✓			✓				✓				✓		✓							✓			
13	Construction Cost & Reliable Estimates	✓		✓	✓		✓	✓	✓		✓		✓					✓			✓				✓	
14	Low Defects in use	✓					✓	✓													✓	✓		✓		
15	Human Resource Management	✓	✓			✓			✓		✓	✓			✓		✓		✓	✓						
16	Clear & Written Detailed Contract		✓			✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓			
17	Stakeholder Management		✓		✓	✓		✓	✓		✓				✓					✓	✓					
18	Competent Project Management		✓	✓		✓			✓	✓	✓			✓		✓						✓		✓	✓	
19	Communication & Relationship Management		✓				✓				✓	✓	✓		✓	✓	✓	✓	✓	✓						
20	Client Responsiveness & Involvement		✓		✓	✓				✓	✓		✓			✓	✓				✓	✓	✓			
21	High Quality Workmanship		✓			✓					✓						✓				✓			✓		
22	Management Capability of Managers		✓			✓					✓	✓	✓	✓	✓	✓	✓	✓	✓					✓		
23	Learning from Previous experiences		✓			✓			✓	✓	✓															
24	Feedback Capabilities in the System		✓																				✓			✓
25	Utilization of Technology			✓	✓					✓			✓											✓		
26	Organizational Accountabilities		✓	✓					✓		✓	✓		✓			✓					✓		✓		
27	Project Site Environment			✓			✓																			✓
28	Claims Management				✓															✓			✓			✓
29	Dispute Management				✓		✓						✓	✓		✓	✓			✓		✓				
30	Compliance with Anti Corruption Rules					✓							✓													✓
31	Scope Definition & Lesser VOs					✓	✓	✓	✓				✓			✓	✓	✓	✓	✓		✓	✓			
32	Fast Decision making process									✓	✓		✓				✓								✓	✓
33	Facility Management						✓							✓								✓				✓
34	Innovation						✓																✓			✓
35	Lesser no of Accident									✓			✓		✓							✓				✓
36	Project Size & Level of Complexity						✓			✓	✓		✓									✓		✓		

2.4 Decision Making

The researchers often argue that management is basically a decision-making process. The basis of this argument is that decisions made by management of any organization help achieving short term and long-term goals and objectives for the organization. Decision is an act of selecting best possible solution from various available alternatives (Dave et al., 2016). Decisions are process of selecting right and effective course of action for achieving desired results. Decision making is simply a sense of management.

Managers are required to make decisions regarding planning, organizing, directing, coordination and control in any organization. The enterprise operators execute decisions and options selected by managers during decision-making process. The performance of any business is based upon decisions regarding objectives, goals, strategies and policies of any organization besides organizational structure (Tengan & Aigbavboa, 2021). Decisions are not only required to tackle and solve problems faced by any organization, but they are important to maximize the advantage of any available opportunity. Correct decisions help organizations to reduce complexity and uncertainty in their business.

Decision making process contains at least three types of processes. The managers decide what to do based on conscious and deliberate logic and judgment. A manager is required to make decisions when various alternatives are available. No organization hires a manager to make decisions where there is only one option available. Managers are responsible to guide organization in the direction that will help to achieve goals and objectives of that organization (Li et al., 2015). Managers analyze various available alternatives and select the best option to achieve organizational objectives. All these processes combine to complete decision-making process for any organization.

2.4.1 Principles of Decision Making

Researchers have defined some principles of decision making which must be kept in mind while making any sort of decision regarding organizational objectives and goals. To increase effectiveness of any decision, purpose of that decision and environmental situation of that decision must be kept in mind (Rankin et al., 2008). If these things are not considered, then the best and correct decisions may become ineffective. This is because every decision has many inside and outside reactions which govern the circumstances that are formed.

When it comes to decisional matters or problems there are two types a) programmed problems and b) non programmed problems. The problems which are of routine nature, repetitive and are well founded do not create much trouble while making decisions. This is because these problems are well defined, and their related solutions are predefined. But in case of non-programmed problems the problem and the related solution is not predefined, and non-programmed problems require special attention while making decisions (Willis et al., 2017). Non programmed problems have special features and circumstances, and decisions must adhere to those circumstances.

Besides this, it is important to understand organizational structure before making any decisions. If organizational structure is centralized and rigid in nature, organization is expected to have confined decision-making authority restricted to top management level only. Such a decision-making process creates problems for employees (Hasija et al., 2019). In contrast to this if organizational structure is flexible, the decision-making process will be divided upon several operating centers and decentralization of decision-making process will help organization to cater problems of various nature in very short time. Planned decentralization of decision-making process increases efficiency of whole organization.

Before making decisions in any organization, objectives and policies of that organization must be understood in detail. This will increase productivity of decision-making. Besides this, analysis of merits and demerits of every alternate is important. This must be done to select the best suited option out of different available alternatives. For decision-making process to be effective policies, goals and objectives of organization must be communicated to every employee of organization. Without proper setting out of goals and objectives by any organization, decision-making process cannot be improved.

2.5 Management by Exception (MBE)

Management by exception is a process of managing organizational goals and objectives by analyzing the results and notifying the top management about substantial difference between planned and actual achieved. The purpose of management by exception process is to involve management when deviation from planned objectives cross a certain limit (Ricketts & Nelson, 2017). This process can be made more efficient by planning which hierarchical level will handle what type of deviation.

If we look at the benefits of using management by exception, we can say that it reduces the number of objectives, goals and results that must be reviewed by the management at each stage (Judd et al., 2015). This help in increasing efficiency of management and make best use of management time. The exceptions will be preplanned and dovetailed in every report generated. In this way, the managers can have a complete snapshot of areas which require decisions regarding control measures. In this way management will control and inquire deviations which they are responsible for and reduce wastage of time on minimal issues.

As with all other things management by exception have some drawbacks too. Management by exception is based on formulation of goals and objectives for any organization and comparing those with the actual results (Lamptey & Fayek, 2012). If the goals set out by any organization are not realistic, there will be huge number of deviations which will result in wastage of time when investigated. Management by exception is about planning which deviation will be catered at which management stage. If the decision-making hierarchy is not planned properly, decision making process will be affected. It is true that if front line employees are allowed to handle any deviation, then a lot of time can be saved but the stature of deviation they can deal with, needs to be planned.

2.5.1 How Management by Exception Works

There is a need to understand how Management by Exception works. The Management by Exception is based on four steps which are explained as under: -

2.5.1.1 Setting Objectives

Setting reasonable goals to serve as a benchmark is the first stage in the management by exception method. Many organizations usually analyze past performances and records to determine the correct goals and objectives for the organization. Managers must try to divide bigger goals into smaller achievable parts and must review the progress on regular basis (Haslam et al., 2017). Allowing for large time intervals between two analyses can cause huge problems at later stage, so the goals and objectives must be planned in a way that they can be analyzed and monitored on daily basis and variances can be identified.

2.5.1.2 Assessing Objectives

After planning goals and objectives for the organization, the next important step is to assess progress on those objectives. But for an effective analysis which leads to better control of organizational goals, there is a need for accurate and real time performance records collected and analyzed on regular basis. Automated record keeping and analysis can be employed because gathering a lot of data manually can take more time than management by exception is designed to save. So, the software and platforms that produce results after monitoring and analyzing the workflow data should be used for that process.

2.5.1.3 Analyzing Deviations

There is a very little chance that a manager will get results that match the targets down to the last detail. So, when a manager is analyzing the reports, he will reach one of the two conclusions a) there was no significant deviation, and no further action is required and b) there are several deviations which are significant and require action. A manager must be aware of who will take the necessary action and what information should be reported to top management. When a deviation is identified, the analyst must take a look into the reasons for the deviation before reporting that to the upper management. As the deviation can be a reason of wrong data entered into the system.

2.5.1.4 Resolving Exceptions

Any organization's management will have full knowledge of which performance standards have not been met, what boundaries have been exceeded, and why the deviation occurred once it is made aware of the deviation. The management must choose what corrective measures to take. The management must also determine whether the deviation is likely to recur and whether it has an influence on other targets. Managers must regularly review and revise standards due to the dynamic nature of company nowadays.

2.6 Decision Support Systems

When a project is under execution, Project managers need correct information on regular basis to measure and monitor construction performance. Managers also require timely analysis reports which assist in decision making process for managers. Research shows that most of the time is wasted on data collection rather than analysis and reports generation(Pinha & Ahluwalia, 2019). Managers need more and more information, but analysts can provide minimal information at a high cost within desired time frame. In order to provide information required for trend analysis and performance measurement, an intelligent decision support system must be used.

Decision support system (DSS) is a computer-based data collection, analysis and report visualization platform which helps managers to decide course of action in any organization (Ma et al., 2020). DSS works on massive amount of data and compile comprehensive information that can be used to solve problems and make decisions. DSS mostly require information about planned goals and objectives besides facts and figures about organizational and project performance.

Main purpose of using a DSS is to present information in such a manner which is easy to understand and work on. DSS can be programmed to generate various kinds of reports usable by management in variety of ways (Ullah et al., 2016). Due to advancement in technology, data analysis and visualization is no longer a tedious task and simple DSS software can be installed in computers and even in cellular communication devices. This makes DSS flexible in terms of data availability and information gathering at any place in any period of time. DSS keeps managers always updated, well informed and increase their ability and efficiency of making decisions.

There are various types of decision support system available in market and are being commonly used. Some of the important and most used decision support systems are discussed in following paragraphs.

2.6.1 Communication Driven DSS

Communication driven DSS are used for internal communication in any organization between employees and partners also. This type of DSS help in conducting meetings and collaboration between team members besides information sharing. These types of DSS are mostly web based or a client server. Online collaboration tools, chat and instant messaging software, and net-metering systems are more examples of communication-driven DSS.

2.6.2 Data Driven DSS

Data-driven DSS primarily use representational, optimization, and accounting and financial models. These type of DSS mostly focus on representation and manipulation of information for use in decision support. Different types of graphs and information visualization techniques are used to help manage, staff and service providers to be on top of decision-making process.

2.6.3 Document Driven DSS

These are the commonly used type of DSS. These decision support systems use data storage and processing technologies for document analysis and retrieval. They help manager and staff in finding any type of document from a huge amount of data. Best example of document driven DSS is search engine which are most commonly used nowadays.

2.6.4 Knowledge Driven DSS

Knowledge driven DSS are also known as advisory or consultation or suggestion systems as they provide suggestion and recommendation to managers. These DSS provide problem solving expertise in a particular domain of knowledge area. These DSS can perform classification, configuration, diagnosis, planning, interpretation and prediction activities that would otherwise depend on human expertise.

2.6.5 Model Driven DSS

Model driven DSS is a complex type of decision support system which help in choosing best option out of different available alternatives. These DSS are mostly used by managers and staff members of any organization or external persons communicating with any organization. These type of DSS can be developed on standalone personal computers or web-based client servers.

2.7 Dashboard & Visualization

Dashboard is a system that help visualize data and information to help in decision making. Dashboard is designed in a way that aligns with organizational and personal goals. Dashboards have an objective to inform the user while not disturbing users from their actual task (J. Skibniewski, 2014). For this reason, data is summarized using charts, tables, gauges and so on. Dashboards also have an option to visualize original data, on which summarization was based, making it easy for the user to interpret the provided information.

A dashboard must be designed in such a way that it is easy to use and visually appealing. The visual interface that defines what users can see and what activities a user can perform on screen is an important factor during use of performance dashboards (Kim et al., 2013). If a dashboard is difficult to use and consumes a lot of time to perform simple activities, then performance dashboard is of no use as workers will avoid using dashboard and will utilize other sources to obtain the required information.

The team responsible for designing dashboard should be aware of user needs, expectations, and limitations earlier in design process. To put it simply, one can say that a pretty face sells a performance dashboard. This means that humans are more excited to use a dashboard which contains their concerned metrics wrapped in fancy graphics. But this one factor alone does not define success of performance dashboard. Design team must be vigilant enough to interact with users and indulge them in design process at earlier stage.

2.7.1 Types of Dashboards

There are three different types of dashboards which are discussed in detail below:

2.7.1.1 Operational Dashboard

Operational dashboards are used by frontline users to monitor and control day to day activities and events. This dashboard is used when data is constantly changing. Operational dashboards help users to react to deviations immediately and make short term decisions. Data used in operational dashboards is more real time, describing what is occurring in the business at the moment.

2.7.1.2 Strategic Dashboard

Strategic dashboards provide an at a glance overview of metrics that are important to monitor business performance. Strategic dashboards support decision makers by providing insight about challenges and opportunities to the management. Strategic dashboards refresh at a slower rate as compared to operational dashboards. Their purpose is to serve top management of any organization and keep them updated about videos Critical Success Factors and metrics of performance.

2.7.1.3 Analytical Dashboard

Analytical dashboards provide access to drill down data and support root cause analysis. Analytical dashboards are used for manually analyzing Deviations and their root cause and provide information to react against the analyzed deviations. Analytical dashboards help in investigating trends, predict outcomes, discover insights, and establish targets based on history.

2.8 Design Guidelines

When designing a performance management dashboard, designers need to focus on what information users need and how users will use that information rather than how users want to visualize that information. Designers should focus on optimizing visual interface rather than focusing on screen layouts in earlier stage of dashboard design. There is not a single right or wrong way to design a dashboard. It all depends on the usage and requirements a dashboard has to fulfill.

A dashboard can be used in two ways a) pull i.e. any user requiring information may utilize dashboard to get that information. B) Push i.e. Information is pushed by dashboard to the user for use. In today's fast paced life, Dashboards need to use the push feature to be more attractive and usable by customers (White, 2015). Dashboard must be designed in such a way that it catches attention of users and draw them towards the critical information that dashboard needs to portray.

The challenging task for any dashboard designer is to fit all available information on single screen. Users may not be attracted if they need to Scroll down or open another screen to view critical information. Users need to have a quick look at their required information and may not be interested to use the dashboard if there are distractions and information is not displayed on a single screen clearly (Dave et al., 2016). A designer should focus on packing a lot of information in very limited space and display that on a single screen, without clutter.

In order to place all information on single screen, dashboard designers may need to work on minimizing number of metrics and objects on screen. A designer must have understanding about users' needs like with information they need to monitor, importance of that information, and the order in which user want to see that information. There is no clear rule about number of metrics that should be used on single screen and designers mostly nest lower priority metrics under higher priority ones. Besides this, designers allow users to personalize dashboard and set their priority according to their own needs.

Designers use graphical elements to display lot of information on single screen and summarize it. This helps designers to put actual data in forms of graphical elements which do not take up valuable space on screen and crowd the view. Overuse of graphical elements may render attractive qualities to the dashboard screen, but the dashboard does not communicate pertinent information quickly. Designers should analyze the fact that provided graphics depict clearest, meaningful presentation of data in least amount of space or not (Wu et al., 2021). A small example may include use of thermometers which are linear and fit in compact space in place of gauges which are circular and consume a lot of space.

2.8.1 Human Behavior

Importance of data visualization techniques and why data visualization is so effective can be defined if we shed light on concepts of cognitive psychology design, neuro-esthetics and science of decision-making persuasion. Cognitive psychology focus on science of how people think and process, use language, attend to information, and perceive environment (Yigitbasioglu & Velcu, 2012). Neuro-esthetics deals with study of how art and aesthetic experience change the body, brain, behavior and how knowledge is translated into specific practices and actions by humans.

Another important discussion is how uniquely powerful power of sight is and why visualization is the focus in this study. When amount of information each of our senses can process in one second was studied, the bandwidth of human senses, it was noticed that the sense of sight wins the race. It may be noted that sight provides the highest bandwidth human brain can process in one second and that equals the bandwidth of any computer network. Figure 1 shows the relative bandwidths of all human senses as researched by Danish physicist Tor Norretranders.

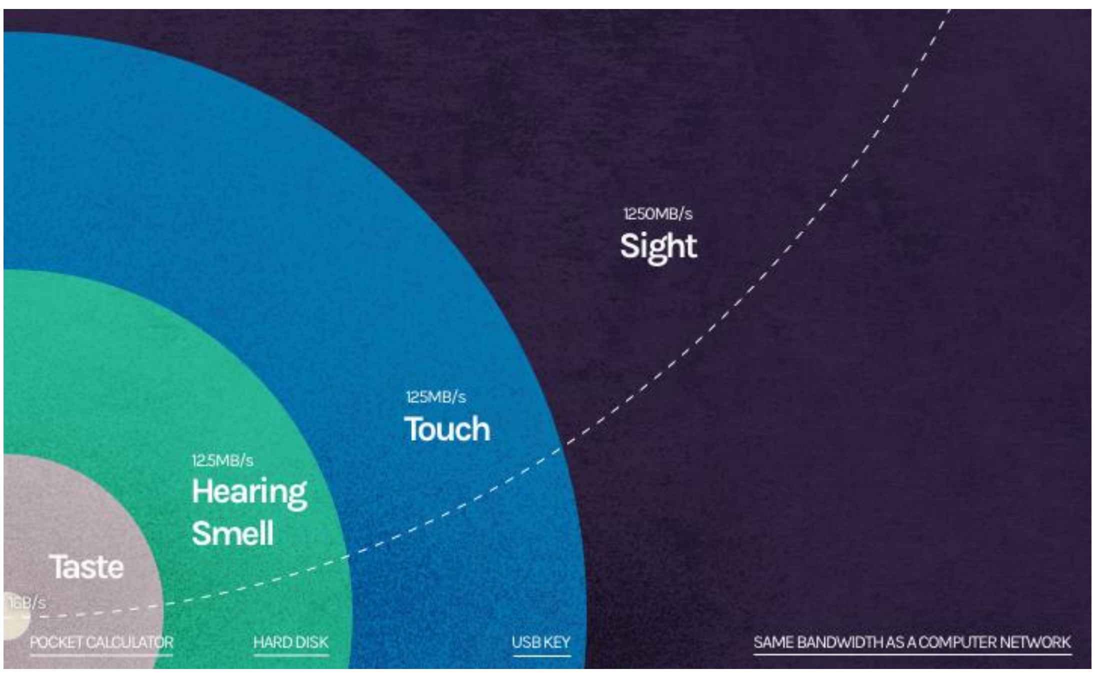

Figure 2.1 Relative Bandwidth of all Human Senses

2.8.2 Gestalt Principles

Gestalt principles, an idea originated in late 20th century, was based on the idea that human brain always try to simplify and organize complex images and designs into organized system that creates a whole, rather than just a series of disparate elements (J. F. Yeung et al., 2009). Human brain is built to see patterns and structure in its environment and give meaning to every pattern and structure. There are six individual principles described by Gestalt theory. These concepts govern the designs and structures of every graphics and visuals today. The concepts of Gestalt theory are discussed in detail in succeeding paras.

Similarity is the first basic concept described by Gestalt Theory. This Concept states that human mind will always group similar things together regardless of their proximity to each other. Similarity maybe based on color, shape or size of elements and It can be used to connect components that aren't immediately adjacent to one another. In dashboard design one can make dissimilar things to stand out from the crowd. That is the reason button for calls to action are often designed in a different color then rest of a page.

Regardless of how the lines were drawn, according to Gestalt principles, the human eye will always follow the path that is the smoothest. Discontinuation is a valuable tool then some designer wants its customer’s eye to follow a certain direction and place most vital parts within that path.

The third concept explained by Gestalt theory is law of closure. The principle of closure, which holds that the human brain will complete any gaps in a design or image to produce a whole, is the coolest of the bunch. This concept is used in UI design, when a partial image fading off the users screen is shown to depict that there is more to be seen and that sense of closure which is not apparent forces user to scroll in that direction (Song et al., 2016).

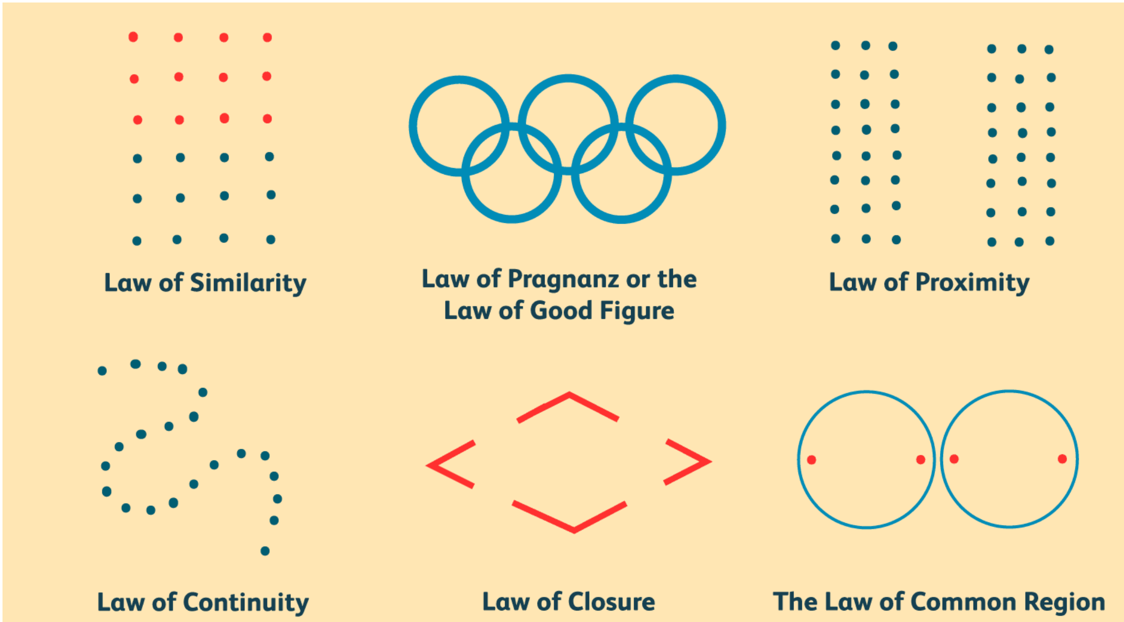

Figure 2.2 Gestalt Principles

Proximity is all about how close elements are to one another. Proximity is used for grouping objects into a single area and capturing the attention of user. Activity proximity is frequently utilized in dashboard design to group items collectively without the usage of sharp borders. Like items should be placed closer together, and there should be space between each group so that viewers can discern the structure and organizational hierarchy that the designer intended.

The law of symmetry and order is known as Pragnanz, a German word for good figure. This principle states that human brain will perceive ambiguous shapes in as simple a manner as possible. The human brain will group together objects that point or are moving in the same direction, according to the common fate principle. This idea is frequently utilized to create the illusion of motion in user interface designs.

2.9 Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis is basically used to reduce/shrink data to small or limited set of summary variables and to find the underlying conceptual structure of whole process. It is a statistical technique which is normally used to find out the correlative relations between variables and to model this correlation with one and more latent variables. A causal relation between manifest indicator and latent variable(s) is assumed in a common factor model – elaborated with all its implications (Zientek, 2008).

To conduct exploratory factor analysis on critical Success Factors identified by thorough literature review, five-point Likert scale was used to conduct a questionnaire survey. Results obtained through questionnaire survey are then analyzed using exploratory factor analysis. Before applying exploratory factor analysis to the gathered responses, some statistical tests are required to be conducted. Details of tests are as under: -

2.9.1 K1 – Kaiser's Eigenvalue

The Eigenvalue represents the total variance explained by each factor. According to K1- Kaiser's Method (Kasim, 2015), factors whose Eigen values are greater than 1 should only be retained. This approach is most used in practice and best known because of its ease of use and theoretical basis. The main purpose of exploratory factor analysis is to produce/retain those factors which understandably and accurately elaborate the observed correlation matrix. Extreme care should be taken while making factor retention decisions in exploratory factor analysis (Ramlee et al., 2016). An array of methods of factor retention exist which include include parallel analysis, Kaiser Criterion and visual scree plot analysis. But Kaiser Criterion is most widely used method and factors with Kaiser's Eigenvalue greater than 1 are considered only.

2.9.2 Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

The KMO test is measure of how suited the data is for factor analysis. This test is used to measure sampling adequacy for each variable in the model. This test depicts proportion of variance among different variables. KMO test returns value between zero and one. For a sample to be adequate, the KMO value must be greater than 0.6. Values closer to 0 depict large partial correlations which are a problem for factor analysis.

Bartlett's test of Sphericity compares observed correlation matrix to an identity matrix. This test is used to check redundancy between variables to summarize them in few number of factors. The test produces correlation matrix comprising all variables. If the produced matrix is an identity matrix then factors are not correlated and variables are orthogonal. If the obtained correlation matrix diverges significantly from identity matrix, then we can say the factors are correlated and fit for implementation of exploratory factor analysis.

2.9.3 Scree Plot Test

Scree plot is a graph of eigenvalues of all factors being used in the analysis. This test includes visual exploration of graphical representation of eigenvalues and checks for discontinuities or breaks. The main purpose of conducting this test is to find out number of factors to retain in an exploratory factor analysis. The line graph produced in scree test is visually checked for a break point or change of slope. The actual number of data points above the break (excluding those points at which break occurs) is exact number of factors that needs to be retained. The logic is that the point divides major or important factors from trivial or minor factors. Scree plot is purely subjective, requiring one's own perspective or judgment.

2.9.4 Factor Loading and Rotation Method

Factor loadings are part of EFA's outcome, and they depict correlations between observed variables by making use of lesser number of factors. Factor loading value greater than 0.6 is suitable for exploratory factor analysis. Results obtained after exploratory factor analysis are hard to interpret because principal axis estimation focuses on computational convenience without taking into account the conceptual clarity (Tarhini et al., 2015).

Rotation of factor is designed to get a theoretically simpler and more interpretable solution by axis rotation within space of factor to bring them near to variables location. Among all orthogonal rotations varimax rotation is undoubtedly the most popular one, despite so many analytic rotations have been suggested.

Rotation will help by minimizing low item loadings and maximizing high item loadings in order to provide a more simplified and interpretable solution. Rotation technique has two types one is orthogonal rotation while other one is oblique rotation (Esmaeili et al., 2013). Orthogonal rotation provides uncorrelated factors. The most common type of orthogonal rotational methods for EFA is varimax rotation which will give a simple structure. In simpler words, varimax rotation (also known as Kaiser-Varimax rotation) maximizes sum of squared loadings variance, where 'loadings' actually mean the correlation b/w factors and variables.

CHAPTER 3: RESEARCH METHODOLOGY

The methodology adopted to develop visualization platform for construction industry has two parts. In first part, critical success factors that govern success of construction industry were identified using literature review and expert interviews. Second part was to develop a framework for visualization platform based on concepts of management by exception and using several visualization techniques. This research followed a three-stage process as shown in Figure 4 and all three stages are explained in succeeding paras.

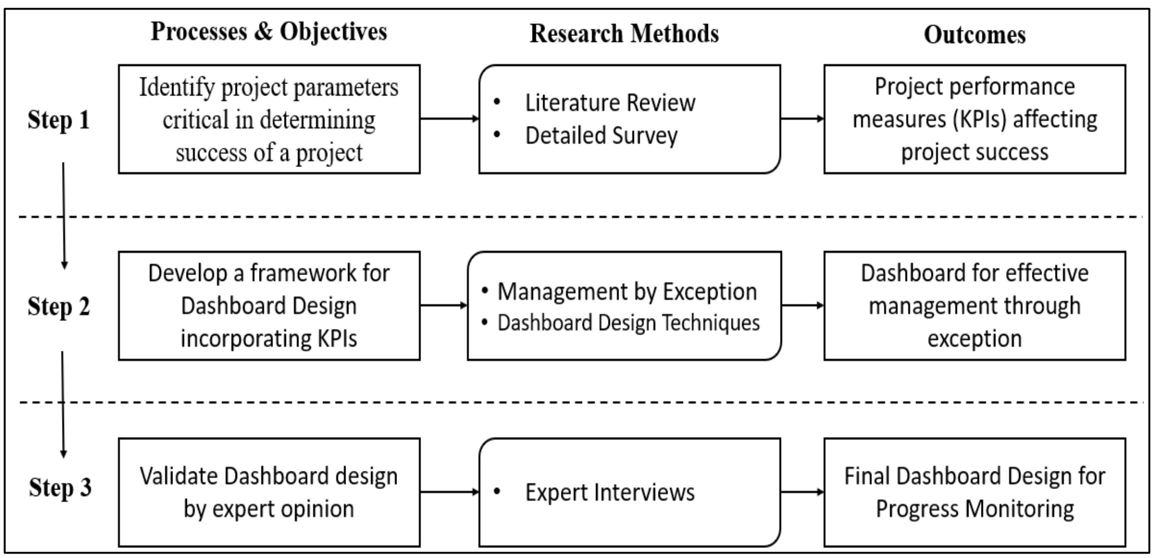

Figure 3.1 Research Methodology

3.1 Research Problem & Gap Identification

First step of this study was to establish research problem and identify gap in the industry. Extensive literature review was carried out using research articles, conference papers and relevant books to establish research gap. Research articles and conference papers related to visualization and use of critical success factors for monitoring performance of construction industry were studied.

Research papers about performance management and monitoring dashboards were analyzed for use of decision support system for management, concept of management by exception, building information modeling, artificial intelligence and dynamic properties in dashboard. Unfortunately, there was no research found which developed visualization platform for construction industry to monitor various critical success factors other than time, cost and quality.

Moreover, there was no hierarchical matrix found during research gap analysis. It was noted that concept of management by exception need to be dovetailed with hierarchical matrix of organization. Procedures for handling problems and discrepancies in day-to-day performance of construction projects must be clearly defined in construction organizations. This helps in monitoring, controlling and identifying problem areas and take corrective actions.

This established our research gap that there is a need for visualization platform which can monitor critical success factors other than the golden triangle rule and depict overall performance of construction organization on single screen.

3.2 Identification of Critical Success Factors & Metrics

After establishment of research gap, next step was to identify critical success factors that govern success in construction industry. Detailed literature review was carried out to identify critical success factors. The total of 25 research articles were studied which discussed performance management, measuring success and key areas of focus to achieve success in construction industry. A list of critical success factors was generated, and frequency of occurrence was noted against each CSF.

A study of the material revealed a total of 37 important success elements. Using a three-point Likert scale (1=Low, 3=Medium, and 5=High), the identified important success elements in content analysis were given a literature score based on their significance and frequency of occurrence in literature, as determined by each individual author. As a result, the literature score for each essential success criteria was determined by multiplying the frequency and impact scores, respectively. Additionally, the literature score was normalized before being used for further investigation. Table 3.1 lists the critical success criteria together with their cumulative score and normalized score.

After detailed content analysis and making a list of 37 critical success factors for construction industry, focus was to reduce no of CSFs as in future all these factors will be visualized on single screen. For this reason, detailed brainstorming sessions were carried out with experts from industry. The experts were selected using technique of judgement sampling which may affect randomness of data. This issue can be resolved if experts from specific field of study are selected. The experts were selected based on their experience in construction management and control fields.

Since it was planned to carry out a detailed survey from experts later in research study, these brainstorming sessions were focused on reducing no of identified critical success factors by either merging the overlapping CSFs or deleting the unnecessary ones. The experts suggested to merge similar CSFs and reduce no of CSFs to properly develop an interactive and easy to use dashboard. Total 30 critical success factors were finalized after detailed literature review and brainstorming sessions with experts.

Table 3.1 Critical Success Factors with their literature score & cumulative score

Ser	Factors	Normalized Score	Cumulative Normalized Score
1	Realistic Scheduling	0.02415	0.02415
2	Profitability	0.03568	0.05983
3	Effective Project Planning & Control	0.01081	0.07064
4	Sufficient Resources	0.01717	0.08781
5	Risk Management	0.02530	0.11311
6	Quality Assurance	0.01650	0.12961
7	Client Satisfaction (Product)	0.02307	0.15268
8	Safety Management	0.02061	0.17329
9	Time Predictability (Project, Design, Construction)	0.01352	0.18681
10	Productivity	0.01556	0.20237
11	Client Satisfaction (Service)	0.02218	0.22455
12	Cost Predictability (Project, Design, Construction)	0.01523	0.23978
13	Proper Procurement Management	0.01027	0.25005
14	Construction Cost & Reliable Estimates	0.02063	0.27069
15	Low Defects in use	0.01243	0.28312
16	Human Resource Management	0.01835	0.30147
17	Clear & Written Detailed Contract	0.02289	0.32436
18	Proper Stakeholder Management	0.02307	0.34744
19	Competent Project Management	0.01873	0.36617
20	Adequate Communication & Relationship Management	0.01800	0.38417
21	Client Responsiveness & Involvement	0.01785	0.40202
22	High Quality Workmanship	0.01181	0.41383
23	Management Capability of Managers	0.01663	0.43046
24	Learning from Previous experiences	0.01384	0.44431
25	Feedback Capabilities in the System	0.02111	0.46541
26	Utilization of Technology	0.01492	0.48033
27	Organizational Accountabilities	0.02200	0.50233
28	Project Site Environment	0.02361	0.52594
29	Claims Management	0.01610	0.54204
30	Dispute Management	0.00865	0.55069
31	Compliance with Anti-Corruption Rules	0.02272	0.57341
32	Scope Management	0.01798	0.59138
33	Effective & timely decision-making process	0.00859	0.59997
34	Better Facility Management	0.01690	0.61687
35	Innovation	0.02254	0.63941
36	Accident	0.00000	0.63941
37	Project Size & Level of Complexity	0.36059	1.00000

3.3 Questionnaire Survey

Online questionnaire survey is an easiest and fastest way to collect data and for the same reason it is most used method to collect responses from industry experts. This research also made use of questionnaire survey for collection of expert opinion on identified CSFs. For collecting the required data, questionnaire was developed through Google forms comprising of two sections. The first section gathered information about respondent’s experience, field of experience, years of professional work and educational background besides current organization. Second section comprised list of critical success factors and experts were asked to rank all CSFs according to their importance. A 5-point likert scale was used for ranking of CSFs with 1 being least important and 5 being most important.

The questionnaire survey was floated to developing countries across the globe through online professional and social platforms like Emails, WhatsApp and LinkedIn. A total of 108 responses were gathered which included experts working from client side besides professionals from contractor and consultant firms. Typically, the central limit theorem needs a minimum sample size of 30 or higher (Chan et al., 2018). The experts had an experience averaging to 12 years and majority of experts were working in contractor firms. The detailed demographics of experts are discussed in results chapter later.

3.4 Statistical Tests

Expert responses were gathered in sufficient numbers, and using simple statistical tools, the responses were checked for consistency and dependability. The consistency and dependability of the gathered data were assessed using the Cronbach's Coefficient Alpha Method. Cronbach's Alpha must be at least 0.6 to be considered acceptable (Wang et al., 2019). The data was collected, and its Cronbach's Alpha value was 0.96, which is a respectable number in terms of data consistency and dependability.

3.5 Underlying Metrics

After finalizing the list of CSFs, the next focus was on how to measure these CSFs. Most of the identified CSFs are not measurable in numeric terms (easy to understand and calculate results) and there was a need to identify underlying metrics for each critical success factor. Detailed literature review was carried out to identify underlying metrics attached with each CSF. The identified metrics helped in giving different numeric measures to CSFs related to construction industry. Identification of metrics is important as numeric values of performance measurement is required when management by exception is employed. CSFs and linked underlying metrics for construction industry are attached as Annex A to this thesis.

3.6 Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) was implemented on the responses gathered against each CSFs. Implementation of EFA was necessary. It was done to group together different factors in order to develop a user interface for visualization platform/ dashboard. Before implementing exploratory factor analysis different statistical tests like scree plot, eigenvalues, KMO test and Bartlett test of sphericity were carried out. After these tests proved that the sample data is fit for implementation of exploratory factor analysis, only then test was implemented on data.

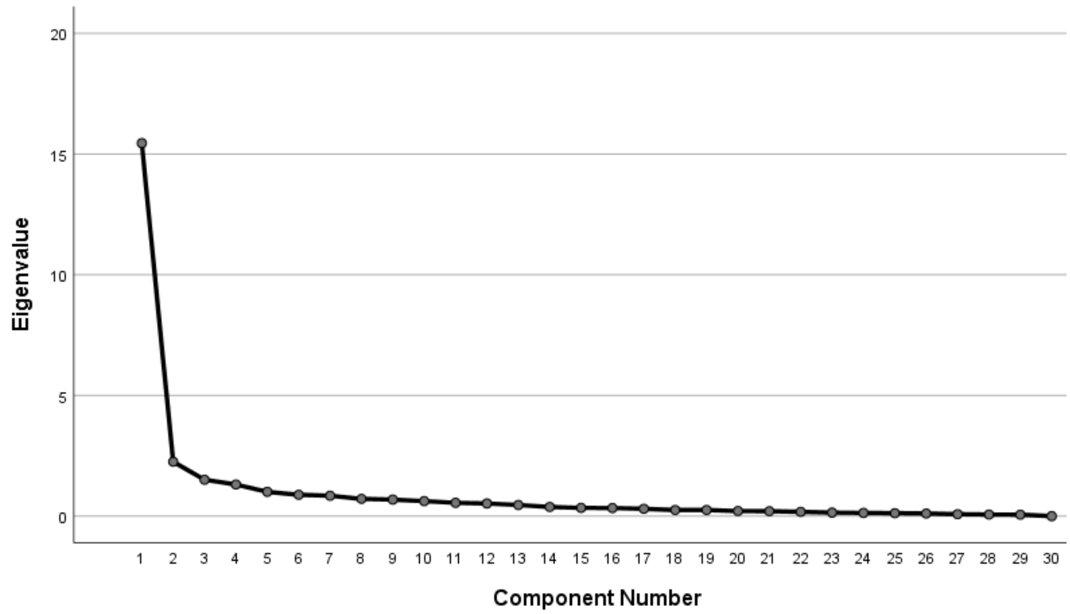

Figure 3.2 Scree plot

When the questionnaire survey results were analysed using EFA, 30 CSFs were sorted in 5 groups. Before implementing exploratory factor analysis different statistical tests like scree plot, eigenvalues, KMO test and Bartlett test of sphericity were carried out. EFA was implemented on the data after these tests proved that the sample data is fit for implementation of exploratory factor analysis. Screenshots of SPSS are attached in figure 5 and figure 6 below. The 5 constructs shortlisted by EFA and linked CSFs along with underlying metrics and planned exceptions are shown in Annex A to this thesis.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.451	51.502	51.502	15.451	51.502	51.502	6.189	20.629	20.629
2	2.252	7.506	59.008	2.252	7.506	59.008	5.922	19.738	40.367
3	1.508	5.027	64.035	1.508	5.027	64.035	4.601	15.336	55.703
4	1.310	4.366	68.400	1.310	4.366	68.400	3.238	10.794	66.497
5	1.005	3.352	71.752	1.005	3.352	71.752	1.577	5.255	71.752
6	.886	2.953	74.704						
7	.845	2.818	77.522						
8	.716	2.385	79.908						
9	.685	2.283	82.190						
10	.622	2.073	84.264						
11	.553	1.844	86.108						
12	.524	1.745	87.853						
13	.462	1.539	89.392						
14	.382	1.274	90.666						
15	.342	1.140	91.805						
16	.335	1.117	92.922						
17	.302	1.006	93.928						
18	.257	.857	94.785						
19	.253	.844	95.629						
20	.211	.703	96.332						
21	.205	.684	97.015						
22	.177	.589	97.605						
23	.147	.489	98.093						
24	.132	.441	98.535						
25	.122	.407	98.942						
26	.110	.366	99.307						
27	.081	.269	99.577						
28	.066	.219	99.796						
29	.061	.204	100.000						
30	8.848E-16	2.949E-15	100.000						

Figure 3.3 Eigenvalues

3.7 Exception Planning

Next step in research methodology was implementation of management by exception concept, as mentioned in previous paragraphs, management by exception starts with planning for exceptions. The metrics identified against each critical success factor were dovetailed with concept of management by exception and three level exceptions were planned for each metric. The three level of exception planning was done as it was planned to have a three-level hierarchical matrix in organization.

As mentioned earlier, concept of management by exception is used to prevent top management from indulging in small problems and catering small issues at lower hierarchical level. The exceptions were planned according to this concept. When the exception value passes a certain limit, the decision-making power is shifted to higher level of management. The exceptions planned against each metric is shown in Annex A.

3.8 Designing User Interface and Validation

After shortlisting critical success factors and incorporating concept of management by exception, next step was to design user interface for the visualization platform. Different concepts related to human behavior and visualization techniques were studied in detail before designing user interface. Mainly, the Gestalt Principles of Visualization and Vilayanur Ramachandran's laws of aesthetic experience were used as a guide for designing. Both these visualization techniques have been discussed in detail under literature review.

Final step of this research was validation of designed dashboard from industry experts. The designed dashboard/visualization platform was presented to group of experts from industry and their comments and suggestions were noted. This was done in order to improve dashboard design and to make it more user friendly and usable for industry experts and professionals. The suggestions and changes suggested by experts were incorporated in final dashboard design and another session was conducted to get final dashboard design. Detailed screen shots of designed dashboard are presented in following chapters.

CHAPTER 4: RESULTS AND ANALYSIS

This chapter contains detailed results and analysis performed during this research besides details of designed dashboard screens. The results of EFA and underlying constructs are discussed here in detail. Afterwards, organizational hierarchy, planned exceptions and dashboard screens are explained here.

4.1 Questionnaire Survey

The questionnaire survey conducted using expert from industry had 108 responses. The detailed demographics of experts involved in the questionnaire survey are as following: -

4.1.1 Professional Experience

First most important question was to establish the experience of the person filling the questionnaire survey. As expected, the respondents had varying years of professional experience. Figure 4.1 shows the distribution of professional experience of respondents in years. Most of professionals (42.6%) had professional experience ranging from 6 to 10 years, while 13% had professional experience of 16 to 20 years, 2.8% of them had experience of above 20 years, 4.6% of them had professional experience of 1 to 5 years and 37% of them had experience of 11 to 15 years.

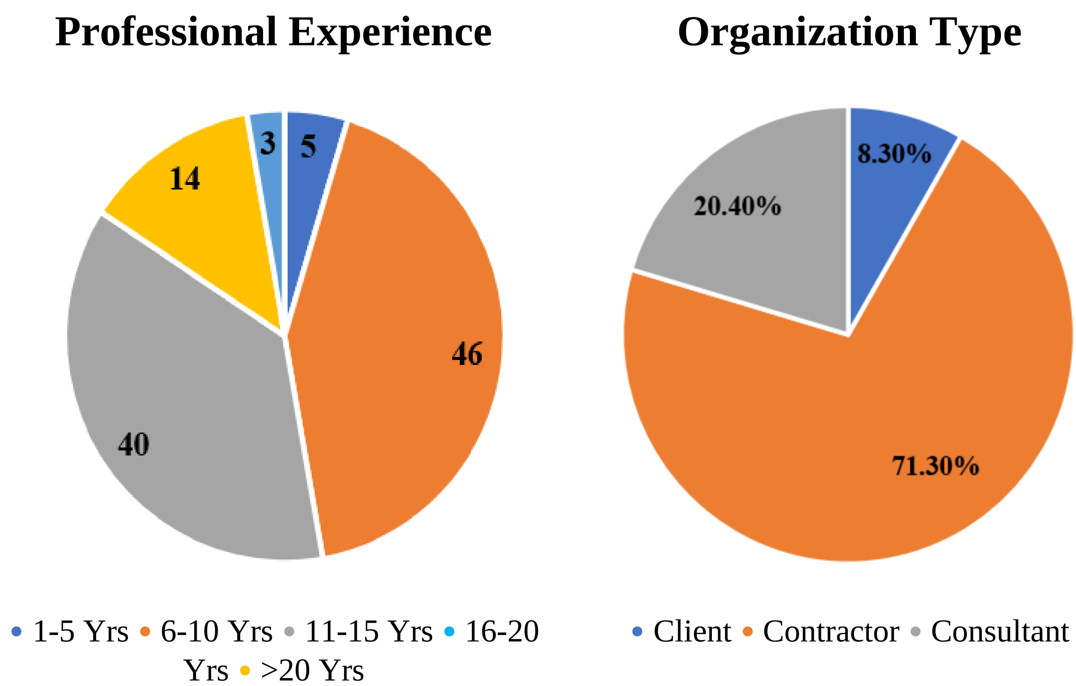

Figure 4.1 Attributes of Professionals considered in Questionnaire Survey

4.1.2 Organization Type

The questionnaire was shared with professionals working in various types of construction organizations with different nature of jobs. As this research is mostly related to developing dashboards for construction organizations especially contractors so most of responses were gathered from professionals working with contractor firms. Figure 4.2 shows spread of professionals with respect to their organization type.

4.2 Statistical Tests on Survey

Various statistical tests were carried out on the data collected through questionnaire survey. Details of all applied tests are as follows: -

- Kaiser – Meyer – Olkin (KMO)
- K1 – Kaiser's Eigenvalue > 1
- Scree Test

4.2.1 Kaiser – Meyer – Olkin (KMO) and Bartlett's Test

There are some tests carried out to check the appropriateness of data and adequacy of the sample for factor analysis before extracting factors. Measures of sampling adequacy, basically checks how tightly correlated an item is with other items in exploratory factor analysis correlation matrix. The data is suitable for factor analysis if its significance is less than 0.05 and it shows that matrix is not an identity matrix. Once the suitability or appropriateness of data is established, Exploratory Factor Analysis can be carried out.

4.2.2 K1 – Kaiser's Eigenvalue > 1

The Eigenvalue represents the total variance explained by each factor. As discussed earlier, the factors having Eigenvalues greater than 1 are retained. This is done to produce those factors which accurately elaborate the observed correlation matrix. Factor retention or deletion decision should be carried out with utmost care as it can immensely affect the extraction process of factors/ constructs. K1 - Kaiser's eigenvalue is applied to survey as shown in Figure 5; those factors whose eigen value are smaller than 1 are eliminated and retained only those factors showing eigen value greater than one.

4.2.3 Scree Test

Scree test is visual exploration of a graphical representation of the eigenvalues for discontinuities or breaks and it is the most popular used method for finding out that how much factors to be retained. A scree plot is basically a line plot of eigenvalues of factors included in analysis. The actual no of datapoints which are above the break (excluding those points at which break occurs) is exact number of factors that needs to be retained. This break point separates major factors from trivial or minor factors. Figure 6 shows scree plot of analysis carried out. It is clear from the scree plot that 5 factors are to be retained and rest will be rejected.

4.3 Factor Loading and Rotation Method

Factor loadings are a part of EFA which depicts the correlations between observed variables by making use of little number of factors. Factor loadings should be greater than 0.6 in order to have useful exploratory factor analysis. Initial results often get hard to interpret because principal axis estimation focuses on computational convenience without considering the conceptual clarity. Rotation of factor is designed to get a theoretically and simpler, more interpretable solution by axis rotation within space of factor to bring them near to variables location. Among all orthogonal rotations varimax rotation is undoubtedly the most popular one, despite so many analytic rotations have been suggested.

Rotation will help by minimizing low item loadings and maximizing high item loadings to provide a more simplified and interpretable solution. Rotation technique has two types one is orthogonal rotation while other one is oblique rotation as shown in figure 3. Orthogonal rotation provides uncorrelated factors. The most common type of orthogonal rotational methods for EFA is varimax rotation which was introduced by (Zientek, 2008) and will give a simple structure. In simpler words, varimax rotation (also known as Kaiser-Varimax rotation) maximizes sum of squared loadings variance, where 'loadings' mean the correlation b/w factors and variables. This results, for smaller number of variables-high factor loadings and for the rest- low factor loadings.

When issue of factor loading also known as cross loading arises, when one variable shows high correlation with two factors, then we use varimax rotation to avoid that. After excluding the factors which has a factor loading of less than 0.6, varimax rotation was applied to the component matrix to interpret the factors as shown in table 4.1.

Table 4.1 Constructs shortlisted after EFA & Factor Loading

Critical Success Factors (CSFs)	**1**	**2**	**3**	**4**	**5**
Resource Management			0.560		
Risk Management			0.727		
Dispute & Claim Management			0.564		
Client Satisfaction				0.586	
Safety Management	0.620				
Innovation Design & Construction Methods					
Time Predictability				0.593	
Productivity	0.591	0.594			
Realistic Scheduling	0.684	0.559			
Cost Predictability	0.717				
Procurement Management	0.768				
Quality Assurance	0.672				
Low Defects while used	0.585				
Profitability					
Human Resource Management			0.623		
Clear & Written Detailed Contract		0.694			
Project Size & Level of Complexity				0.697	
Stakeholder Management	0.762				
Communication & Relationship Management	0.577	0.610			
Client Responsiveness & Involvement					0.571
Competent Project Management					
Use of Technology		0.765			
Organizational Accountabilities		0.597			
Scope Definition & Change Management		0.686			
Fast Decision-Making Process		0.701			
Effective Project Planning & Control			0.708		
Facility Management			0.622		
Management Capabilities of Managers			0.614		
Feedback Capability of System					0.659
Learning from Previous Experiences	0.762				

4.4 Proposed Organizational Breakdown Structure

The organizational breakdown structure/ decision making hierarchy planned in this research has three levels which include chief operating officer/ managing director with his/ her team at top. There are several regional offices which will be managed by a specific team led by regional manager. All regional managers will be reporting to the owner/ CEO. The regional manager will establish different PMUs for projects in its area of responsibility (AOR). Project manager is the responsible person in each PMU to execute projects as per identified critical success factors. The OBS planned in this research is shown in Figure 4.3.

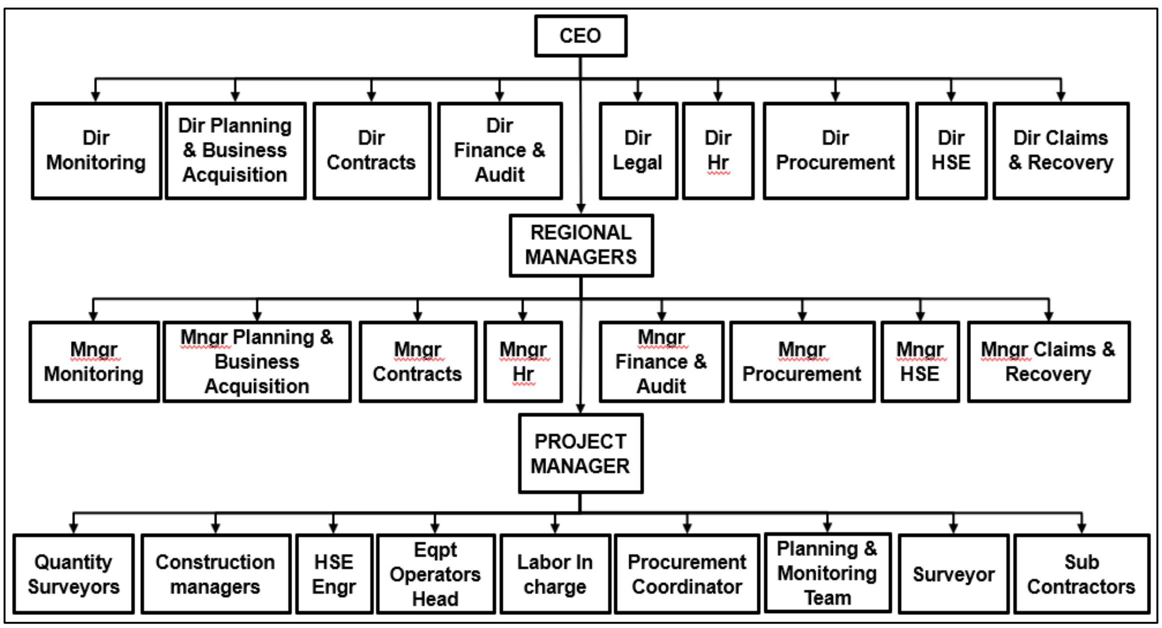

Figure 4.3 Proposed Organization Breakdown Structure

The organizational breakdown structure is required to be linked with 5 constructs generated by exploratory factor analysis (EFA). The last two constructs were combined to get a workable base for dashboard design. The factors and respective OBS level are shown in Table 4.2.

Table 4.2 OBS level and Linked Constructs

OBS Level/ Group	Linked Constructs
Level 3 (Proj Manager)	Safety Management
	Cost Predictability
	Procurement Management
	Quality Assurance
	Low Defects while used
	Stakeholder Management
	Communication and Relationship Management
	Learning from Previous Experiences
Level 1, Level 2 (CEO & Regional Manager)	Resource Management
	Risk Management
	Dispute and Claim Management
	Human Resource Management
	Effective Project Planning and Control
	Facility Management
	Management Capabilities of Managers
Level 2 (Regional Manager)	Productivity
	Realistic Scheduling
	Clear and Written Detailed Contract
	Communication and Relationship Management
	Use of Technology
	Organizational Accountabilities
	Scope Definition and Change Management
	Fast Decision-Making Process
Level 1 (CEO)	Client Satisfaction
	Time Predictability
	Project Size & Level of Complexity
	Client Responsiveness & Involvement
	Feedback Capability of System

After this the exceptions were planned to implement management by exception concept in this research. There was a limit attached to each CSF and management will be notified using dashboard screen if that limit is crossed. The purpose of exception planning is to guide user about the sensitive areas requiring attention and save managers time in decision making process. The exceptions planned for each metric is shown in Annex A.

4.5 Dashboard Design & Validation

The group of factors identified after implementation of EFA and planned exceptions made basis for dashboard design. The 3-level dashboard was designed having different CSF available to different hierarchy level. The dashboard design includes notification scenario for any exception that arises. Besides this, user can set exceptions as per his/ her own requirement / organizational goals. Screens were designed incorporating Gestalt principles of visualization. Color scheme was planned to make it more eye catching and attractive. The designed dashboard screens are attached at Annex B. The designed dashboard was presented and discussed with experts from industry. The experts shared valuable comments and reviewed the dashboard to suggest changes. The suggested changes suggested were incorporated to make the dashboard more usable for end user.

CHAPTER 5: CONCLUSIONS

5.1 Review of Study

This research study was distributed in two parts mainly. First part covered identification of Critical Success Factors that are applicable in construction industry. Second part was related to designing dashboard for construction industry. A thorough literature review was carried out to find out critical success factors that are applicable in construction industry. The construction related CSFs were then scrutinized and shortlisted using expert opinion and questionnaire survey. Underlying metrics for each critical success factor was identified through literature review.

After scrutinizing critical success factors and conducting questionnaire survey, exploratory factor analysis (EFA) was applied on questionnaire results. This was done to group together similar nature critical success factors and to develop a schema for development of dashboard. After that organizational breakdown structure (OBS) was planned with three levels of management including managing director, regional managers and project managers. The OBS was linked with EFA results and dashboard screens were developed using different visualization techniques. Concept of management by exception was also dovetailed to improve decision making process. For that exceptions limits were planned for each metric and incorporated in DB. In the end, developed dashboard screens were validated using expert opinion to improve usability of designed dashboard.

5.2 Research Findings

The construction industry is focusing on three success factors i.e., cost, time and quality for measuring success. Construction industry has not yet focused on variety of critical success factors to measure success or failure on projects. Variety of performance management and progress monitoring dashboards have been designed but neither involved variety of success factors nor any dashboard had idea of management by exception involved. In addition to this, absence of management by exception concept in construction industry has always hindered the decision-making process.

Moreover, properly planned and designed dashboard was required to improve efficacy of construction industry using visualization platforms. Researchers have focused on need for and importance of DB for enhancing performance of industry, but no proper framework was developed. Previously designed dashboards focused on single factor at a time neglecting other factors. Dashboards are not dynamic and provide update after a fixed time period which creates huge lags during decision making process.

5.3 Future Research Ideas

Future research ideas based on this research include Research may be based on development of underlying metrics for some CSFs that were neglected in this research. Another idea is dashboard may be developed by use of AI and backend software coding. A framework for uploading data to dashboard must be designed to regulate and ensure correctness of data being supplied to dashboard.

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