SMART VISUAL MANAGEMENT SYSTEM
Automated Digital Dashboards, Streamlining Operations & Promoting a Paperless Environment in a Manufacturing Industry

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by

KAMAL DEEP SAHU
(Roll No. 2K22/IEM/06)

Under the supervision of
Dr. N. Yuvaraj & Dr. Md. Shuaib
Assistant Professor, Department of Mechanical Engineering
Delhi Technological University

To the

DEPARTMENT OF MECHANICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-110042, India

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DEPARTMENT OF MECHANICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

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Place: Delhi — Kamal Deep Sahu

Date: 30/05/2024 — (2K22/IEM/06)

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

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I, Kamal Deep Sahu (2K22/IEM/06) hereby certify that the work which is being presented in the thesis entitled "SMART VISUAL MANAGEMENT SYSTEM- Automated Digital Dashboards, Streamlining Operations & Promoting a Paperless Environment in a Manufacturing Industry" in partial fulfilment of the requirements for the award of the Degree of Master of Technology, submitted in the Department of Mechanical Engineering, Delhi Technological University is an authentic record of my own work carried out during the period from January 2024 to May 2024 under the supervision of Dr. N. Yuvaraj and Dr. Md. Shuaib.

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DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-42

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Certified that **Kamal Deep Sahu** (2K22/IEM/06) has carried out his search work presented in this thesis entitled **"SMART VISUAL MANAGEMENT SYSTEM- Automated Digital Dashboards, Streamlining Operations & Promoting a Paperless Environment in a Manufacturing Industry"** for the award of **Master of Technology** from Department of Mechanical Engineering, Delhi Technological University, Delhi, under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Signature
Dr. Md. Shuaib
Assistant Professor
Department of Mechanical Engineering
Delhi Technological University, Delhi

Signature
Dr. N. Yuvaraj
Assistant Professor
Department of Mechanical Engineering
Delhi Technological University, Delhi

Date : 30/05/2024

SMART VISUAL MANAGEMENT SYSTEM
Automated Digital Dashboards, Streamlining Operations & Promoting a Paperless Environment in a Manufacturing Industry

Kamal Deep Sahu

ABSTRACT

Visual Management System (VMS) is an innovative, automated, digital, and standardized technique that helps organizations to proportion facts and highlight the actual-time development. It additionally covers the essential informational parameters in the workplace to inform the manufacturing team, enforce visualization standards, and highlight or prevent problems. Moreover, VMS affords a standardized shape for visualizations covering corporation level to shopfloor level to practical level KPIs and dashboards while making sure that groups comply with a standardized KPIs size technique. Our objective is to enhance operational efficiency and bringing transparency within an e-mobility manufacturing company by standardizing, digitalizing and implementing a robust visual management system. It will optimize the production processes and minimizes the waste occurrence which facilitate us to real time decision making fostering the culture of continuous improvement and thus ultimately will maximize our overall productivity in the organization with agility. It also enables the cross linkage of systems like manufacturing execution system, ERP system etc. The aim is to create a digital platform for dashboards to reduce the human intervention, manual errors and promote paperless environment. In this age of automation, real-time tracking plays a pivotal position in ensuring that production stays on path, both in phrases of productivity and efficiency. Recognizing this imperative, we are introducing the Visual Management System in the plant of an e-Mobility manufacturing company. VMS improves communication and trouble-fixing competencies. By imparting visibility on crucial records through VMS groups can deal with troubles before they turn out to be critical issues, measure progress in the direction of objectives, and paintings collectively extra effectively. This in flip may additionally result in a quick decision-making procedure, and less mistakes leading to expanded performance and productiveness.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

VM	Visual Management
QRQC	Quick Response Quality Control
KPIs	Key Performance Indicators
FG	Finished Goods
AHQ	Anand House of Quality
RFID	Radio Frequency Identification
OEE	Overall Equipment Effectiveness
TPS	Toyota Production System
JIT	Just-In-Time
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
LAN	Local Area Network
RLS	Row Level Security
SOP	Standard operating procedure
API	Application Programming Interface
BOM	Bill Of Material

Chapter 1
INTRODUCTION

1.1 About Visual Management

Visual management is an effective method for raising productivity in the workplace. By establishing a distinct link between the project's vision, basic values, objectives, and general culture, it accomplishes this. This relationship encompasses all parties engaged, the actual workplace, work procedures, and other management systems. It makes this clarity possible by utilizing visual cues that appeal to the senses of sight, touch, hearing, and other senses. These cues provide a steady flow of excellent information that is clear, pertinent, and correct. With only a quick glimpse with this information, everyone working on the project may quickly understand the present state of affairs.

Paint marks indicate traffic lanes, which help to direct traffic and avoid accidents. The tactile and auditory alerts of impending danger are given by rumble strips. Vehicle speed is really restricted by speed bumps. In order to better control traffic flow, traffic officers are immediately recognized by their uniforms and cars. Navigating the freeway is made easy with the help of signs and lights. With the help of the infrastructure, which transmits the expectations and norms, the complete system establishes a self-regulating environment. Similar goals of self-regulation and clarity are pursued by visual management in the building industry (Krzysztof Knop. 2020).

There's a catch, though, there isn't a common vocabulary. The most popular phrase used by researchers to characterize this idea is "visual management," although other titles that have been used include "visual workplace," "visual control," "visual factory," and "shop floor management." It may be perplexing to see this discrepancy. A more pressing issue is the inclination to minimize Visual Management as merely a means of housekeeping or quality control. To put it simply, visual management is a kind of project management that makes use of visual aids to facilitate communication between planners and construction workers. These tools can be signaling (highlighting crucial information), limiting (avoid mistakes), self-regulating (automatically directing behaviour), informational (offering data and updates), or signaling (limiting). Creating a work atmosphere that is self-explanatory, orderly, and always seeking improvement is the ultimate objective.

Visual Management (VM) relies on a variety of tools to communicate information clearly and efficiently. While these tools are important, they shouldn't overshadow the overall VM strategy. Employees can easily create their own visual tools for daily tasks. These tools are placed in the open workplace for easy access. Common features of VM tools include: presenting information in a way that allows people to easily obtain it, anticipating information needs to avoid gaps, integrating information displays directly into the work process (not in separate documents), and relying on minimal verbal or written communication. One way to categorize these tools is by function: information boards (signs), signal boards, work-in-progress limiters (kanban cards), and error-proofing devices (poka-yoke). This variety of tools can be confusing, so a table summarizes common VM tools with their definitions, roles, and practical uses. For example, the table might show how Kanban can be used for production control in manufacturing industry (Lavindra de Silva, 2021).

The advantages of visual aids are commonly acknowledged. Mestre et al. (1999) discovered that they may manage connections, convey organizational vision, denote group membership, and enhance business communication. Bovee and Thill (2005) emphasize the significance of these techniques in stressing, bringing people together, unifying them around a cause, and simplifying, emphasizing, summarizing, and reinforcing concepts. They can be modified or abandoned entirely as needs evolve. However, merely copying these tools from different settings might be harmful. Managers must examine their organization's preparation for such a transformation. Spearman and Zazanis (1992) caution that improperly using complex technologies such as Kanban boards might have undesirable implications such as inconsistent production speeds, interruptions in material flow, and quality problems. The key takeaway is that visual tools are a means to an end, not the end itself. As Ortiz and Park (2010) suggest, these tools should support the system's fundamental principles. Spear and Bowen (1999) illustrate this perfectly with the Toyota Production System. While outsiders often focus on copying Toyota's visual tools like Kanban and Andon boards, Toyota view them as temporary solutions to specific problems. The focus is on continuous improvement, and better approaches may emerge (S. Waschull, 2022).

This highlights the need for a strategic approach to VM. While the literature offers practical examples of various VM tools, it lacks a broader understanding of their overall benefits. Furthermore, the concept of VM as a managerial strategy should be considered independent of specific production systems like Lean. The framework builds upon foundational elements like 5S, visual standards, and visual performance centers (Hirano, 1995; Galsworth, 2005). These elements provide a strong base for more operational tools like visual signals, controls, and guarantees. The upper portion of the framework highlights the role of continuous improvement tools, knowledge dissemination methods, and internal/external marketing tools in supporting and enhancing a visual workplace. This framework addresses a gap in the current lean literature by offering a practical approach to creating a visual workplace that leverages the strengths of VM.

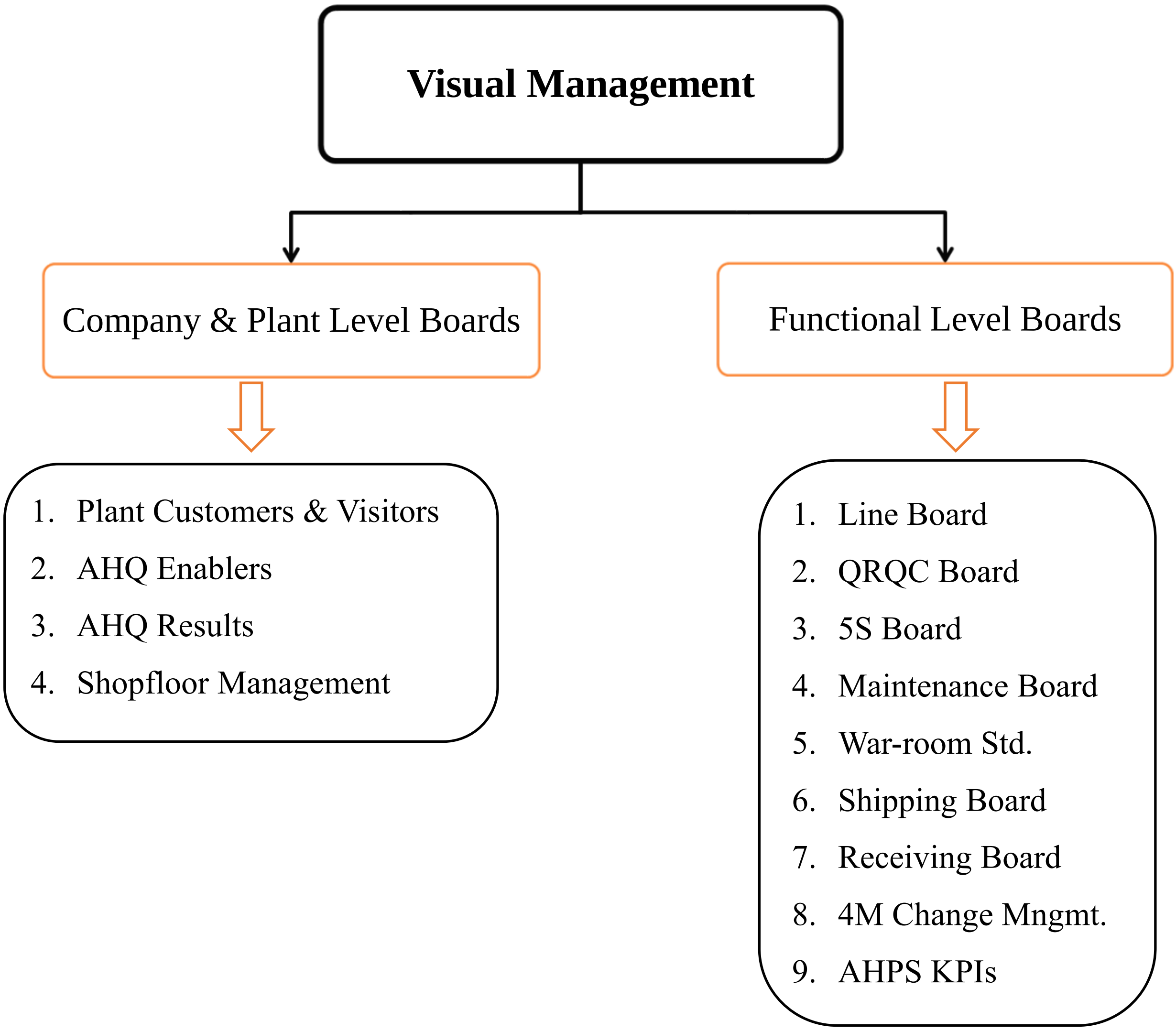


Fig. 1.1: Visual Management Classification

1.2 Historical Background

The history of visual management and its closely related counterpart, data visualization, is extensive and captivating. Its ancient origins show how much people have always wanted to use visual clues for organizing, communication, and progress. This historical journey shows how even seemingly basic instruments may have a significant influence on quality and efficiency when used correctly. One of the first reported examples of visual management goes back to roughly 2500 BC. The Egyptians used the Royal Cubit, a standardized measuring instrument, for construction projects. This visible depiction of a unit of measurement promoted uniformity and made communication easier among employees.

From the Industrial Revolution to formalised visual tools 'The Industrial Revolution' saw the increasing use of machine processes that applied energy to raw materials in a repeatable way in order to make them into useful products. The rise of formalised visual tools runs slightly in parallel to the Industrial Revolution and can be seen as coinciding with the 18th and 19th centuries. From this time onwards, there are more examples of formalised visual management techniques. Robert Owen is considered one of the founding fathers of social reform. Around 1800, he created a communication system called the 'Silent Monitor' (Algan Tezel, 2016). This visual board communicated information about employee behaviour that created a sense of accountability and drove positive work practices. The early-20th century saw further developments. Henry Gantt's eponymous Gantt Chart, invented in 1910, was introduced as a powerful planning and visual-control tool. Charles Knoeppel, another pioneer recognised that graphical methods and industrial efficiency went hand in hand. He also promoted the use of visual-control devices to enhance the communication between personnel and make processes more visible (Belekoukias, 2014).

The Toyota Production System: Without recognizing the crucial significance of the Toyota Production System (TPS), the history of visual management would not be complete. Although the origins of just-in-time (JIT) thinking, a fundamental component of Toyota Production System (TPS), can be found in Kiichiro Toyoda's intricate production manuals from the 1930s, visual management at Toyota really took off in the next several decades. In the 1930s, standardized work sheets with explicit task sequences, cycle periods, and inventory levels were put into place. TPS's visual management procedures saw constant evolution and improvement from the middle of the 1940s to the

1970s. It has become customary to post standard operating procedures above workstations so that supervisors could quickly assess if employees were following the protocols. An explosion of innovative advancements took place in the 1950s. In order to visually indicate the demands for materials, the Kanban system was developed in 1953 and uses cards. Kaoru Ishikawa devised the Ishikawa diagram, often known as the fishbone diagram, in this year. This powerful tool helps with problem-solving and quality improvement by creating visually portrayed cause-and-effect relationships. Ishikawa advocated for the use of seven basic visual tools, including flowcharts, check sheets, and Pareto charts, on the grounds that they could resolve 95% of quality-related problems.

Another key development of the 1950s was the introduction of what is now known as the 5S (sort, set in order, shine, standardize, and sustain). This workplace organization style originated as a 2S system in Japan before progressing to 4S and eventually 5S inside Toyota. Osada improved and popularized the concept throughout the 1980s. Toyota also developed the concept of Andon boards, a visual quality control system that uses lights to detect manufacturing anomalies, in the 1950s. Shigeo Shingo first introduced Poka-Yoke (mistake-proofing) devices in the 1960s. These smart technologies, which are frequently physical in origin, prevent mistakes from arising in the first place. By the late 1970s, the success of the Japanese economic model and the competitive advantage acquired via TPS. Visual management will surely continue to change as time goes on. The development of visual management throughout time reveals its enduring strength as a pillar of efficient problem-solving, good communication, and ongoing improvement. The fundamental idea is the same whether one uses modern visual systems like Toyota's or the standardized measuring instruments of the Egyptians: using visual signals to improve success by increasing clarity and transparency (Abdelkhalek, Eva S., 2019).

1.3 Objectives of Visual Management System

- Performance measurements at all levels may be seen clearly and consistently with the use of a uniform shopfloor dashboard framework. Large-scale metrics such as Overall Equipment Effectiveness (OEE), manufacturing output against objectives, quality rate (often expressed as First Pass Yield), inventory turnover, and safety incident rate are the focus of KPIs at the company level. Functional level dashboards delve deeper into certain subjects. Production dashboards might track machine availability, while quality dashboards may look at defect Pareto charts to see where issues are most common. A maintenance dashboard may additionally show the Mean Time Between Failures (MTBF) and the Preventive Maintenance completion rate.

- Creating a centralised online system with real-time dashboards, which can aggregate the data from multiple sources, to automatically do the data analysis. In reducing human error and removing the need to manually review the data, paper reports would be rendered unnecessary and real-time data-backed insights could result in more sustainable, paperless environments allowing data-backed decision-making.
- Because this control is at the centre of the operation – a multilocation dashboard – you can manage performance metrics and data visualisation across all your locations at once. And because building the dashboard and defining what metrics you want to show and what hours to update them all at once, you might be just a few clicks away from uniformity and instantaneous insight across the entire operation. Helpful to update inventory levels or sales numbers for everybody with one press of a button.
- Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) have always had separate data silos. In order to dissect them, routes of communication must be established. This makes real-time data flow possible. For instance, manufacturing changes from the MES can instantly appear in the ERP's inventory and planning sections. This enhances overall visibility, simplifies processes, and maximizes the use of available resources.
- Effective workplace standards serve as a communication center. They educate teams on expectations, processes, and best practices. This clarity allows them to regularly produce high-quality work. The rules also create work standards, which serve as a baseline for performance. They act as a preventative tool by highlighting prospective concerns, assisting teams in avoiding frequent mistakes. Ultimately, these standards serve as a road map to success, encouraging a productive and efficient workplace
- Conventional KPI frameworks, like regulatory capital adequacy ratios and health organization metrics, provide consistency and industry-wide performance comparisons. However, they should complement company-specific KPIs for unique strategic goals, not replace them.

1.4 Scope of Visual Management System

Representing reports and result are the operational part in a production corporation. All those should be kept improving for the clean go with the flow of information amongst all of the personnels in the corporation. The visual system may be applied throughout all the operational areas in a company as follows:

1. *House of Quality*: Using visual aids like matrices and diagrams to organize and rank customer needs and convert them into technical specifications by understanding the relationships between various parameters enables decision-makers to make well-informed choices during the product development and quality planning phases.
2. *Operational KPIs* (Quality, Productivity, Safety, Delivery): Visual dashboards showing key performance indicators (KPIs) allow teams for quickly measure performance against goals. The Color-coded graphics highlight areas of concern and areas of success, allowing for quick action and continuous improvement efforts.
3. *Plant Roadmap* (Quality, Sustainability, Zero Defects): Visual guidance outlines performance targets and tasks for quality, sustainability and any deficiencies, and ensures consistency and clarity across the organisation. The Visual progress helps track milestones, identify dependencies, and ensure timely execution of plans.
4. *Internal, External and Supplier Audits*: Visual audit checklists and scorecards facilitate thorough and systematic auditing processes. Visual representations of audit findings help in identifying trends, areas for improvement, and compliance issues for corrective action.
5. *Awareness of Company Policies* (Quality, Safety and Ethics etc): The visual presentation of company policies, such as posters and infographics, increases employee knowledge and understanding. Visual signals reinforce important messages about quality standards, safety regulations, ethical behaviours, and other company principles.
6. *Skilling*: Visual training materials, such as videos, illustrations, and interactive modules, enhance learning effectiveness and retention. Visual skill matrices and competency maps provide clear pathways for skill development and career progression.
7. *Kaizens*: Visual boards, or digital platforms, showcase ongoing kaizen efforts, their current status, and their impact. These visual representations can also be dynamic, such as for before and after scenarios, to emphasize improvements and encourage ongoing improvement efforts.
8. *Customer Awards*: Showing customer awards and recognition is a great way to celebrate success and inspire teams. Reminiscing about customer satisfaction metrics and customer testimonials reinforce how important it is to meet and exceed customer expectations.

9. *Change Management*: Visual change management boards or charts track proposed changes, their status, and impacts on different areas of operations. Visual communication tools, such as timelines and flowcharts, clarify change processes and roles, reducing resistance and fostering acceptance.
10. *Complaint Handling*: Systems for visually tracking complaints classify and rank complaints in order of importance for prompt response. Fishbone diagrams are one type of visual root cause analysis tool that may help discover underlying problems and put remedial measures in place.
11. *War Room Review*: Visual DWM (Daily, Weekly, Monthly) charts provide real-time insights into performance trends and deviations from targets. Visual representations of action plans and responsibilities ensure accountability and drive progress during war room reviews.
12. *Machine & Tooling*: Visual maintenance schedules and checklists ensure timely inspection and maintenance of machines and tools. Visual indicators including color-coded status markings, presence or absence of warning devices, maintenance requirements and potential safety hazards.
13. *Plant & Zone Wise 5S*: Plant and zone-specific visual 5S boards and shadow boards keep everything tidy, standardized, and organized. Workers are guided in following 5S guidelines and preserving workplace order by visual cues like floor markings and signs.
14. *Receiving and Delivery Controls*: Visual commands such as Kanban Systems and TAG RFID optimize the reception and distribution process by the signalling level and moving reserve. The deadline and the visual display of the delivery calendar enables active management of consumables and client bonds.

1.5 Some Illustrations of Functional Level Dashboards :

Skill Matrix

A skills matrix is a powerful tool that organizations use to visualize and manage the skills and abilities of their employees. These are the specific competencies and knowledge needed for different roles and projects within an organization. Examples include technical skills (software proficiency), soft skills (communication, teamwork), and industry knowledge. These can be individuals, teams, departments, or entire organizations. By comparing the skills required with the available skills, you can easily identify areas where your employees lack the skills they need, which will allow you to plan training programs and hire employees to fit your specific needs. When training a project team, this ensures a good combination of skills in consideration of skill matrix. Employees can use matrix to check the skills required for promotion and plan their own training and development methods. When forming teams for projects, it helps in ensuring the right mix of skills by looking at the skill matrix. Employees can use the matrix to see the skills needed for advancement and plan their own learning and development path (Harry Warrender, 2012).

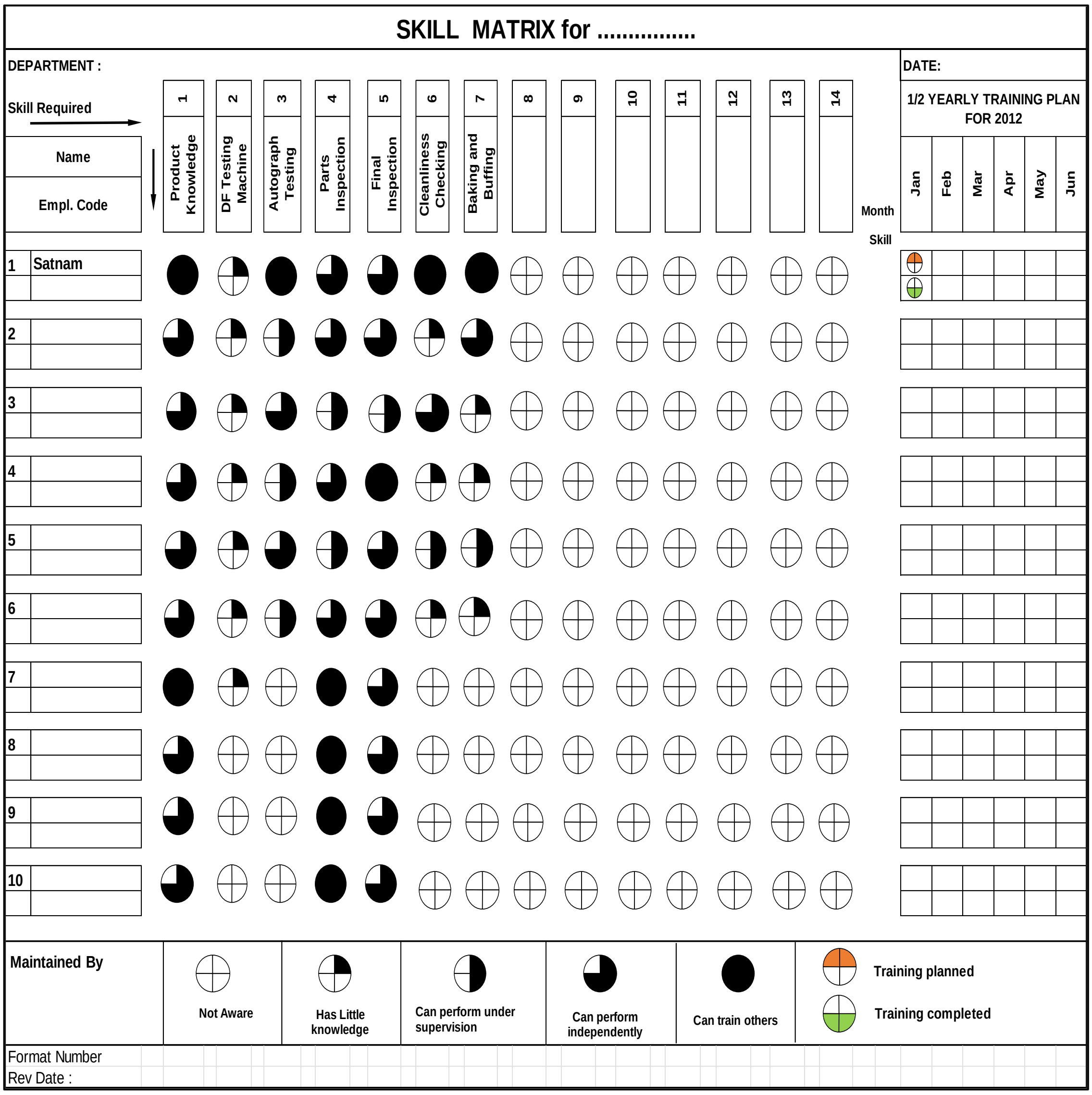


Fig. 1.2 : Skill Matrix

5S Map

The 5S map is a tool used in the workplace organization methodology known as 5S namely Sort, Set in Order, Shine, Standardize, & Sustain. This basically acts as a visual representation of the specific areas targeted for improvement through 5S. First, the map creates a baseline showing the current layout of the target area, which includes identifying the locations of tools, equipment, materials, and clutter present. Maps become planning tools. Once it has sorted out the items you don't need, this can use the map to plan where to distribute and label the remaining items during the decluttering phase. This may include a drawing area for tools, shelves for materials, waste bins, etc. Overall, the 5S map provides a clear visual aid to understanding the current state of the work area, planning improvements, and communicating those plans to others involved in her 5S activities (Nicola Bateman, 2013).

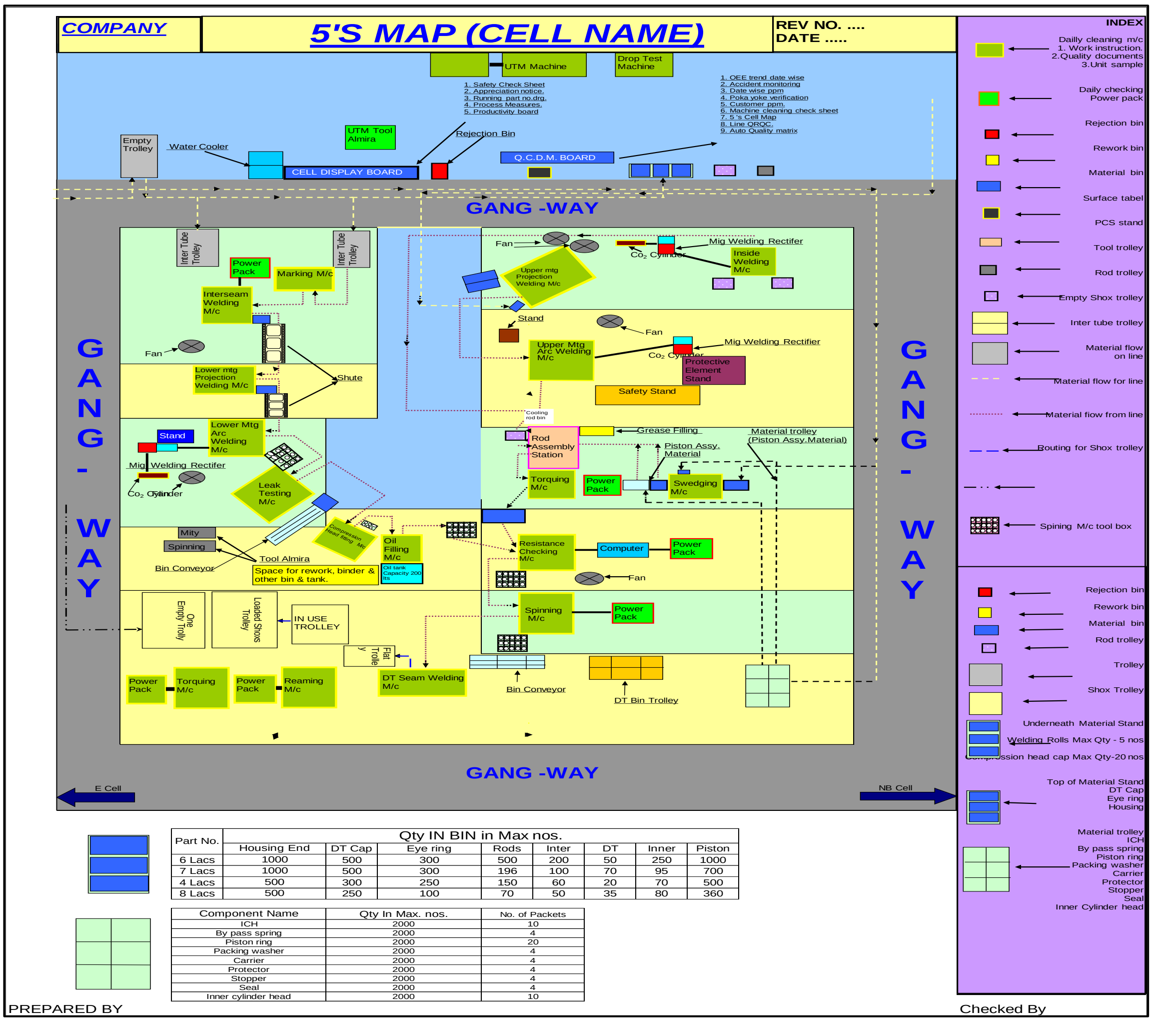


Fig. 1.3 : 5S Map

Plant Layout

A plant layout is essentially a blueprint for a manufacturing facility. It dictates how the physical space will be organized to achieve optimal production. This involves arranging various elements like machinery and equipment, workstations, storage areas, material flow paths, supporting services like restrooms and break rooms. The Plant Layout or Zone Map is shown in *figure 1.4*.

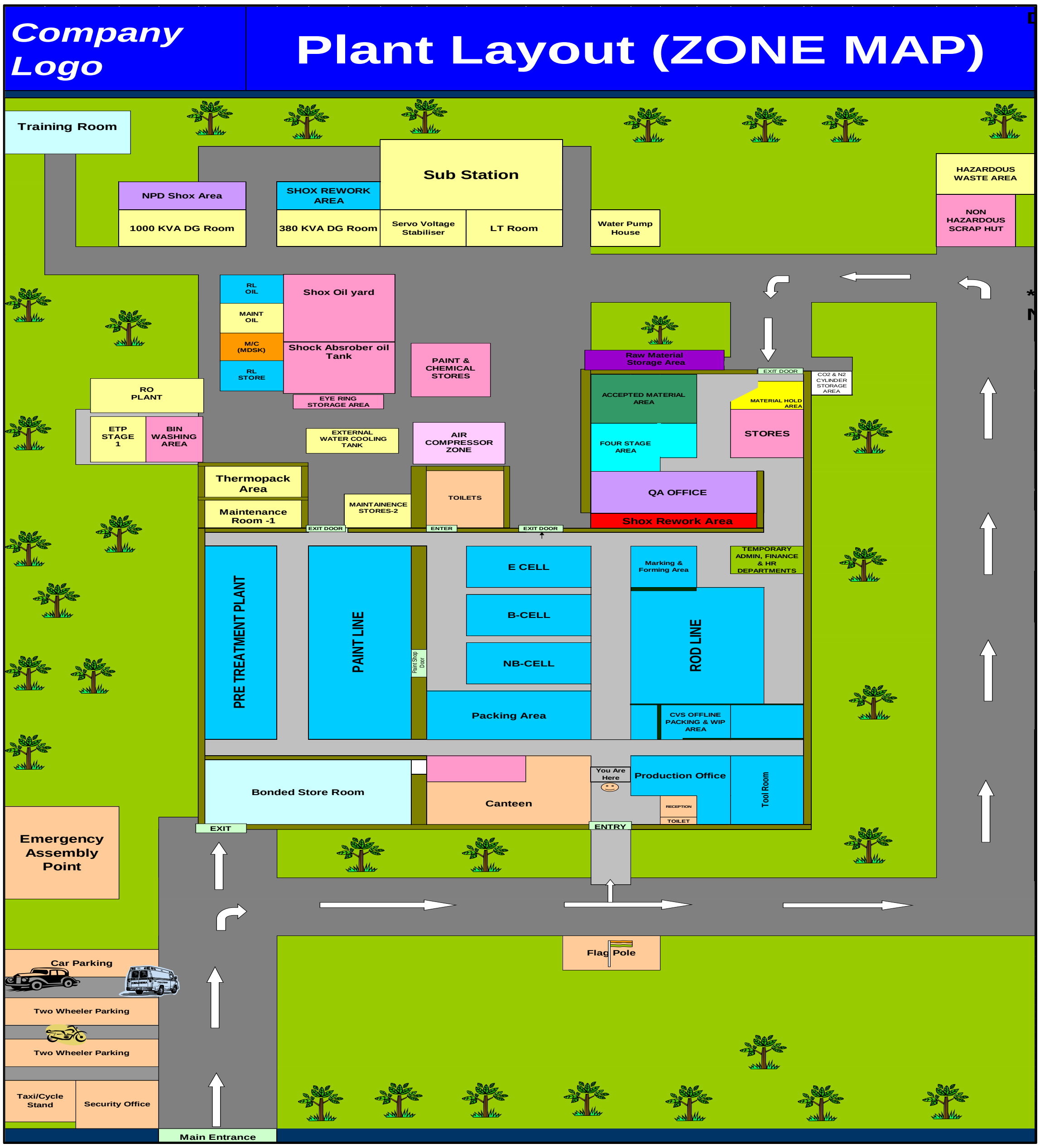
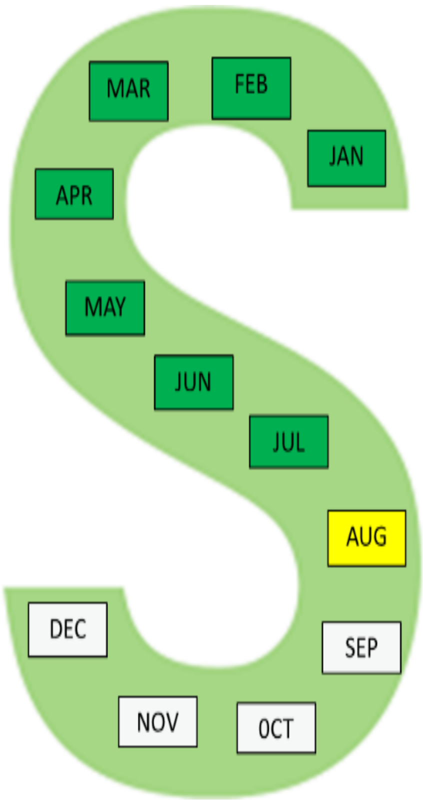


Fig. 1.4 : Plant Layout

Safety Indicators

Safety indicators are tools used to measure the success of safety programs and identify potential hazards. There are two main types of safety indicators. Leading indicators are proactive measures that help predict and prevent accidents and injuries. The purpose is to identify potential risks before they develop into incidents. Examples of leading indicators include the number of safety inspections conducted, the number of employees receiving safety training, and the use of personal protective equipment (PPE). Lagging indicators are responses that track the number of accidents, injuries, or illnesses that have already occurred (Paul Beynon-Davies, 2017). While lagging indicators can show where problems are occurring, they don't necessarily help prevent future incidents. Examples of lagging indicators include recorded accident rates, lost work days, and workers' compensation claims. An effective security program uses both leading and lagging indicators. Leading indicators help you identify and correct potential problems before they result in an accident, while lagging indicators help you track the progress of your safety efforts and identify areas for improvement.



Key
Incident Free
Near miss/First Aid
Lost time /Recordable

Month (Nos)	
JAN	0
FEB	0
MAR	0
APR	0
MAY	0
JUN	0
JUL	0
AUG	3
SEP	
OCT	
NOV	
DEC	

Day's Without "Zero" Accident	35 Days

Fig. 1.5 : Safety Indicators

Productivity Indicator

A Productivity metrics are metrics used to evaluate how efficiently something is accomplished. It's like a car's gauges, telling you whether your car is running smoothly and performing as expected. There are also performance indicators for individuals, businesses, and even the economy as a whole. The goal is to understand how resources can be deployed to achieve the desired outcomes in each of these scenarios. By tracking performance metrics over time, you can identify trends and make adjustments to improve performance. This is important for people who want to succeed and for businesses who want to become more competitive (Brandalise, 2018).

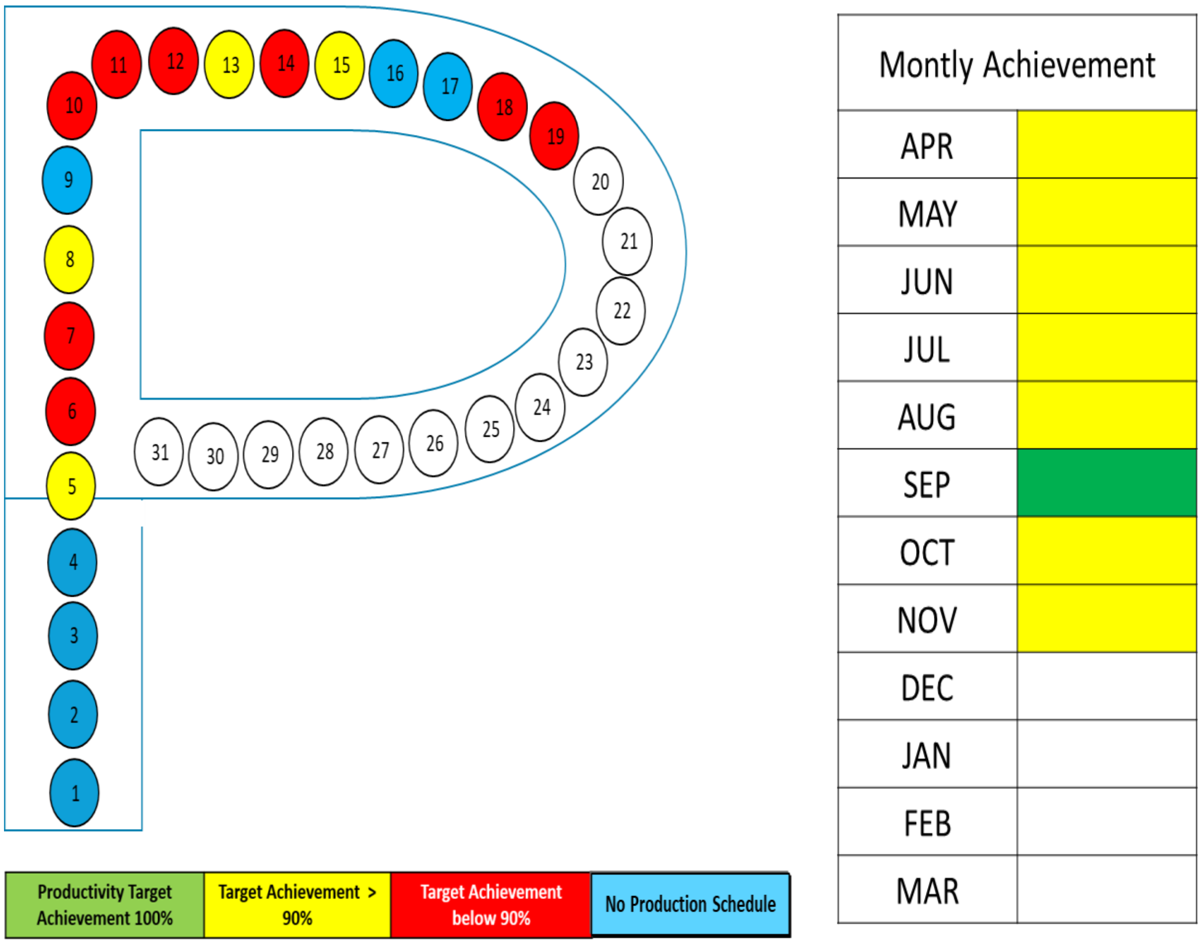
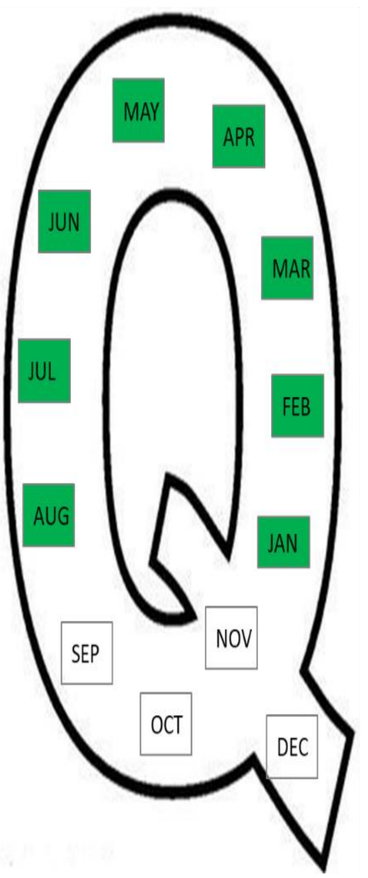


Fig. 1.6 : Productivity Indicators

Quality Indicator

In an industrial setting, a quality indicator is a measurable element that reflects how well a product or service meets set standards. These indicators are essentially tools that help companies track their performance on quality. There are two main ways to categorize quality indicators: **Customer-focused,** products do meet customer expectations and needs. This can involve things like customer satisfaction surveys, warranty claims, and return rates. **Product-focused,** products are being produced according to specifications and free from defects. This can involve metrics like defect rates, production yield, and adherence to industry standards. By monitoring these indicators, companies can identify areas for improvement and ensure they're delivering high-quality products or services. Overall, quality indicators are a cornerstone of industrial quality management. They help companies track progress, identify problems, and make data-driven decisions to continuously improve their offerings (Adam, 2018).



Key
No Customer Quality Disruptions
Customer Quality Disruptions

Month (Nos)	
JAN	0
FEB	0
MAR	0
APR	0
MAY	0
JUN	0
JUL	0
AUG	0
SEP	
OCT	
NOV	
DEC	

Day's Without "Zero"Quality Incident	No Customer Complaints

Fig. 1.7 : Quality Indicator

Chapter 2
LITERATURE REVIEW

2.1 Literature review

A literature review is carried out and is essentially a critical summary of existing research on a particular topic. It examines scientific sources such as academic journals, books, and theses to provide an overview of current knowledge. The main purpose is to summarize previous studies summarizing the key findings and methodologies used in previous studies. Reviewing existing research can help identify gaps in knowledge and identify areas where additional research is needed. This places our own research questions and projects within the broader context of existing knowledge and provides a context for further research. A well-written literature review demonstrates our understanding of the topic and shows how our research builds on previous research. Literature reviews form the basis of various academic endeavours such as research papers and dissertations.

In 2020, Krzysztof Knop presents a comprehensive and insightful overview of the confusion surrounding terms like "visual management", "visual inspection", "visual inspection" and "visual testing" in production. and quality management research. This is especially true for non-industry researchers or those working with languages like Polish, where some terms have no direct equivalent. This article explains these concepts. We break down sometimes confusing definitions, explain where each term is used, and show the relationships between them. We review existing research on visual tools in manufacturing and quality control. Define the appropriate context for these terms and when they can be used interchangeably or independently. An important point to remember is that direct translation of these terms into a language such as Polish may not be accurate. This article highlights the close relationship between "visual instruction" and "visual inspection" and "visual inspection" and "vision inspection" and suggests that the two may be used interchangeably. We also identify situations in which all of these concepts may intersect.

Lavindra de Silva, 2021 Catalog of digital solutions space for prioritizing the needs of manufacturing SMEs is a comprehensive literature review that examines how the manufacturing sector is experiencing the digital revolution. 4.0 is a prime example. However, research has mainly focused on large enterprises, ignoring the unique challenges faced by small and medium-sized enterprises (SMEs). These challenges include limited knowledge, resources, and awareness about digital technologies. The main reason for this gap is that the focus is on the technology itself, rather than the problems it can solve. This article proposes a new approach to thinking about digitalization as a tool for using technology to solve business problems. The objective is to identify common challenges and corresponding digital solutions that are relevant for the majority of manufacturing SMEs. To achieve this objective, workshops were organized with 128 SMEs as part of the study. The result was a comprehensive list of 59 digitalization priorities ranked by importance. Note that 86% of participants mentioned at least one of the five key points when making business decisions. This study provides valuable information to guide future efforts. By focusing on solving problems and prioritizing the needs of SMEs, we can increase the accessibility of digitalization tools and enable these businesses to thrive in the digital age. This goal can be achieved through targeted research, the development of user-friendly systems and clear standards for the digitalization of SMEs.

Algan Tezel (2016) provides comprehensive information about visual management (VM). VMs are an important but distinct topic that is often mentioned in Lean Manufacturing discussions. They use a mix of academic and consulting terminology, highlighting the fragmented nature of his current VM discussions. The paper proposes a practical classification system for virtual machine tools and a framework for implementing a visual workshop. It also addresses the lack of clarity regarding the benefits of VM within organizations by suggesting nine potential features. Finally, the author determines many promising areas for future VM research. This sentence is approved by a more theoretical understanding of the virtual management strategy (VM). This highlights the importance of focusing on virtual machine functionality rather than specific tools such as Kanban cards. The authors emphasize that there is no universal framework for virtual machines and call for further research. They propose a social materiality perspective to investigate how VM reflects organizational values and how employees perceive them. Furthermore, they propose to explore VM from the perspective of visual research and socio-technical means. This article highlights that applications of VM outside of manufacturing are under-explored. This highlights the need to investigate the effectiveness of VM in different contexts, its contribution to overall goals, and employee perceptions of VM. Finally, the authors discuss future research directions, including virtual machines as information management interfaces, the interpretation of visual tools by different groups, and the potential of new technologies in virtual machine design.

In 2019, Abdelkhalek, Eva S. propose construction sites are complex environments. Workers from various crews move around constantly, the layout changes frequently, and construction itself can create visual obstacles. This dynamic nature makes construction one of the most hazardous industries, with a high risk of accidents. Improving safety is crucial to prevent these accidents and protect workers. Visual Management (VM) offers a powerful tool to achieve this goal. VM uses visual aids to communicate information clearly and effectively. This can include signs, labels, and other displays strategically placed around the site. VM isn't a new concept. In fact, it's a core principle of Lean Construction, which originated in Japan in the 1950s. Lean practices like the 5S system (sort, straighten, shine, standardize, and sustain) emphasize organization and clear communication, both of which contribute to a safer workplace. Some companies even include a sixth S for safety, highlighting its importance. Research has shown a strong link between implementing 5S and improved safety performance. This paper explores the potential of VM to enhance construction safety in Lebanon. It will examine different VM tools and their impact on accident prevention. The paper will also present case studies and survey results to provide real-world examples of how VM is being used in Lebanon, along with its effectiveness in improving safety outcomes.

In his article, Harry Warrender describes factories where clear communication and organization thrive. This is where the visual controls shine. Unlike traditional methods that rely heavily on textual instructions, visual guidance uses a variety of tools to transform the shop floor into a self-explanatory workspace. Everything has a designated place in the factory, marked with transparent paint and labels. This is not only about aesthetics, but also about efficiency. Employees can instantly identify where tools and materials can be found, eliminating unnecessary time searching. Color-coding tools for specific parts is even more to prevent accidental mix-ups. Visual management is not just about keeping things in order, it is about empowering employees. Procedures are clearly visible, often with pictures that describe the right and wrong ways to perform tasks. This fosters a culture of self-sufficiency that reduces reliance on the manager's explanation and reduces the risk of error. The benefits go beyond immediate production. Clear visual aids facilitate the integration of new employees into the workflow, reduce training time and ensure consistent quality. In addition, visual inspection helps maintain compliance with safety regulations. Clearly marked walkways and designated storage areas create a safe working environment. The impact of visual leadership goes beyond these personal benefits. By creating a transparent and information-rich workplace, it promotes a sense of belonging and responsibility among employees. When everyone can see the bigger picture – material flow, production goals and potential bottlenecks – they become active participants in the improvement process. This collaborative environment is key to long-term productivity and efficiency gains. In essence, visual management turns the factory floor into a giant communication board. By replacing extensive text instructions with clear images, it simplifies complex processes, empowers workers and paves the way for a more efficient and error-free production environment.

Nicole Bateman and Peter Hines (2013) describe lean, which was originally developed for high-volume manufacturing such as cars, but has proven to be surprisingly adaptable. This study examines how the Royal Air Force (RAF) successfully implemented Lean in its Tornado jet fighter programme. The author is focusing on the experience of the royal Air Force, and is trying to provide valuable information on the use of Leans in an environment that is intended for public sector services. The RAF project is a persuasive example of lean operation other than automobile production. This study deals with specific methods used by the Royal Air Force to implement a thin concept. The author analyzes how Lean's major principles are translated as part of RAF and how to conform the implementation strategy to this environment. Research shows that the five core principles of Lean (value, waste, flow, pull, and excellence) remain relevant to the Tornado program, but some of these principles need special consideration in the public sector. Note that the "pull principle", which emphasizes consumer-driven production, requires special adaptation. Based on their findings, the authors propose three main points regarding the use, waste, flow and pull principles of value in the public sector. In addition, they make a separate claim regarding the principle of perfection, especially in the context of military organization. In essence, this study shows that Lean principles can be successfully applied in a public service environment with some adaptations, especially in addressing customer needs. This finding highlights the importance of contextual fit for successful Lean implementation. The research goes a step further and shows that the core lean principles themselves may need to be rethought to fully embrace the unique characteristics of different environments.

Paul Beynon-Davies in 2017 published a paper ‘Making sense of visual management through affordance theory’ this literature discusses visual management, a technique used to improve workflow by making work activities more visible. It clarifies the specific meaning of visual management within operations management, contrasting it with the broader concept used in other disciplines. The authors point out a surprising lack of academic research on visual management, attributing this to several reasons. Firstly, knowledge about visual management comes from practitioners rather than academics. Secondly, the principles are based on practical experience rather than formal theories. Thirdly, these systems are often manual and lack the digital aspects that attract the attention of information systems and operations management researchers. The focus of the paper is on a specific class of visual management systems that use physical objects to coordinate routine work. Examples include Kanban boards in manufacturing, whiteboards in hospitals, and flight strips in air traffic control. These systems persist despite the trend towards computerization because they offer affordances, or action possibilities, that are difficult to replicate digitally. The authors build a theory to explain how visual management works in these physical systems. They contend that the ways in which visual aids are positioned inside organized physical environments are what give them their affordances. They include three real-world examples—a visual aid used in a garment repair business, a whiteboard in an intensive care unit, and a Kanban system used in software development—to demonstrate this notion. The argument made in the paper's conclusion is that visual devices may be utilized to describe how visual management works using the affordances theory. The authors then go into how to create and apply visual management systems using this notion. They also point out the shortcomings of their analysis and suggest directions for more study.

Fernanda M. P. Brandalise (2018) provides a comprehensive insight about Visual Management a technique for managing information that aligns perfectly with the core idea of Lean Production – making processes more transparent. This transparency is crucial for continuous improvement efforts, as it allows for information to flow freely between different levels of a project. However, implementing VM in construction presents unique challenges. Construction projects are one-of-a-kind endeavors, work sites constantly change, and construction itself can create visual clutter. This paper seeks to understand how a specific set of VM best practices can aid production management. It will explore what makes these practices "advanced" and pinpoint the reasons behind their effectiveness. The research is based on two Brazilian construction companies that are leaders in Lean Construction implementation. Unlike past VM studies, this investigation goes beyond just looking at the visual tools themselves. It looks at how these tools can be integrated into management processes that can use a variety of visual aids. The study also investigated whether these visual tools are used dynamically to support decision-making, especially in collaborative environments. Another important contribution of this paper is its best practice classification system for WC. The system classifies these practices based on how integrated they are with daily management tasks. This classification will help construction companies understand which VM practices will benefit their specific needs the most.

Adam Lewiński, 2018 purposes in his paper while many tools can improve processes, quality, and delivery times, implementing them individually isn't enough. A system for maintaining these tools is crucial. Enter Kamishibai, a visual management approach used in a Polish heavy industry company. Kamishibai utilizes a specially designed board with colourful cards. Each card has written instructions for conducting an audit. The board is divided into two sections. One section holds pockets for storing cards after audits. The other lets auditors record problems, causes, and corrective actions. Designing a Kamishibai board requires considering: The work system (changes, workdays), Audit frequency (based on workload and audit levels), Audit scope (entire area or specific points). Traditionally, audits involve trained teams with schedules and checklists. Kamishibai empowers anyone in the factory to audit. The main thing is the simplicity of the cards. These two-sided cards have the same questions on both sides, but the answers are visualized differently. Green indicates correct standards and red indicates non-compliance. This visual aid helps everyone learn the correct work procedures. The walk begins with the drawing of a random card. The auditor then checks the standards according to the card instructions. Finally, they place the cards on the board based on the results: green side: positive result, red side: mismatch found.

Barbara Pedo 2022, “Visual management requirements to support design planning and control in a digital context” This research aims to develop new requirements for digital visual management in design projects. Existing virtual machine requirements were reviewed and refined through design firm research. The important point is that existing manufacturing and construction-based VM requirements cannot be fully applied to infrastructure design. This study proposes a revised set that takes into account the unique context of infrastructure projects. Digital virtual machines offer clear advantages, especially in the areas of information tracking, and accessibility. However, achieving the simplicity of digital virtual machines remains a challenge. This study highlights both the benefits and limitations of current digital VM practices. Furthermore, the importance of different requirements varies depending on factors such as the type of VM practice, the level of planning, and the stakeholders involved. For example, flexibility is essential for operational tasks where changes are frequent, while simplicity is more necessary at the strategic level to avoid overly complex long-term planning. The study also explores how digital virtual machines can be implemented through different communication and collaboration approaches. This facilitates the development of hybrid VM system frameworks that combine digital and manual techniques. Although this study focuses on the early stages of design science research (problem identification and understanding), it provides valuable insights. The proposed set of requirements should be further evaluated in future studies. Additionally, the study was limited to a single company, although it provides valuable insights into successful VM practices and the challenges of implementing digital VMs.

S. Waschull predicts that in 2022, the rise of digital technologies in Industry 4.0 will change the way factories operate, impacting both manufacturing workers and office workers. Although research has investigated the changing nature of manual labour, the impact on white-collar jobs and how these jobs will change due to digitalization remains unclear. To fill this gap, an in-depth study of organizations facing digitalization was conducted. This result confirms that digitalization affects both types of workers simultaneously. It is important to note that the impact on people depends heavily on how and when human factors are incorporated into the design and implementation process. In the absence of knowledge about best work design practices, the personal motivation of system developers became a key factor in achieving positive outcomes for employees. At the organizational level, this study highlights the importance of involving system users from the beginning when setting project goals and of using social performance indicators alongside operational indicators. This study provides valuable real-world data for the development of human-centered models and theories. These models must incorporate the challenges and opportunities that digital technologies will pose in the future for both blue-collar and white-collar workers.

2.2 The Functions of Visual Management

A literature review was performed to identify functions of Visual Management. The details of the review resulted in a taxonomy of the functions identified from different resources and they are illustrated in *Table 2.1*:

Table 2.1: Functions of Visual Management

Functions	Description
Transparency	Communicate information about processes, performance, and goals clearly and easily for everyone to see.
Discipline	Promote adherence to standards and procedures through visual cues and reminders.
Job Facilitation	Make tasks easier to understand and complete with visual aids like instructions, flowcharts, and checklists.
On-the-Job Training	Provide readily available information for learning and improving skills.
Problem-Solving	Highlight deviations from the norm and potential issues through visual indicators.
Shared Accountability	Foster a sense of ownership and responsibility for processes and outcomes.
Continuous Improvement	Encourage ongoing analysis and improvement by making data and performance metrics visible.
Simplification	Constant efforts on monitoring, processing, visualizing and distributing system wide information for individuals and teams.
Unification	Partly removing the four main boundaries (vertical, horizontal, external and geographic) and creating empathy within an organisation through effective information sharing.

2.3 Knowledge Gap

This literature review highlights the need for a strategic and systematic approach to VM. While the literature offers practical examples of various VM tools, it lacks and find gaps in a broader understanding of their overall benefits. Furthermore, the concept of VM as a managerial strategy should be considered independent of specific production systems like Lean. The framework builds upon foundational elements like 5S, visual standards, and visual performance centres. These elements provide a strong base for more operational tools like visual signals, controls, and guarantees. The upper portion of the framework highlights the role of continuous improvement tools, knowledge dissemination methods, and internal/external marketing tools in supporting and enhancing a visual workplace. This framework addresses a gap in the current lean literature by offering a practical approach to creating a visual workplace that depict the strengths of VM. A number of contexts were focussed with the traditional manufacturing systems to find the various scope of possible improvements using visual management systems. For Visibility and Transparency information are not been reflected anywhere and are processed in people mind and stored in logbooks. Companies tries to process the sustained improvements on the continuous basis for its growth. Organisations considers only big improvements through a considerable investment. Job Facilitation provides deliberate attempt to provide a variety of visual assistance in order to consciously lessen worker's physical and/or mental strain on familiar, everyday jobs. Expecting individuals to do their work successfully without giving them any assistance. The officials impose warnings and dismissing or giving punishments. Either specific training or no training is provided. People usually learns from experience or daily routine work. So, a large gap found in the research field how to handle such scenarios effectively and systematically.

2.4 Research Questions

Research questions are an essential part for any research project, and they guide the researcher in exploring the research topic systematically. In this study, the research questions will guide the investigation and implementation of the visual management system in a manufacturing industry through automated digital dashboards to streamline the operations, error free environment and to promote paperless ecofriendly space. Based on the knowledge gap and research paper analysis, multiple questions can be framed to streamline the operation in a manufacturing industry. The following research questions will be explored in this study :

1. How to develop and implement automated digital platforms for dashboards to reduce human intervention, manual errors and to reduce paper consumption in an industry that ultimately leads to sustainability ?
2. How to create standardized structure using visual charts like graphics, barcode colour, trendline for shopfloor dashboards covering from company level to functional level KPI's & Dashboards ?
3. What technology and approach needed to centralized real-time dashboards, which can aggregate the data from multiple sources, to automatically do the data analysis from multi-locations dashboards and their updates ?
4. How to enable cross system linkages to ease the routes of communication such as Enterprises Resources Planning, Manufacturing Execution System ?
5. How to optimize cost and time before and after implementing smart visual management system ?

These research question aims to evaluate the effectiveness of visual management system in any manufacturing industry. It will provide insights into how the effectiveness of VMS can be measured and evaluated, including key performance indicators, cost analysis, and time consumption rate. Overall, the research questions will guide the investigation of the practical application of Visual Management System implementing phase wise, providing a comprehensive understanding of the technique's principles, advantages, limitations, challenges, and potential benefits. The answers to these research questions will contribute to the existing body of knowledge gap and provide practical recommendations for industrialists to develop and implement automated digital platforms for dashboards.

Chapter 3
METHODOLOGY

In today's digital era, where information is constantly flowing, clear and effective visualization tools are more important than ever. Visual management system meets this need by seamlessly integrating with digital tools and software. Prioritize access to real-time data, foster collaboration, and keep everyone informed. This keeps everyone on the same page, improving decision-making and overall efficiency.

3.1 Data Collection and Surveys

The surveys are conducted to focus on the areas for the development of visual dashboards. The data are collected accordingly and proceeded with the categorization and standardization of the reports. The dashboards are being prepared mainly on two levels. These are as follows :

Company and Plant Level: These boards mainly cover an overview of company and plant shopfloor improvements. These dashboards are mainly focused on monitoring the overall performance of the plant. It gives the macroscopic view to track the performance matrices for the alignment in the direction of company goals.

Functional level: These dashboards contain information related to core functions like Line Status, Safety, 5S, Maintenance, etc. These are the microscopic matrices for monitoring and tracking basic functionalities and operations in the plant and will ultimately impact the plant-level performance and productivity.

3.2 Present State Evaluation

In this phase, the current practices followed by the company are focused on. It includes different areas evaluation helps us to identify the most relevant areas to work on for their digitization. Since the aim is to digitalize all the reporting formats, monitor the real time progress and enables the quick decision making through data driven insights. By following this technology, the company complementary goal of sustainability will also be achieved. The present state of the current practices followed by the company is evaluated based on the 3 factors as shown in the *Fig 3.1*.

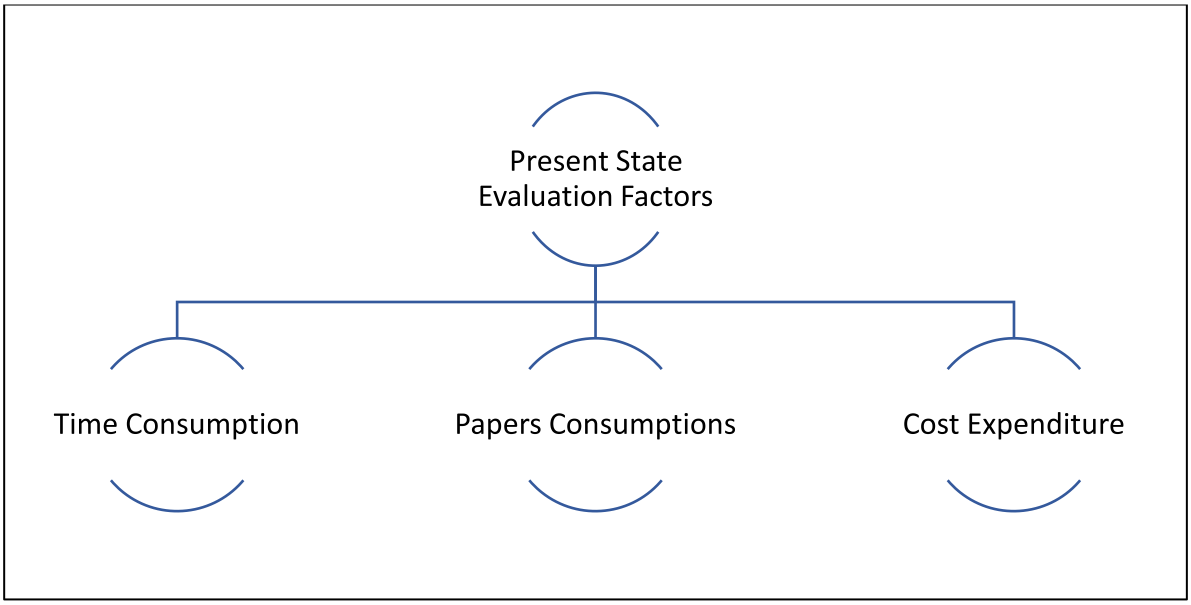


Fig. 3.1 : Factors of Evaluation

3.2.1 Time Calculation

In the current practices, the company consumes a large number of papers in daily, monthly, weekly and yearly reporting and their representation. The data is drawn from the company to determine the current position of the company which gives a clear picture of the points needed to be improved. The company came across to know that there are 102 highly important areas which the company should focus on standardization, digitalization and automation in order to cover performance monitoring of the overall plant. Multiple activities need to be performed sequentially to represent a single performance report as shown in *Figure 3.2.*

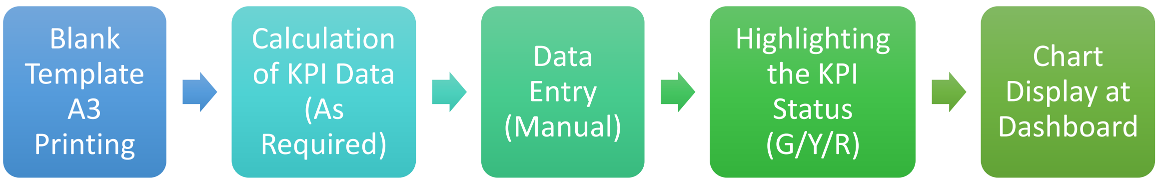


Fig. 3.2 : Performed Activities to Display a Report

For the calculation of time required to represent the performance matrices, the standardized work chart is used to find the time consumed by each of the required activity. Sum up all time entities to and multiplying the same by the frequency of updating of the chart will gives us the time consumed in updating the display board having a specific updating frequency. The matrix shown in *Table 3.1* represents the time required by each activity involved in producing a performance report while the matrix shown in *Table 3.2* represents the time required to maintain the dashboards manually.

Table 3.1: Activity Time Matrix

Activity	Remark (Action)	Activity Time (min.)
Blank Template A3 Printing	Manual	0.33
Calculation of KPI Data (as Required)	Manual	1
Data Entry	Manual	0.7
Highlight the KPI Status (G/Y/R)	Manual	0.5
Chart Display at Dashboard	Manual	0.5

Table 3.2: Dashboard Update Time Matrix of Current Practices

Updating Frequency	No. of Charts	Calculated Time (Min.)	No. of Updates in a Year
One Time	19	0	0
Daily	22	127.26	250
Monthly	49	148.47	12
Quarterly	10	30.3	4
Yearly	2	6.06	1

It is found that on an average 3.03 minutes is required to produce a progress report and a total of 33723.9 minutes (562.065 hrs) are required to maintain the dashboards annually which is a quite large figures and are considered under necessary but non - valued added activities.

3.2.2 Paper Consumption Calculations

The second evaluation is based on paper usage. Alternative goal of the plant is to achieve sustainability in which paper is the major source of wastage being caused every year. The carbon footprint on producing a standard A4 size sheet is 4.72 g CO_2eq. This needs to be reduced in order to create a healthy and sustainable environment. The company consumes a total of 2842 units of A3 size sheets annually to cover up 15706 data points across all the performance matrices of the plant. The distribution of these data points is shown in the *Table 3.3* based on the updating frequency.

Table 3.3: Updating Frequency Wise Data Points Distribution

Updating Frequency	Avg. Data Points Per Chart	No. of Updates Annually	Total No. of Data Points
Daily	58	250	14500
Monthly	90	12	1080
Quarterly	29	4	116
Yearly	5	2	10

Data is gathered from the plant about the actual number of printing papers being used based on their updating frequency. A certain amount of wastages is also been considered which is subjected to variation with an average of 10%. *Table 3.4* represents the actual numbers of printing papers used annually for performance report representation. We came across that a total of 1944.8 numbers of A3 printing papers is being used annually including wastages.

Table 3.4: Updating Frequency Wise No. of Papers Distribution in a Year

Updating Frequency	No. of Dashboards	Actual Printing Frequency	Total Prints in a Year
Daily	22	Once per Week	1056
Monthly	49	Once per Month	588
Quarterly	10	Once per Quarter	44
Yearly	2	Once in a Year	80

3.2.3 Incurred Cost Calculation

The third evaluation of the current practices followed by the company is based on the cost incurred. In this analysis, various costs are involved in the representation of dashboards in the form of hard copies. It includes the paper costs, printing costs and salary expenditures too.

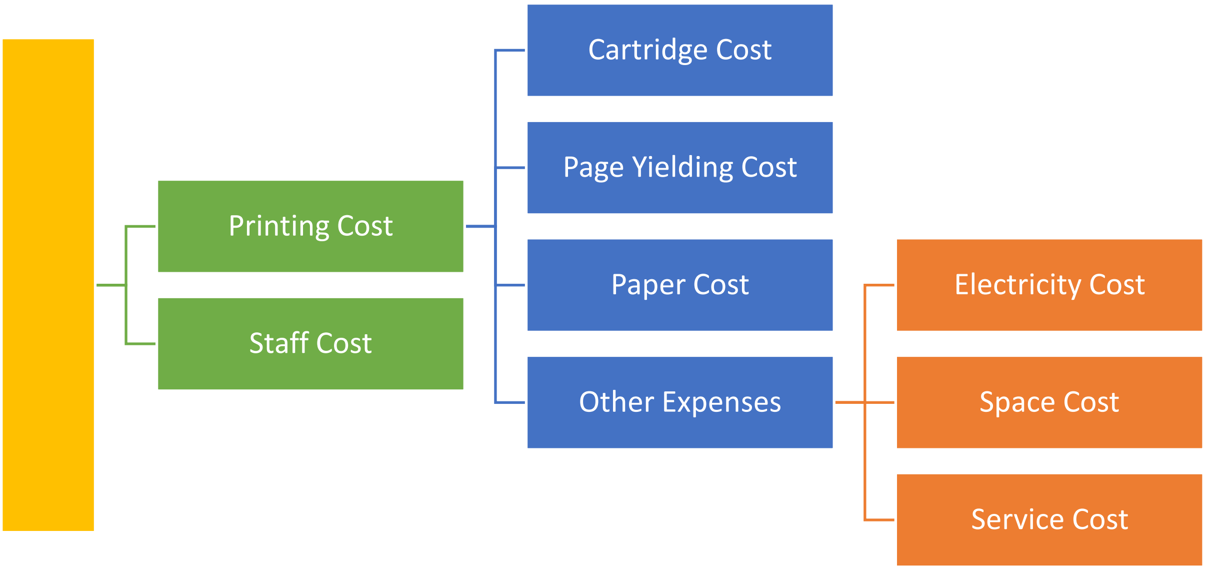


Fig. 3.3 : Cost Factors and their Components

i) *Staff Cost Calculations:* The total number of papers that is being used annually are 2842 in numbers including both A3 and A4 sized sheets which cover the total of 15706 datapoints. The time required by each data point manual entry on the paper is measured on an average as 30 seconds and the average time for filling each data point in the Excel template is 30 seconds. The time required to enter all the 15706 datapoints in excel format is calculated as:

Time required for data entry in hours = (Average time of recording a data point + Average time of data entry of one point) * Total number of data entry points/3600

Thus, the time required for data entry = 262 hours

The average time for making the a PPT & Printing of a paper, each are measured as 60 seconds.

Thus, the total time required for making the ppt and printing is calculated as 95 hours

Thus, the total time required for making all the dashboards as 357 hours within a year.

The average hourly wage of a staff member is Rs. 500. This wage is calculated based on the number of working days of the plant with the average CTC of the employee involved in the responsibilities of the same.

Thus, the total staffing cost of maintaining the dashboards for a whole year is calculated as ₹ 178250.

ii) Printing Cost Calculations: In printing a paper, there are certain cost involved in INR as

a) Cost per paper = ₹ 3

b) Colour Cartridge Cost (At a time 4 numbers) = ₹ 10000

c) Page yield = ₹ 2000

d) Colour Printing Cost of an A3 paper is calculated as = (Colour Cartridge Cost) / (Page Yield) + Cost per Paper = 10000 / 2000 + 3 = ₹ 8

e) The other expenses per paper is calculated as ₹ 0.5

f) Thus, the total cost of producing a single performance report paper is calculated = Other expenses per paper + printing cost of paper = 8+0.5 = ₹ 8.5

We have the number of A3 papers = 1944

g) Thus, the total printing cost = ₹ 22365

The total amount spent by the company in current year is the sum of staff cost and printing cost which is ₹ 200615. This shows that the company spent a significant amount on maintaining the dashboards and need to be reduced on an annual basis. On maintaining these dashboards manually will not be fruitful for the innovation in future since the company is looking to step towards automation. This can be eliminated by introducing the visual management system across all the 12 functional areas covering 102 dashboards.

3.3 Visual Charts Standardization

Standardization includes the establishing of uniform procedures, symbols, indicators and practices across the organization or specific areas within it. The key aspects in standardization can be – Visual cues and Symbols, Layout and displays, Documentation and Reporting Formats etc. There are certain benefits of standardizing the documents as:

a) Consistency: Standardized documents ensure uniformity in formatting, language, and style, which makes them easier to read and understand. This consistency enhances clarity and reduces the chances of misinterpretation.

b) Efficiency: When documents follow a standard format, it becomes quicker and easier to create, review, and distribute them. This efficiency is particularly valuable in business settings where time is often of the essence.

c) Compliance: In regulated industries, standardization helps ensure compliance with legal and industry-specific requirements. By following established standards, organizations can demonstrate adherence to rules and regulations, thereby reducing the risk of penalties or legal issues.

d) Quality Assurance: Standardized documents often undergo rigorous review processes to ensure accuracy, completeness, and quality. This helps maintain high standards and minimizes errors or inconsistencies in the content.

e) Cost Savings: Using standardized templates for frequently used documents can save time and resources that would otherwise be spent on creating them from scratch.

There are 3 types of visual charts in Visual Management System

- Graph form - These visuals represent the quantitative data in the form of bar graph and line graph.
- Image form - These visuals represent group policies and awareness posters.
- Pictorial form - These are the indicators with visual status with different colour codes.

3.3.1 Visual Graphic Structure

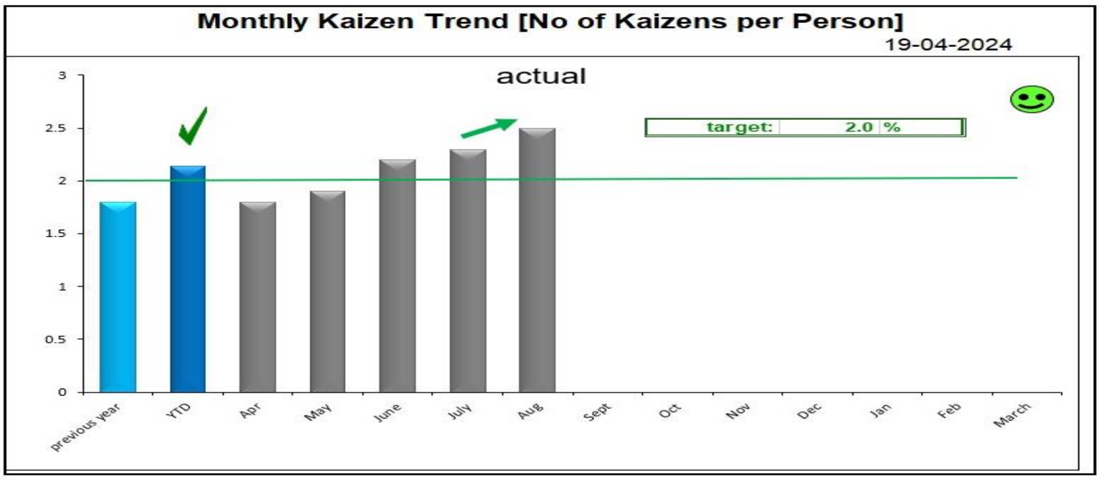


Fig. 3.4: Visual Graph

3.3.2 Barcode Colour Standardization

Table 3.5: Bar Colour Code Table

Previous Year Bar	
YTD Bar	
Monthly Bars	
Target Line	

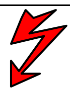
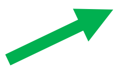
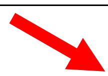
3.3.3 Overall Smiley Status Standardization

Table 3.6: Smiley Status Table

Monthly goal **and** YTD goal achieved	
Monthly goal **or** YTD goal **not** achieved	
Monthly goal **and** YTD goal **both not** achieved	

3.3.4 Trend Line Standardization

Table 3.7: Trend Line Table

Goal achieved	
Goal Not achieved	
Improvement trend over last month	
Deterioration over last month	

3.4 Phase wise Architecture

The ANAND visual management system's digitalization journey started at ANAND plant. The implementation is divided into four different phases as mentioned in the architecture below:

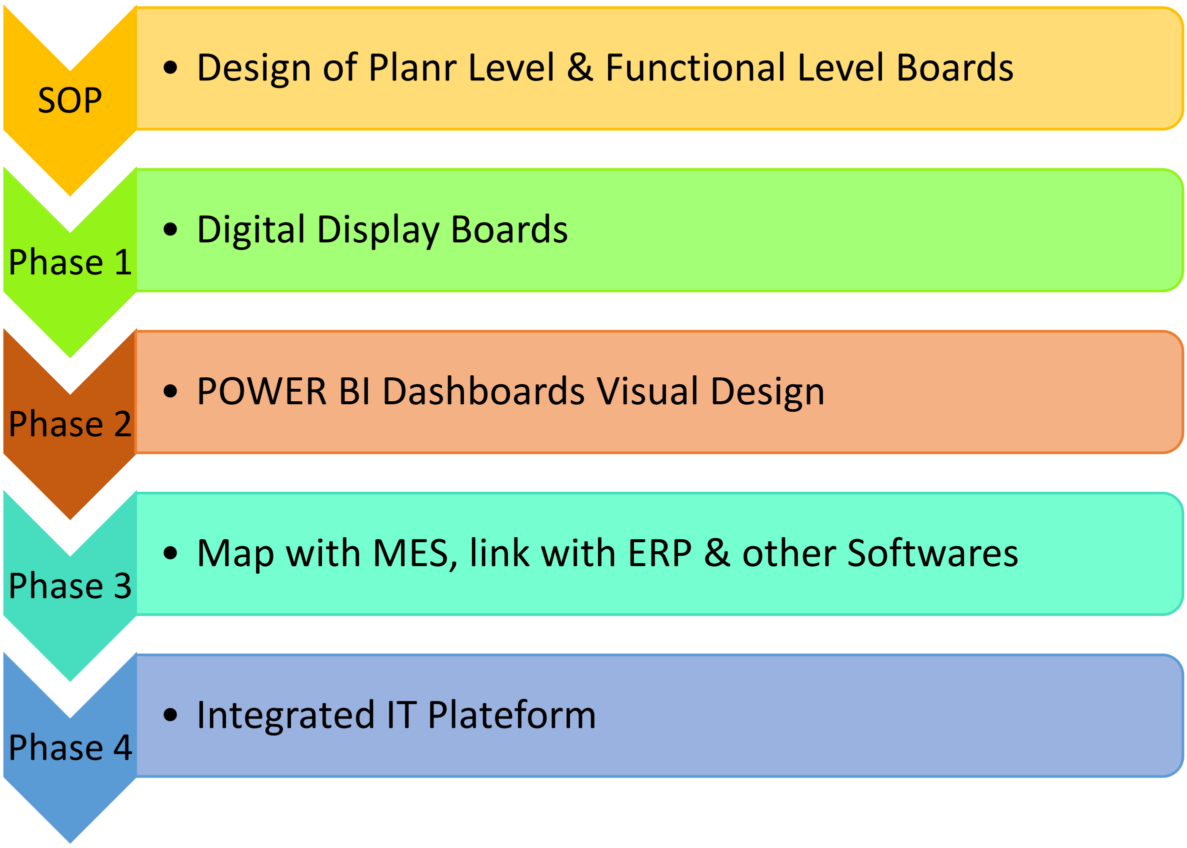


Fig. 3.5 : Phasewise Architecture

3.4.1 Phase 1: Digital Display Boards

Digital display panels now can be shown on LED TVs and specific control system. Public spaces like corporate and factory gates employ LED displays with different LEDs, and some divisions like manufacturing lines, shipping, and maintenance use dedicated digital displays to provide pertinent information. These boards are updated at predetermined intervals with 180 data points and over 100 predefined visualizations. The system also includes 160 dashboards for further data visualization. The architecture for Phase 1 implementation is shown in *figure 3.6*.

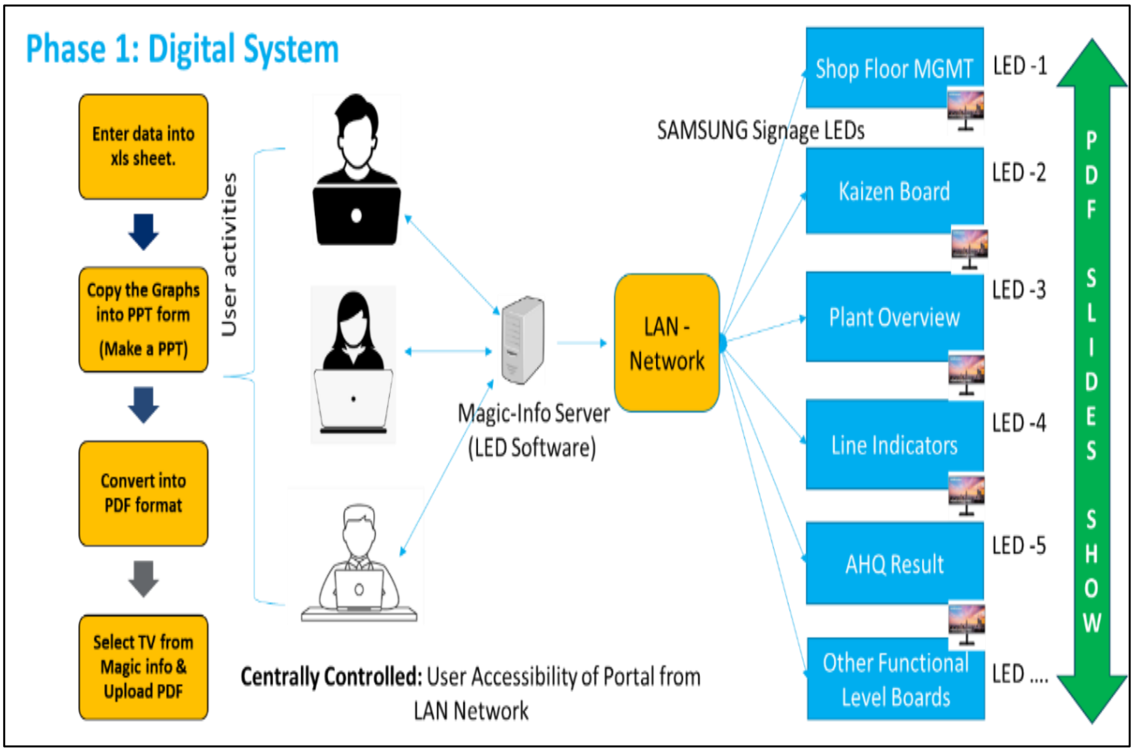


Fig. 3.6 : Architecture for Phase 1

Fig. 3.7 : Phase 1 Activities

A network of LED displays connects to the Magic-Info server software over a local area network (LAN). This allows users to enter data and update dashboards on the server, which in turn controls the content displayed on the LED signs.

It can easily be created a dynamic LED display. Simply filling out a pre-designed template with your information, choose the appropriate LED sign from Magic-Info, and upload the data. The system will automatically convert everything into a timed PDF slideshow, ready to be displayed on chosen LED sign.

Fig. 3.8 : LEDs Display Boards

Thus, in this new system, the time consumed by maintaining dashboards in hours is shown in the *Table 3.8.* The total time required in maintain the dashboard in phase 1 is 23373 minutes or 389.55 hrs in a year. The dashboard update time matrix after Phase 1 is shown in *Table 3.9*.

Table 3.8: Element wise Activity Time Matrix in Phase 1

Activity	**Remark (Action)**	**Activity Time (min.)**
Blank Template A3 Printing	NA	0
Data Entry	Excel	0.5
Calculation of KPI	Excel	0.1
Highlight the KPI Status (G/Y/R)	Excel (Conditional formatting)	0
Preparing PPT for Dashboard	PPT	1
Uploading for Display (LED/TV)	Manual	0.5

Table 3.9: Dashboard Update Time Matrix After Phase 1

Updating Frequency	Number of Dashboards	Annual Time Consumption (hours)
Daily	22	88
Monthly	49	103
Quarterly	10	21
Yearly	2	4

3.4.2 Phase 2: Dashboard Automation

Instead of using PowerPoint slides and images, Phase 2 introduces interactive dashboards with charts generated using Power BI. Users can enter dates directly into forms on SharePoint, and the corresponding LED displays will automatically update to reflect the new data in the charts. The following illustration as shown in *figure 3.9* represent the system design for Phase 2, which leverages Power BI and Power Robot to create these dynamic dashboards.

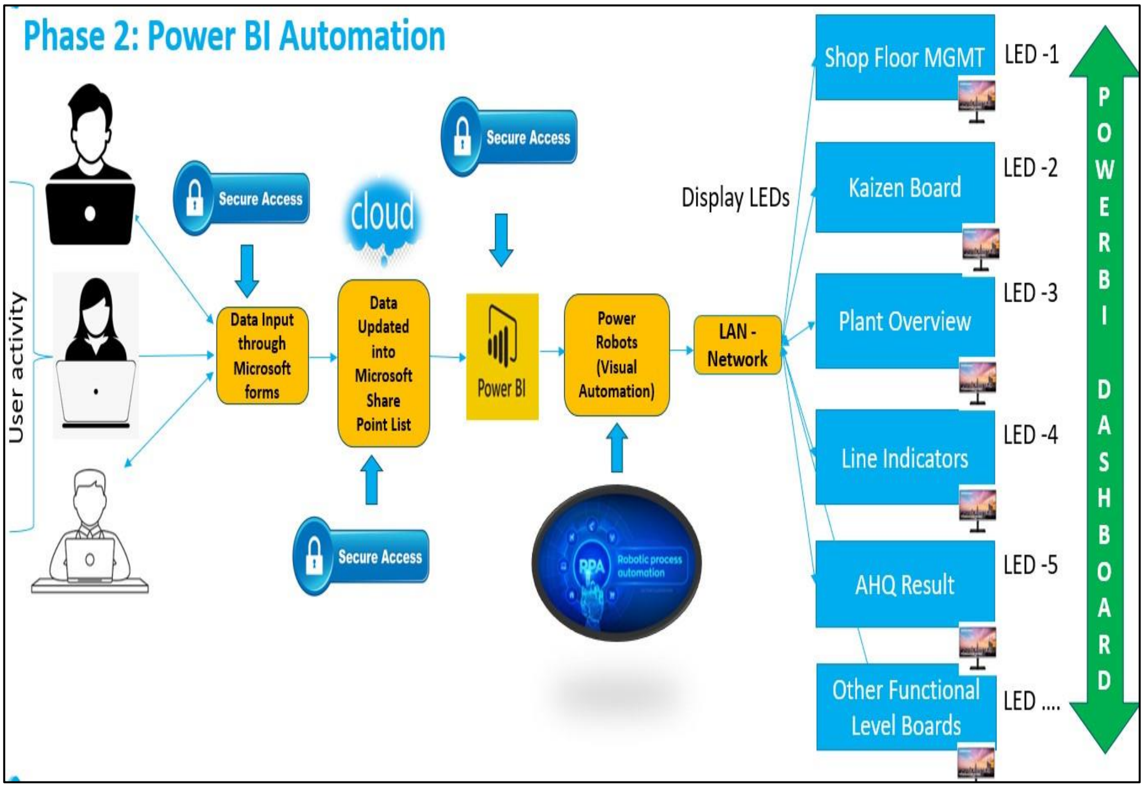


Fig. 3.9 : Architecture for Phase 2

It shows the design & development of a high-level system architecture that outlines the components and their interactions which considers the integration with existing systems and technologies. Components used for the development of the systems are Microsoft Forms, Share list, Power BI & and Power Robot.

For Phase 2, Plant requires the following hardware and software to ensure proper display functionality on their LED TVs.

Table 3.10 : Hardware and Software Configurations

Hardware (display) Infrastructure Configuration:		
Sr. No.	Items	Configuration Details
1	LED TV (Samsung Signage): Crystal UHD, LED-55 Inch	QB55B, OS-Tizen 4.0 (VD Linux)
2	Desktop System for controlling display (optional)	8GB-RAM, 500GB-HDD, Intel Corei5, Windows10 Pro.
3	Network Connectivity	LAN & Wi-Fi (Local or Remote)
4	LED Display Stands	As per requirements
Software Configuration:		
1	Power BI- Existing License can be used for the same	Pro. License (03 Min. in Number)
2	Power Robot	01 in number.
3	Microsoft 365	With the support of Power Apps, MS Forms, Share List.

The same Hardware & Software infrastructure will be used for Phase 3 & Phase 4 implementation for visualization.

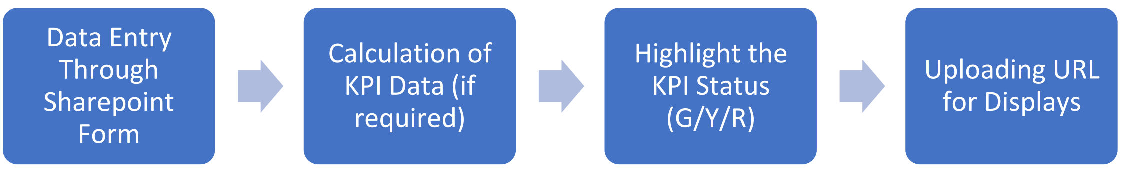


Fig. 3.10 : Phase 2 Activities

The Element wise activities time matrix in this phase is shown in the *Table 3.11*.

Table 3.11: Element Wise Time Matrix for Phase 2

Activity	**Remark (Action)**	**Activity Time (min.)**
Data Entry through SharePoint form	Manual	0.5
Calculation of KPI Data (if required)	Power BI	0
Highlight the KPI Status (G/Y/R)	Power BI (Conditional Formatting)	0
Uploading for Display (LED/TV)	Manual	0.5

Analysis of time required to maintain the 102 dashboards annually based on *Table 3.11* is represented in *Table 3.12* below.

Table 3.12: Phase 2 Dashboard Update Time Matrix

Updating Frequency	**Number of Dashboards**	**Annual Time Consumption (hrs.)**
Daily	22	37.8
Monthly	49	44.1
Quarterly	10	9
Yearly	2	1.8

Thus, the total time required in maintaining the dashboard annually during phase 2 is 10017 minutes or 166.95 hrs.

The following steps taken to implement the Phase 2 :

Step1: Graphics Development

To clearly present data, we need standard charts and graphs (visualizations) for common situations. These visualizations should be used consistently across all dashboards for easy comparison. The complexity of your data will determine the best platform for building these dashboards. Choosing a platform that works with our existing technology and has the features that needed. Popular options include Power BI, Python libraries, Tableau, and Google Data Studio.

The Shopfloor now features interactive visualizations instead of static dashboards. These were created using Power BI, a tool that connects to data and transforms it into clear visuals. With Power BI, everyone can easily able to see and share information and optimize performance.

Figure 3.11, 3.12, 3.13 shows an example of Power BI graphics developed for 5S Map, Daily Line Meter and Daily Indicators respectively.

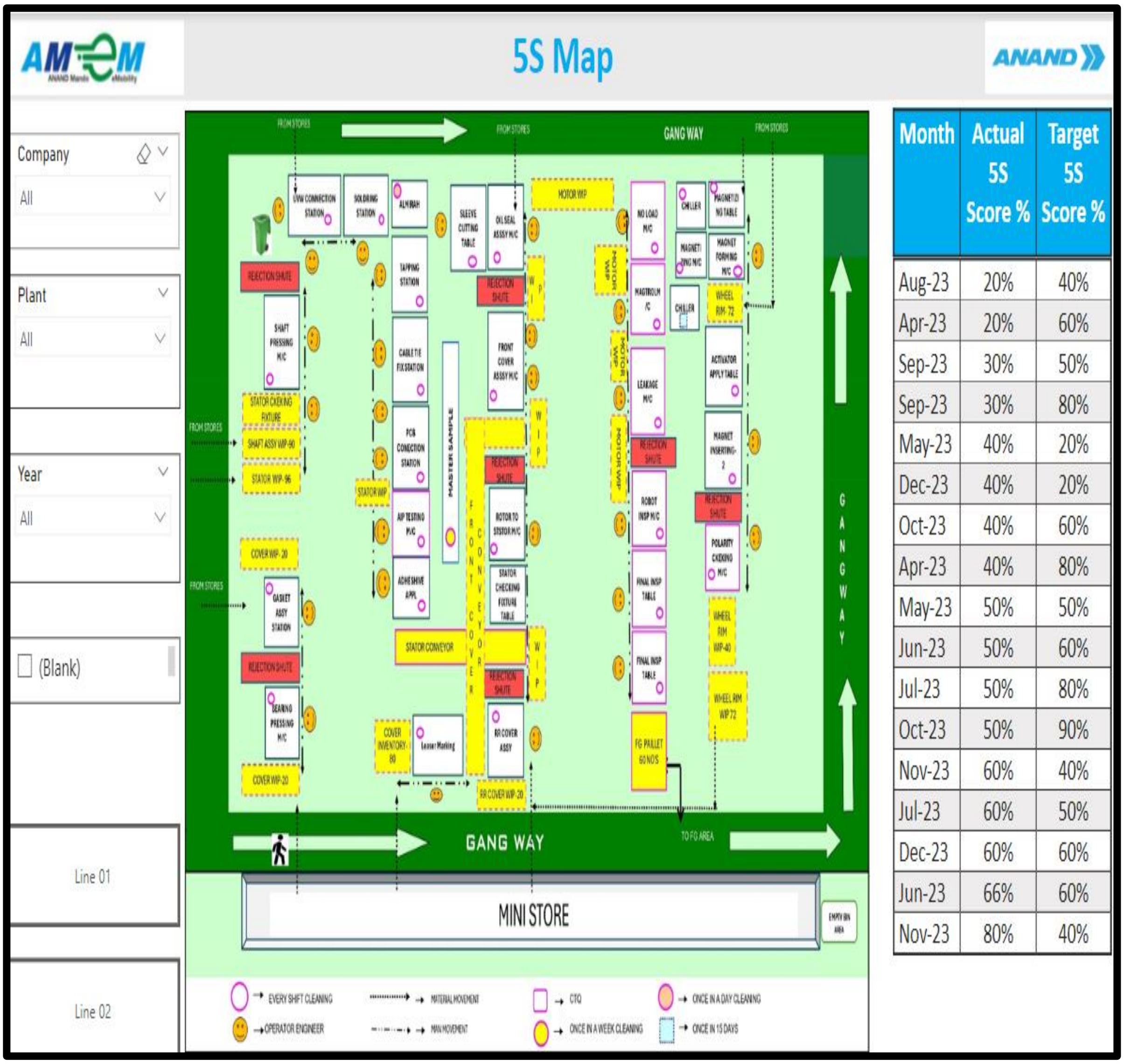


Fig. 3.11 : Example of Power BI Visual – 5S Map

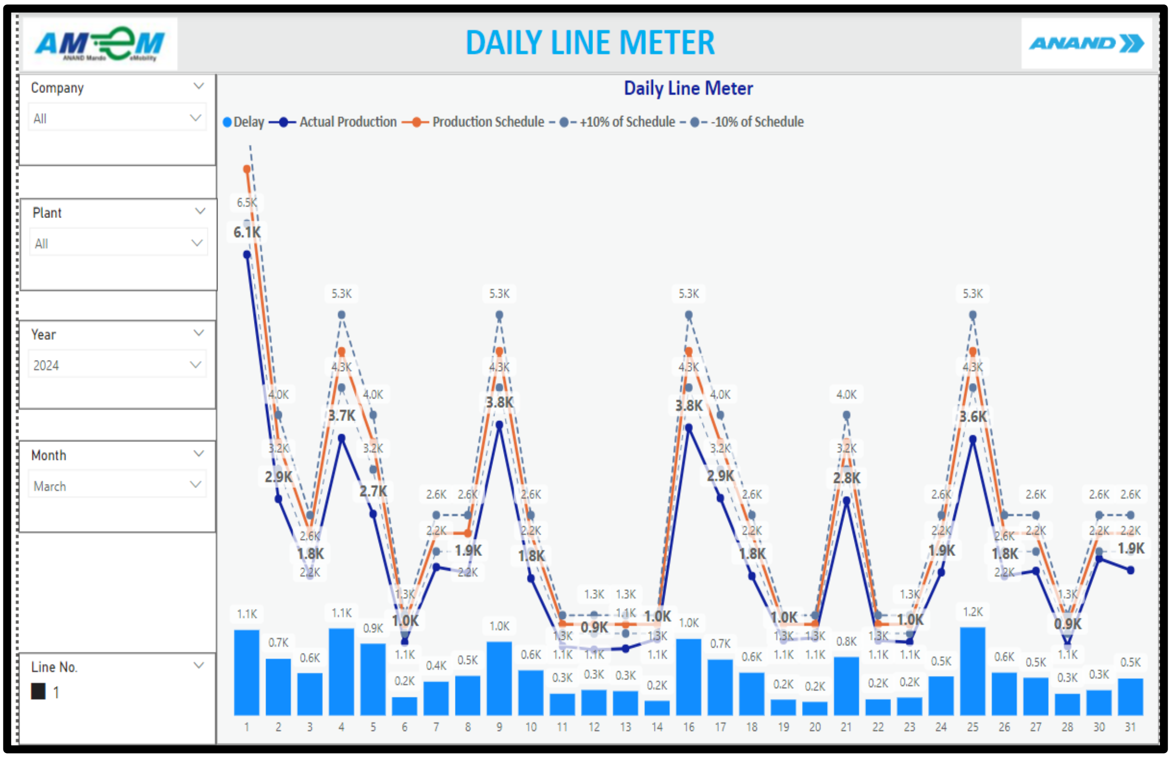


Fig. 3.12 : Example of Power BI Visual – Daily Line Meter

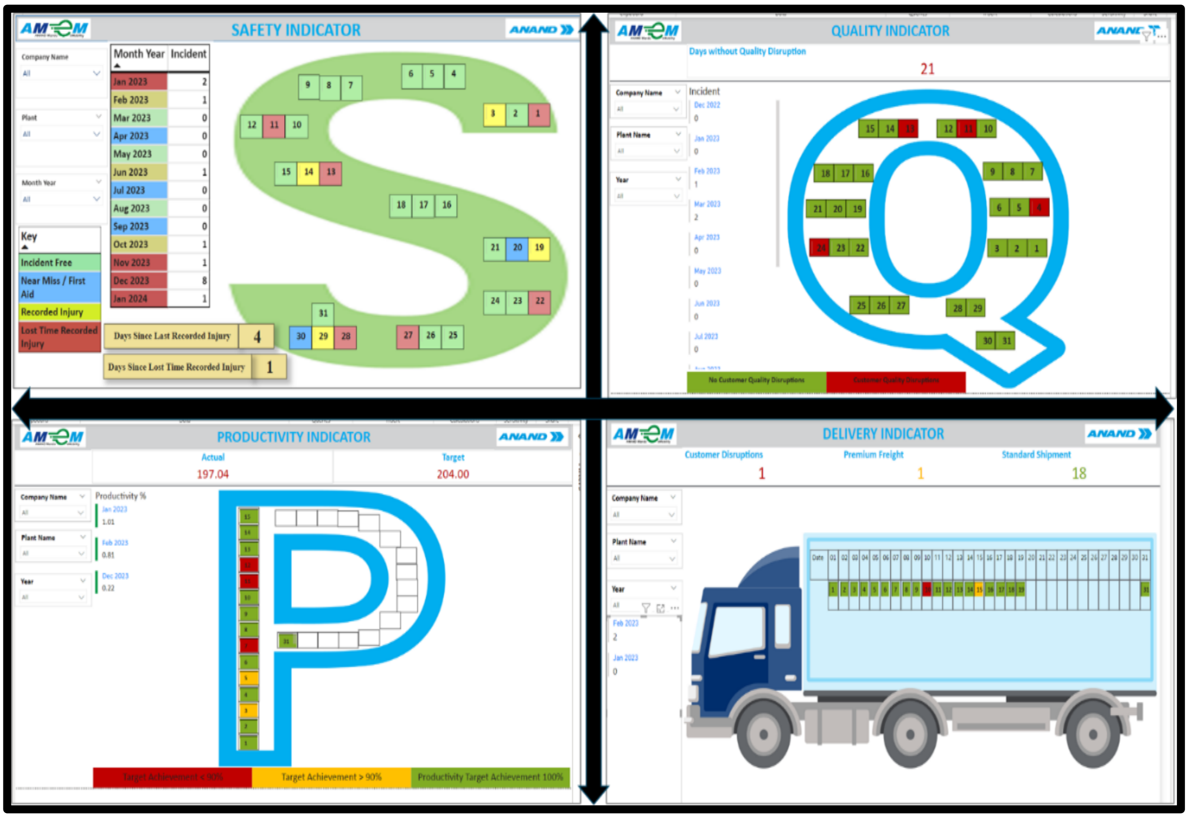


Fig. 3.13 : Example of Power BI Visual – Daily Indicators (Safety, Quality, Productivity & Delivery)

Step 2: Dynamic Row Level Security (RLS)

Dynamic RLS, or Dynamic Row Level Security, is a way to control what data users see in reports and dashboards based on their login credentials. It's more flexible than static RLS, which assigns pre-defined roles to users. Its core function is to filters data based on the user's login information. For instance, a sales report - with dynamic RLS, each salesperson would only see their own sales data when they log in. It reduced Role Management so don't need to create multiple static roles for each user's specific data access needs. It allows for more control. Dynamic RLS provides fine-grained control based on custom attributes stored in the data itself. Dynamic row-level security works like a personal keycard. This allows users to access specific rows of data based on predefined rules, ensuring that only what they are authorized to see is visible. This feature is available in databases and platforms such as Power BI and keeps sensitive information locked on a per-user basis (Whitelock Wainwright, 2022).

The following are the significant advantages of Dynamic RLS:

- Unlock granular control over your data with Dynamic Row Level Security (RLS)- Dynamic RLS lets you define custom rules that determine what information each user or group sees. This is ideal for situations where users have varying access needs, such as multi-tenant applications.
- Dynamic RLS goes beyond static roles. Instead of predefined permissions, It can set custom conditions based on factors such as user information, current session information, and general context. This allows for very specific filtering based on the user's context.
- Filters that adapt in real time- Dynamic RLS often uses expressions that evaluate the user's context at query time, returning only data that meets certain criteria.
- Policies as a security guideline- Many systems implement dynamic RLS using policies. These policies define the rules of a specific table or view, and apply by the database itself every time the user accesses data.

Dynamic RLS offers a promising approach. Your security needs can change, and dynamic RLS allows you to easily configure policies without changing your application code. This provides significant flexibility and adaptability.

For example, a sales application can use dynamic RLS to ensure that salespeople only see data for the region to which they are assigned. The dynamic conditions here will be the user's role and corresponding territory. The implementation of dynamic row-level security may vary depending on the database management system that uses RLS

Step 3: Creating Playlists as per LEDs

While LED display systems typically include software for playlist creation, managing multiple playlists with this software can be cumbersome. Everything from adding visuals to scheduling their display requires manual effort. Scheduling itself is fortunately straightforward. However, juggling data, timings, and software upkeep becomes a challenge, especially with multiple playlists. Upgrades and patches can even disrupt the visuals being shown.

The plant in India is pioneering the use of Power Robot, a cutting-edge tool officially certified by Microsoft. This first-of-its-kind application in India allows us to create massive playlists exceeding 1,000 entries. Power Robot personalizes the content by tailoring playlists to customer needs. It then displays live data visualizations on various platforms, including LED displays, smart TVs, laptops, tablets, and even mobile devices.

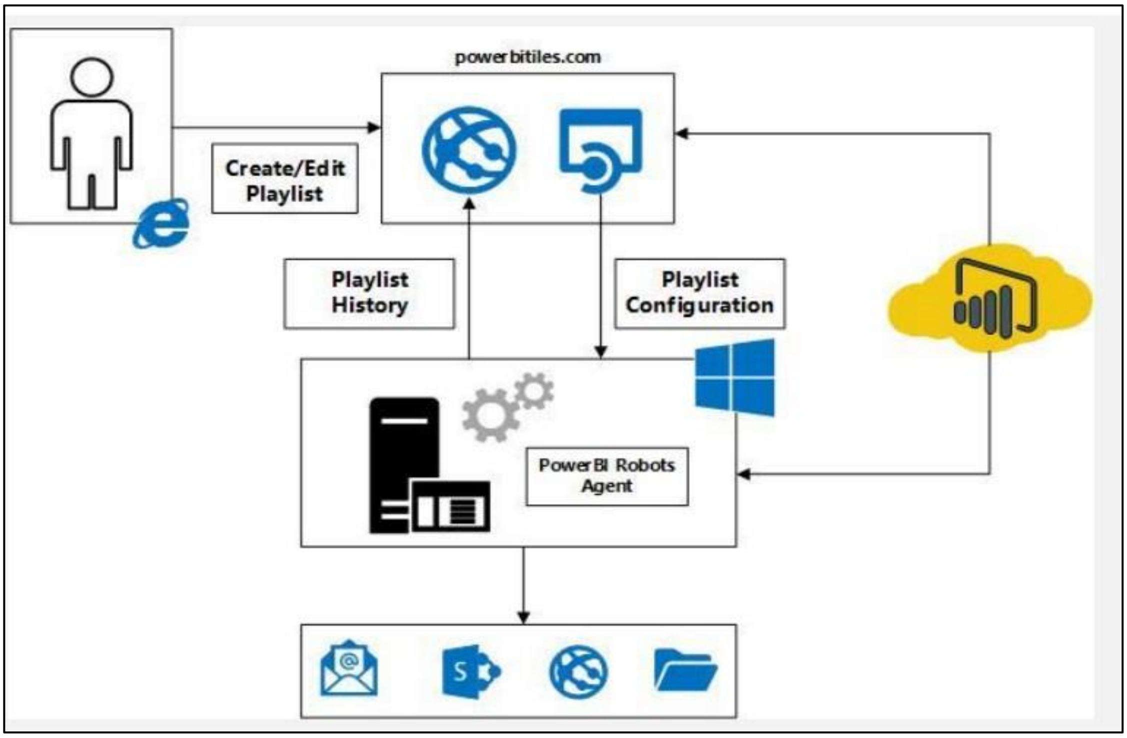


Fig. 3.14 : Playlists creation

When a user signs up for a Power BI robot, only an email address is required. This is used to identify the user and send important information such as policy updates and changes to her Power BI bot. We may also use it to inform the user about other DevScope products or services. User’s email address will not be shared with anyone, and can opt out of receiving marketing emails at any time through user’s account settings. The Power BI robot website also uses cookies, so that the users don't have to log in again. The users can learn how to manage cookies in browser settings.

- Power BI Robots prioritizes user privacy. It doesn't collect any personal data, and all information it uses is stored locally on your own devices or servers, not on those of Power BI Robots.
- For security reasons, the company don't rely on your system's scheduling tools. Instead, they use a local scheduler called Hang Fire that runs directly on the machine with the Power BI Robots Agent. This way, none of company’s data content or credentials are ever stored on our servers. It only stores encrypted playlists containing Power BI report URLs and filters on the local machine's secure storage. These playlists are located in an encrypted file named "PBIRobotsService.config" within the application folder.
- The system gathers user’s Power BI login details twice: during agent setup and playlist creation. This is because displaying and generating images from Power BI requires the Power BI SDK. This SDK obtains a security token to access the data securely. This token functions like a temporary passcode, stored locally and expiring after a set time. It follows the OAuth protocol, a common authorization standard.
- DevScope operates by not persisting the web application's access token on the server. In simpler terms, DevScope avoids storing the web application's authorization key on the server.
- For web applications, tokens are temporary and only last for the duration of your browsing session. They are stored securely on the device in a cookie created by your browser. For the Agent Service app, the token is encrypted and saved locally on your device, separate from your web browser.
- Security adheres to Microsoft's recommendations for interacting with the Power BI API. This is achieved by leveraging the official Microsoft SDKs
- The permissions required by our app are explicitly defined in its Azure directory.
- DevScope guarantees that no tokens are ever used because they aren't saved on our servers at any point of the workflow. They are always saved locally, either on the client's browser or the agent’s computer. We went through a big engineering effort to guarantee that we don’t keep any Microsoft security credentials on our side.

Dashboards can be grouped into categories and displayed as slideshows on LED screens. A remote control allows the user to navigate these playlists, which update automatically with the newest user data. It can even set the time each dashboard stays on screen.

Step 4: Data Upgradation responsibility & SOP

Data in the share lists is kept accurate by assigning update responsibility to plant and function owners. To gather information and update the list, we use Microsoft Forms. These forms are access-controlled to ensure each data point is only updated once. However, admins and function owners can modify user-submitted data if necessary. Updating multiple entries can be done directly in the share list, which can also be extended to include historical data for a specific timeframe.

Figure 3.15 shown below is chart wise responsibility matrix :

2	Category	Sr. No.	Chart Type	Department	Frequency of Update - Current
46	SHOPFLOOR MANAGEMENT	44	Monthly Line Efficieny (OEE Trend %)	Production	Monthly
47	SHOPFLOOR MANAGEMENT	45	Safety Indicator	Production	Daily
48	SHOPFLOOR MANAGEMENT	46	Quality Indicator	Production	Daily
49	SHOPFLOOR MANAGEMENT	47	Delivery Indicator	Delivery	Daily
50	SHOPFLOOR MANAGEMENT	48	Productivity Indicator	Production	Daily
51	Line Board	49	Line 5S Map	5S Cordinator	One time
52	Line Board	50	Skill Matrix	HR	Monthly
53	Line Board	51	Production Sq. List	Production	Daily
54	Line Board	52	Daily Line meter	Production	Daily
55	Line Board	53	Daily OEE / Productivity / MOP	Production	Daily
56	Line Board	54	Product Meter	Production	Daily

Fig. 3.15 : Department wise responsibility matrix

User will access Microsoft forms on their system with the use of credentials to update the data. Figure 3.16 shown below is an example of a Microsoft form. With Microsoft Forms, user can control how often the user see the latest data. The user can choose to refresh it as often as every 5 minutes, or can set it to update daily, weekly, monthly, or even yearly – all based on the users needs.

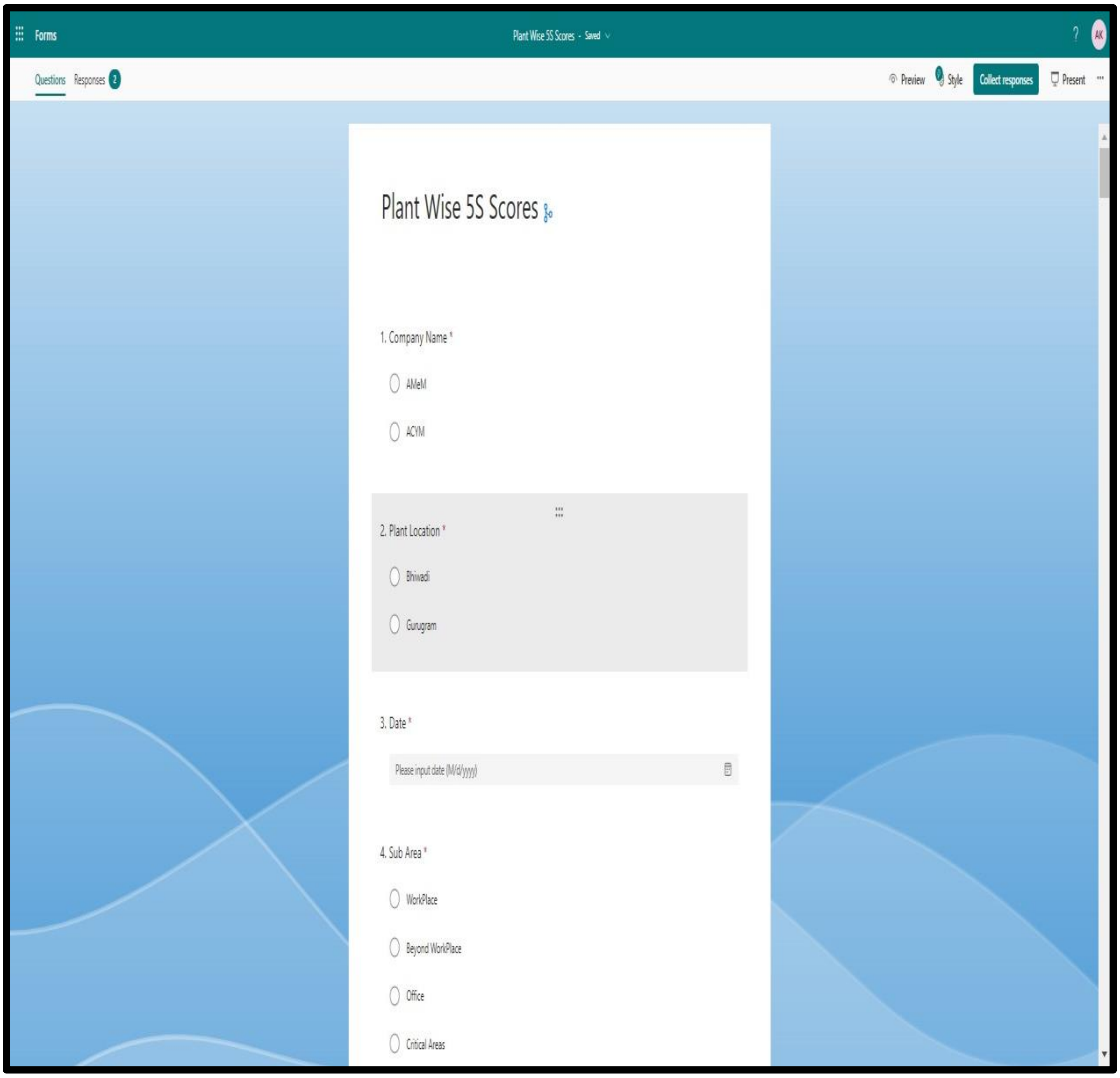


Fig. 3.16 : Microsoft Forms

3.4.3 Phase 3 & 4 : Planning and establishing a path for further progress

Instead of manually entering data, this phase uses live data feeds from SAP, MES, and other software to create interactive dashboards with Power BI visuals. This approach provides real-time insights in the operations, refer to Figure 3.17 for activities in Phase 3 and Figure 3.18 represents the overall architecture for Phase 3 & 4.

To make this dashboard, the plant will need to connect various software programs. This connection will be achieved through APIs, which act as intermediator between different applications. To prioritize which software to connect first, we need to identify the most critical data points for the dashboard. Once we get to know that, we can focus on integrating the software that holds that data.

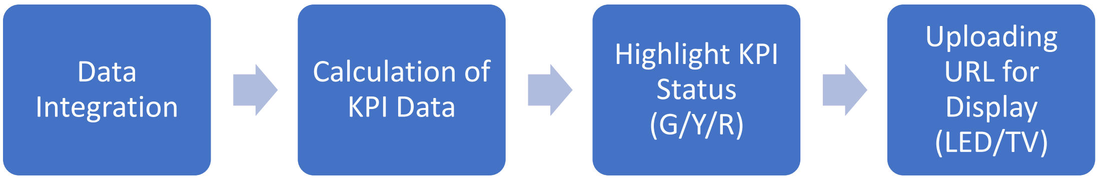


Fig. 3.17 : Phase 3 Activities

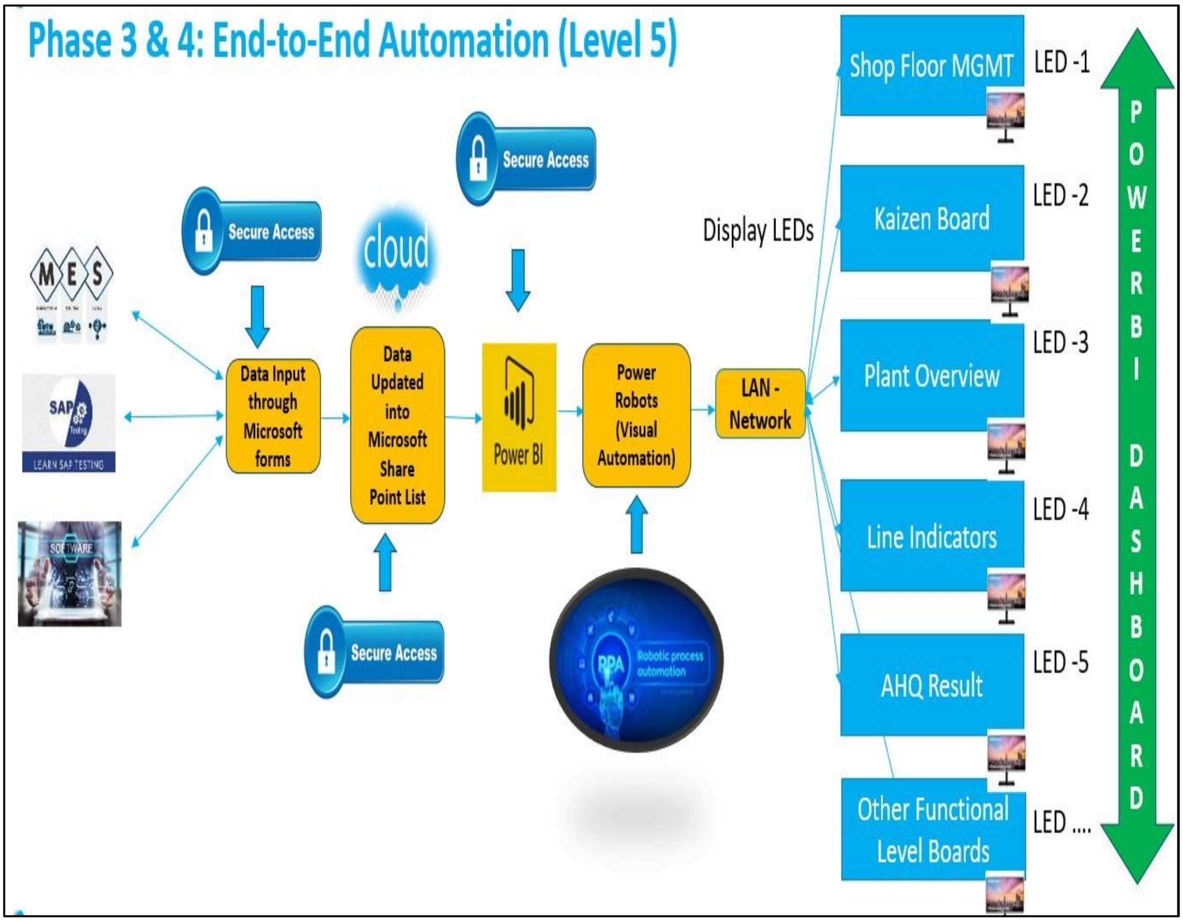


Fig. 3.18 : Architecture for Phase 3 & 4

The element wise activity time matrix is shown in the *Table 3.13*.

Table 3.13: Phase 3 Element wise activity time matrix

Activity	Remark (Action)	Activity Time (min.)
Data Integration – API + 07 (Direct from Machines)	API Driven + Machine	0.2
Calculation of KPI Data (if required)	Power BI	0
Highlight the KPI Status (G/Y/R)	Power BI (Conditional Formatting)	0
Uploading for Display (LED/TV)	Auto Refresh	0.2

Adding a software API to your dashboard is about bringing its data and features on board. Start by studying the API's guide to understand how to interact with it. This includes things like connection points (endpoints), security checks (authentication), data formats, and any special instructions. Once it's familiar, get access by obtaining keys or tokens, following security best practices to keep things safe.

Before displaying data on the dashboard, take steps to make it clear and useful. This might involve cleaning up mistakes, combining similar data points, or picking out only the information we need. Once the data is prepared, seamlessly integrate it into user's dashboard. This means updating charts, tables, and other visuals to reflect the new information that've retrieved through the API. In short, get the data ready and then show it off in the most informative way possible.

Make sure the system can handle anything the API throws its way. Test common scenarios, but also consider unusual situations to find potential weaknesses. When errors happen, the code should respond gracefully, preventing crashes and confusing displays. Most importantly, verify that the data displayed on the dashboard perfectly matches what the API provides. To keep things speedy, optimize the code. Implement caching mechanisms to store frequently accessed data locally. This reduces unnecessary API calls, making the dashboard more responsive and efficient.

Table 3.14: Scoring between API's

Criterion	Weights	Rating (API 1)	Score (API 1)	Rating (API 2)	Score (API 2)
SAP/Power BI Compatibility	5	Yes (5)	25	Yes (5)	25
Data Security	4	High (4)	16	Medium (3)	12
Data Refresh Rate	3	Real-time (5)	15	Near Real-time (4)	12
Data Filtering/Transformation	2	Yes (5)	10	No (1)	2
Ease of Use	1	Easy (5)	5	Medium (3)	3
Cost	1	Free (5)	5	Subscription (3)	3
Total Score			**76**		**57**

API: API stands for Application Programming Interface, acts as a middleman between different software programs. It allows them to talk to each other and exchange data or functionality.

Screening and Scoring need to be performed to find the best suited API application for the required perspective. Screening Criteria:

SAP and Power BI Compatibility: Does the API support the specific versions of SAP and Power BI being used. The company has to ensure the compatibility of the sofware's with future upgrades if possible.

Data Security: This is to ensure whether the API offers robust security features to protect sensitive manufacturing data during transfer between SAP and Power BI. The company has to ensure the encryption, secured access control and audit logs.

Data Refresh Rate: How often can the API refresh the data in Power BI. Real time data is critical for VMS. It is necessary to select the APIs with low latency and options for schedules or on-demand refreshes.

Data Filtering and Transformation: Can the API filter and transform the SAP data before sending it to Power BI. This can be crucial for streamlining data preparation in VMS dashboards.

Ease of Use: How easy is it to setup and maintain the API connection? Consider the factors like documentation quality, support options and coding requirements.

Cost: Does the API have a free tier, a subscription fee, or a per-user cost? Choose an option that aligns with our budget and usage needs.

All these points to be kept in mind before selecting a suitable API software.

The company came across to know that there are two best suited API software's available in the market to link the SAP and MES with the Power BI software's as:

API 1 (SAP Cloud Platform Open Connector) – This API from SAP itself allows us to connect various SAP applications including SAP ERP system, Power BI for data visualization. It offers real-time data access and basic data transformation capabilities

API 2 (Scribe Software Power BI Connector) – This API from Scribe Software provides a more robust solution for SAP to Power BI Integration. It boasts high-performance data extraction, advanced data transformation options, and scheduling functionalities for data refreshers. It also offers additional features like data security management and user authentication.

Weights are given to each of the screening criterion as per preferences. This can vary from plant to plant. The ratings are assigned to each of the criterion for different API as shown in the *Table 3.14*.

The phase 4 will see a major upgrade in our data collection. Those charts and graphs we track on the factory floor (visual management charts) will be linked directly to the machines themselves. This will be achieved through a new company-wide system based on Industry 4.0 principles. Essentially, in phase four, our machines will talk to a central hub, sharing real-time data that will be automatically displayed on our visual charts. This will give us a constantly updated picture of what's happening on the production line, allowing for faster decisions and better control.

Chapter 4

RESULTS & DISCUSSION

4.1 Time Consumption

A lot of time were being consumed in the traditional practices that company followed because of manual data entry, calculation, preparation and displaying the dashboards. All the activities were being performed manually in maintaining the dashboards. It is calculated as that the company spent 562 hours in a year in maintaining the reports on the display boards which is quite large in terms of cost and inefficiency. The company has gone through 3 different phases for bringing the complete automation in maintaining the reports on digital screens. Different variations in time consumption were observed while moving through phases. Related variations in the time of updating dashboards on specified frequency also has been observed as shown in the *Figure 4.1*.

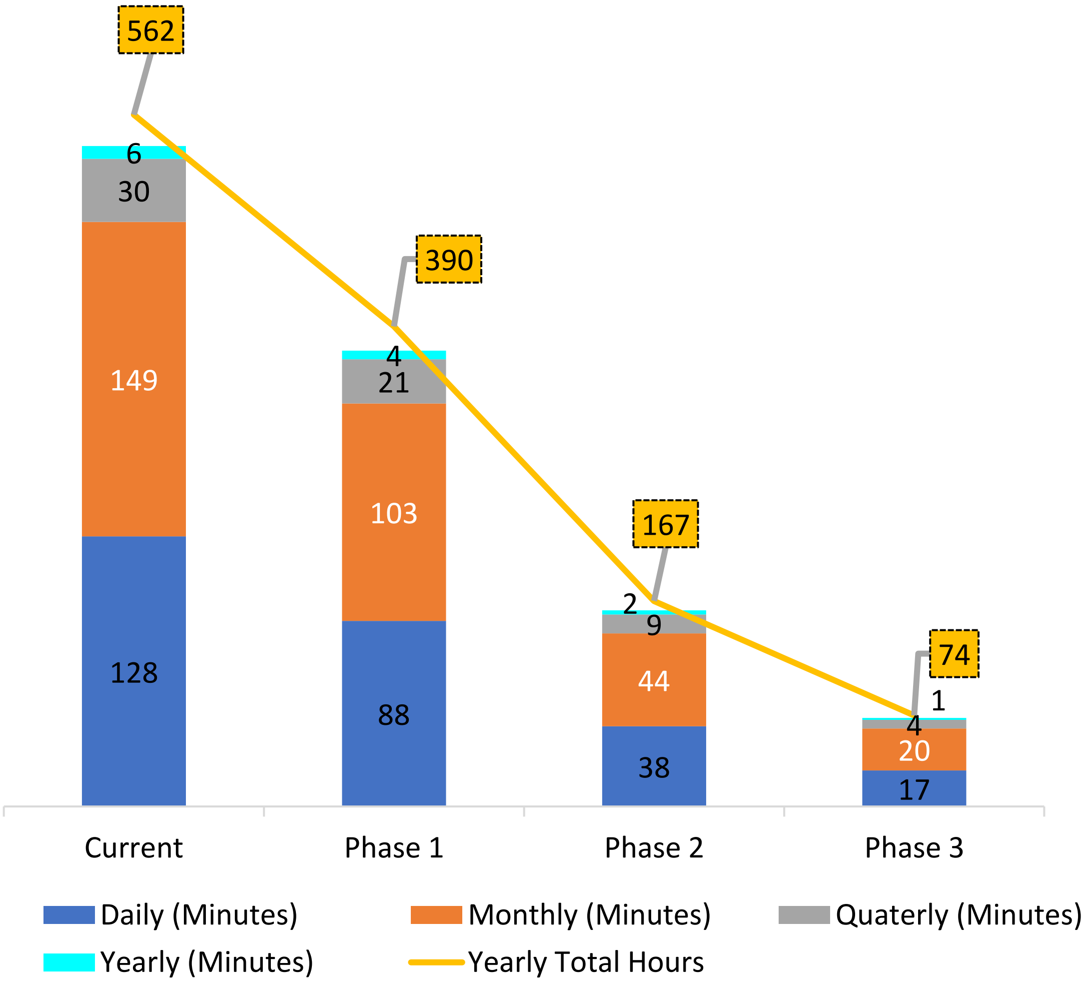


Fig. 4.1 : Phase wise and Update frequency wise time reduction

It is been observed that implementation of Phase 1 leads to the time consumption of 390 hrs in maintaining the dashboards annually. There is quite significant drop in time consumption can be observed from *Figure 26* in maintaining a single dashboard the dashboards annually based on their updating frequency contributing a total of 30.6% droppage of time. In this phase data entry has been done on excel templates and automatically generated graphs are being uploaded to the digital displays in pdf format manually.

It is noticeable that bringing the latest tools and technologies like Power BI and Power Robot will enable the plants to reduce these figures furthermore. In this case study, the time consumption has been further reduced by 57.18% while implementing from Phase 1 to Phase 2. In this phase, few elemental activities like manual calculating the KPI and highlighting its status has been eliminated. In the phase 3, of the implementation, the data driven KPIs has been calculated automatically along with data collection directly from MES and ERP software through APIs. This enables company to save the updating time by 55.68% which is quite significant. Considering all the phases helped the plant to reach these figures to 74 hrs/year. Thus, by completely implementation of VMS in the plant helped it to reduce the overall time of updating the dashboard by 86.83% which is really a great achievement.

4.2 Cost Analysis

The second major result that is been evaluated in this project is cost incurred. It is basically the comparison of the cost expenditure by the company with and without the implementation of VMS. Various cost factors like printing cost and staffing cost are been considered for the calculation. It is found that the company spend INR 2,00,615 annually to maintain the dashboards. While the direct BOM is used to find the implementation cost including hardware cost, software and APIs cost, server and maintenance cost, installation cost etc. The fixed cost incurred only once which includes hardware, installation costs while on the other side, variable costs like subscription, electricity, server and maintenance costs are also been considered. It is calculated as the company spent INR 10,62,900 as the fixed cost while the yearly based expenditure is INR 1,87,339 which is INR 13,276. Thus, the company saves the yearly expenditure by 6.61% by implementing VMS to the plant.

4.3 Paper Consumption

The third parameter to evaluate this project is based on paper consumption and the carbon footprint throughout its lifecycle. In section 3.2.2, it is shown that annual consumption of papers in the plant is 2842 in numbers for the representation of visual reports on the dashboards. Out of which 1944 in numbers of papers are being consumed in A3 size. This leads to the 341 Kg of carbon emission in the atmosphere through its life cycle. This practise is not sustainable and need to be eliminated. Paper free reporting is the best option that plant has chosen for this purpose. This implementation of dashboards representation helps the plant to achieve paper free reporting and leads to Zero Carbon footprint.

The discussion highlights various visual management tools and their practical benefits. These tools can directly improve efficiency and worker comfort through visual cues and instructions like signs for navigating the workspace or guides for setting up machines. In some cases, VM tools enforce specific procedures or limitations through visual controls like kanban systems, poka-yokes, or inventory level markings in 5S. They also prove valuable in training employees, both new and existing, by providing a clear understanding of the workplace layout, processes, standards, and operations. However, the discussion often overlooks the significant role VM tools play in marketing, both internally and externally. Additionally, VM tools go beyond just identifying workplace problems. They can also be used to communicate the problem-solving process itself and even share the implemented solutions and new standards. Ultimately, VM tools serve as facilitators for group discussions and improve team coordination. Much like a nervous system, a VM strategy establishes a network of information flow throughout the workplace, with various tools working together to achieve this goal.

This further explains how Lean tools, originally designed for manufacturing, have shown success in various service industries like healthcare and software development. While some see them as basic process improvement methods, Lean offers more than just efficiency gains. Toyota exemplifies this by using Lean for deeper performance improvement. This highlights the need for a more understanding of Lean principles. This also mentions that while some Lean tools like 5S and A3 reports have clear guidelines, there is room for customization. Designing these visual tools effectively using ergonomics and visual design principles is crucial for their success. While VM tools can significantly improve operational efficiency by reducing waste, costs, quality issues, and safety concerns, it is crucial not to prioritize them over the core VM strategy. This research focuses on the identified functions of VM, aiming to shift discussions beyond just visual tools and towards a more holistic understanding of the concept.

Visual Management offers a wide range of benefits for organizations. By understanding the core functions of VM, companies can develop customized visual tools that address their specific needs. These tools are easy to create, but their purpose should be aligned with the overall VM strategy. Just because a visual tool works in one workplace does not guarantee success elsewhere. Tailoring tools to the identified function is key. Finally, these functions can be used to assess how effectively VM is being implemented in different workplaces. The key to Visual Management (VM) seems to be clarity and discipline. These aspects act as the foundation for VM's other functions to be effective. Simply delivering information is not enough. VM creates discipline by embedding clear goals and meaning into the work environment through visual tools and systems that people naturally follow. Transparency is another key aspect which allows employees to understand the intent behind messages, fostering self-control and leading to consistent actions and results. VM tools can be used internally and externally to build shared ownership and a desired company image. However, it crucial to constantly monitor the environment and present clear, concise visual information. Finally, a standardized approach across departments is essential for achieving unification within the organization.

Chapter 5

CONCLUSION AND FUTURE SCOPE

This project presented a vast experimental analysis of how implementation of a Visual Management System can be beneficial for the overall development of the plant. It enables the company to sustain in this competitive environment and thus also a kickstart to the company to move towards industry 4.0. Bringing automation in producing and representing the reports saves quite large time of a manufacturing plant. This also represents the development can be sustainable and managerial activities can be easily performed without producing even a single paper wastage. It is an efficient method of managing and displaying the progress report on real time basis. *Table 5.1* is representing the advantages gained by the plant in the given case study.

Table 5.1: Phase wise advantages gained by VMS

	Existing Practice	Phase 1	Phase 2	Phase 3
• Standardization	✗	✓	✓	✓
• Manual Activities (Nos.)	09	5	4	0
• Work Content (Time)	562 hrs./year	390 hrs./year	167 hrs./year	74 hrs./year
• Use of Paper & Printers	✓	✗	✗	✗
• Paper usage per plant/year	2842 Nos	0	0	0
• Carbon Footprint for paper	341 KG/year	0	0	0

It can be clearly observed that VMS enabled the plant to sustainable and efficient reporting. There is significant reduction in time consumption through the phases while standardization of the reports has been improved. The annual cost expenditure in maintaining the dashboard is surely reduced because of bringing the automation in the system. However the total cost of implementation is increased, but this technology enables the plant to keep regularly updating their progress benchmarks which will surely help it to grow with a good pace. This eliminates the scope of mistakes because the number of manual activities that need to be performed sequentially has also been reduced throughout the phases. This practice covers all the essential information in the workplace to inform teams, enforce work standards and highlight the issues.

Thus, in overall, VMS is an innovative, automated, digital and standardized approach that helps the companies to share information and highlight the real time progress to ensure that production remains on oncourse, in terms of productivity, quality and efficiency.

This paper argues that Visual Management has been under-represented in production management research. Most studies focus on specific VM tools or functions, limiting the understanding of VM as a broader strategic approach. The abundance of related terms and scattered research makes it difficult to grasp VM as a whole. Another misconception is that VM is exclusive to lean production. VM is actually a communication strategy that relies heavily on visual cues, making it applicable across industries and production systems. The functionalities of VM extend beyond typical production settings, VM can be used anywhere communication and interaction between people and processes are crucial. Recognizing these generic functions can help spread VM adoption to other industries beyond manufacturing.

For practitioners: The common features of VM tools, the categorized tool list, and the implementation framework provide a practical guide for real-world VM applications. The identified VM functions can inspire the creation of new VM approaches in various production settings, even beyond factories and workshops.

For researchers: The study calls for deeper discussions on practical lean concepts like VM. A broader view that considers ergonomics, visual communication, and design can improve the quality and scope of VM research. Researchers can test and refine the proposed framework and VM functions in real-world settings. The VM function concept can also be used to analyze existing VM tools for research purposes. The categorized list of tools helps researchers understand the practical applications of VM. Finally, the identified research directions can guide future VM research efforts.

Overall, this research clarifies the connections between VM and other production/operations management practices. It highlights the growing importance of VM in the field, explaining related terms and proposing VM's functionalities within a work setting. A deeper understanding of VM should encourage the development of original VM solutions instead of simply copying existing tools. This will lead to new VM benefits in various production settings, potentially expanding existing VM strategies or providing a strong theoretical foundation for entirely new VM implementations.

The paper highlights various purposes of VM beyond just transparency and maintaining discipline, which are common focuses in lean production. To fully benefit from VM, it is crucial to consider an organization's social, technical aspects, and existing management practices. The paper proposes exploring VM in different settings like healthcare and education based on the established theoretical concepts. Developing a comprehensive VM framework tailored to construction could be beneficial. The paper suggests research directions like real-world case studies and action research to understand VM's implementation in different contexts. The paper acknowledges the interrelated nature of VM functions and proposes investigating how organizational factors might influence them. Exploring potential new VM functions, their interactions with other management practices, and VM's role in computer-mediated work are suggested as promising areas for future research.

The current research suggests a need for a stronger theoretical foundation for VM strategies. A deeper understanding of the core concepts would not only help differentiate and connect related terms, but also allow for a more systematic approach to implementing VM's various functions. These tools can be adapted as needs and overall objectives evolve. Importantly, there's a lack of a universally applicable VM framework in current research, highlighting the need for further exploration in this area.

Instead of focusing solely on the technical aspects of visual management, we can also consider it from a social and functional perspective. By viewing VM tools as resources that shape interactions between people and technology (socio-technical affordances), managers can design strategies that influence how workers, managers, and even customers learn, navigate, and are guided within their work environments.

While virtual machines (VMs) are finding use beyond factories, their implementation in non-manufacturing settings like construction sites, schools, and hospitals presents unique challenges. We still need to explore, test, and refine how VMs can best function in these environments. The link between using VMs and achieving overall project goals needs clearer definition for different work settings. Current understanding is based on informal observations, and more rigorous studies are needed.

Diverse approaches that treat VM as an interface for conventional and IT-based information and knowledge management efforts in different work contexts will continue to be seen. In relation to this, the study of how similar visual tools are interpreted differently across different social groups i.e. customers, workers and managers as boundary objects will constitute another research direction. Specific visual tools will be examined and devised from the workplace ergonomics and user interface design perspectives. Additionally, developing technologies such as the Internet of Things, Big Data, mobile and wearable devices, virtual, augmented and spatial reality will find a greater place in the content and form of visual tools.

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DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

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BRIEF PROFILE

My name is Kamal Deep Sahu. I am from Bilaspur, Chhattisgarh. I have completed my Bachelor of Technology in Mechanical Engineering from Chhattisgarh Swami Vivekanand Technical University, Chhattisgarh with 79.84 %. At present, I am pursuing Master of Technology in Industrial Engineering & Management from Delhi Technological University, New Delhi. I have completed my project topic "SMART VISUAL MANAGEMENT SYSTEM - Automated Digital Dashboards, Streamlining Operations & Promoting a Paperless Environment in a Manufacturing Industry".

Software Skills

Power BI, Python, MS Excel, SQL