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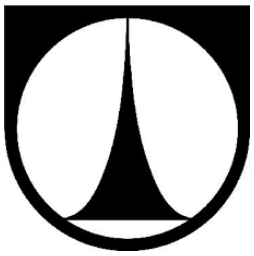

MAINTENANCE IN THE ORGANISATION

Master Thesis

Liberec 2021 Elavarasan Sankaran

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Mechanical Engineering

MAINTENANCE IN THE ORGANISATION

Master Thesis

Study programme:	N2301 Mechanical Engineering
Study branch:	Manufacturing Systems and processes
Author:	**Elavarasan Sankaran**
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Master Thesis Assignment Form

Maintenance in The Organisation

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1. Prepare an introduction to maintenance issues in the organisation.
2. Conduct a survey of current maintenance status quo and its management in the current organisation.
3. Identify potential risks affecting the maintenance in the organisation.
4. Identify reasons for the quality and effectiveness of maintenance in relation to the process approach
5. Create recommendations for organisations.
6. Conclusion.

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[2] Pelantová, V. - Havlíček, J.: Integrace a systémy managementu. Liberec: Technická univerzita v Liberci, 2014. 1. vydání. ISBN 978-80-7494-164-1.

[3] Veber, J. a kol.: Management kvality, environmentu a bezpečnosti práce. Praha: Management Press, 2006. ISBN 80-7261-146-1.

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Liberec March 5, 2020

DECLARATION

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ABSTRACT

The context presented in this thesis is maintenance in the organisation. The first part of the thesis includes types of maintenance, maintenance strategy, maintenance management, approaches to maintenance planning and trends in maintenance. The practical part of the thesis describes the essential characteristics of the organisation and deals with the collection and evaluation of maintenance in the organisation. An analysis is performed from the data concerning the optimisation of the company's maintenance process leads to improved maintenance in the organisation and increase the reliability of maintenance processes and the implementation of a quality control system and the process approach.

KEYWORDS

Maintenance, Maintenance Management, TPM, Evaluation Criteria

ABSTRAKT

Kontext prezentovaný v této práci je údržba v organizaci. První část práce zahrnuje typy údržby, strategii údržby, správu údržby, přístupy k plánování údržby a trendy v údržbě. Praktická část práce popisuje základní charakteristiky organizace a zabývá se sběrem a hodnocením údržby v organizaci. Analýza se provádí z údajů, týkajících se optimalizace procesu údržby společnosti, vede ke zlepšení údržby v organizaci a ke zvýšení spolehlivosti procesů údržby a zavedení systému řízení kvality a procesního přístupu.

KLÍČOVÁ SLOVA

Údržba, Správa údržby, TPM, Kritéria hodnocení

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LIST OF ABBREVIATIONS

FMS	Flexible manufacturing systems
FFM	Failure Finding Maintenance
TPM	Total Productive Maintenance
TBM	Time Based Maintenance
CBM	Condition Based Maintenance
PM	Predictive Maintenance
RBM	Risk-Based Maintenance
FTA	Fault Tree Analysis
RCM	Reliability Centred Maintenance
FMECA	Failure Mode Effects and Criticality Analysis
MTTR	Mean Time to Repair
MTTM	Mean Time to Maintenance
ACC	Associated Cement Companies
SI	Serial Number
RMX	Ready Mixed Concrete
PLC	Programmable Logic Controller
CRF	Cursed Rock Fine
JP	Jayalakshmi Plastics
PET	Polyethylene Terephthalate
JIT	Just in Time
HDPE	High-density polyethylene
FIFO	First in First out
QMS	Quality Management System
KPI	Key Performance Indicator

1. INTRODUCTION

Maintenance aims to ensure the entire performance and availability, at the optimum cost and under acceptable conditions of quality, safety, and environmental protection, of the production equipment, utilities, and related facilities. For a long time, maintenance was viewed as a subordinate activity involving an inevitable waste of money. There was a tendency to group it with wear and obsolescence-related troubleshooting and fixing machinery. Companies today, however, recognise that maintenance is not merely a partner in manufacturing. It is an essential production prerequisite. Its connection to the efficiency of equipment is a matter of integrated policy at senior management. As such, it becomes a management obligation for maintenance purpose [1].

Maintenance today is taken into account from the very beginning of developing a new business, equipment, operation, or commodity. Maintenance is an essential part of the strategy and vision of the organisation. In any modern company, specific short-term and long-term maintenance plans and objectives are created. Maintenance is included in the financial preparation, as are all other aspects of the company. It is also essential to fix the performance and expense of the entire maintenance process to avoid additional losses. However, there is still a need to spend annually on upkeep. The company would benefit from a competitive process, running without failures and downtime.

Due to maintenance costs, as in most corporate activities, work performance and financial resources are discussed. For this purpose, a variety of analytical techniques are used. The practical part of this research would be to increase the reliability of maintenance processes and implement a quality control system and the process approach.

2. MAINTENANCE

"Maintenance is the combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it may perform the required function", in the publication [1], p.3.

Maintenance is one of the fundamental processes in organisations, which is essential, regardless of the organisation's activity. It is one of the processes that have a direct impact on product quality. Unfortunately, maintenance is often seen as a less critical activity in organisations. However, in today's highly competitive world, no company can afford to neglect the maintenance of its assets. As a result, awareness of maintenance as an essential element in the functioning of the entire company begins to spread in the world of industry.

The cost of maintenance can be an essential factor in the sustainability of a company. In manufacturing, maintenance costs could consume 2-10 % of the company's production costs, according to the publication [1], p.3. Contemporary management of many organisations considers maintenance as an integral function in achieving productive operations and high-quality products while maintaining satisfactory equipment and machines reliability as demanded by the era of automation, flexible manufacturing systems (FMS), "lean manufacturing", and "just-in-time" activities. Similar product organisations can implement different maintenance systems, but different in technology advancement and manufacturing scale, and the different systems may operate successfully. Using knowledge and judgment backed by various formal decision tools and techniques, maintenance systems are therefore developed. Scheduling manages day-to-day decisions about what maintenance duties to perform and providing the means to perform these duties [1].

2.1. CLASSIFICATION OF MAINTENANCE

Maintenance is classified into:

- Corrective Maintenance
- Preventive Maintenance
- Predictive Maintenance

2.1.1. CORRECTIVE MAINTENANCE

Corrective maintenance means that repairs are carried out after the equipment has deteriorated and can no longer perform its usual function. Corrective maintenance can be

described as the maintenance needed to put it back in working order when an object has failed. And it is carried out on all goods where there is no significant effect of failure or wearing out, and the cost of this maintenance is lower than the preventive maintenance[2].

ADVANTAGES OF CORRECTIVE MAINTENANCE

- Reduction of down-time
- Minimum planning is required
- Potentially increased margins [3]

DISADVANTAGES OF CORRECTIVE MAINTENANCE

- Breakdown occurs at inappropriate times, leading to bad and hasty maintenance
- Excessive production delay and reduce performance
- Faster degradation of the organisation
- Increases the risk of injuries and less production for employees and machinery
- Direct loss of earnings
- It may not be used for equipment governed by legislative provisions, such as cranes, lifts, and hoists, etc. [4]

2.1.2. PREVENTIVE MAINTENANCE

Definition

"Preventive maintenance (PM) actions are carried out according to prescribed criteria of time, usage, or condition and are intended to reduce the probability of failure or the functional degradation of an item ", in the publication [1], p.77.

Preventive maintenance is maintenance carried out to prevent failures, excessive production loss, and safety risk. Where machinery is maintained until it happens to break down. There are several different variants of this type of maintenance, and different studies are done to determine the safest and most effective way to maintain equipment. These preventive interventions need to be carefully planned, as they cause the equipment to shut down. The period between individual inspections and preventive interventions is usually determined by a designer who knows the service life of the individual components of the device. Recent research has shown that preventive maintenance is effective in avoiding age-related equipment failures. Efforts to reduce repair costs exist relative to after-fault maintenance.

The use of preventive maintenance reduces the number of downtimes and the frequency of unplanned machine repairs [5].

ADVANTAGES OF PREVENTIVE MAINTENANCE

- Reduction of failure of machinery and downtime
- Less odd-time fixes and eliminates crew overtime
- Greater workplace protection
- Lower repair cost and maintenance cost
- Higher quality of goods and fewer redesigns and scraps
- Increasing of chances of earning an incentive bonus for production [5]

DISADVANTAGES OF PREVENTIVE MAINTENANCE

- More money upfront
- Over maintenance
- Need of more employees [5]

2.1.3. PREDICTIVE MAINTENANCE

Machinery conditions are regularly tracked in predictive maintenance, and this helps the maintenance crew to take prompt steps, such as system modification, repair, and so on. It makes use of human consciousness and other sensitive resources, such as audio gauges, amplitude meters, strain gauges for pressure, temperature, and resistance, etcetera. For example, unusual sounds that come from a spinning machine predict a problem. Trouble predicts an overly hot electric cable. Simple hand contact can point out several unusual conditions (status quo) for equipment and predict a problem. Therefore, this method is more effective than regular preventive maintenance, based on a schedule. Long-term measurements can be examined with the help of analytical tools, which in turn allows more efficient planning of additional maintenance tasks. A wide range of characters can be measured [5], [6].

ADVANTAGES OF PREDICTIVE MAINTENANCE

- Reduction in maintenance cost
- Reduction in machine failures
- Reduction of downtime of repairs

- Reduction of stock of spare parts
- The increased service life of parts
- Increased overall production [7]

DISADVANTAGES OF PREDICTIVE MAINTENANCE

- Require monitoring equipment
- Requires skill-full data interpretation
- Data source limitation
- Limits of machine repair activity [8]

2.2.MAINTENANCE STRATEGIES

Organisations mostly combine two types of maintenance strategies. Namely, post-failure maintenance and maintenance with predetermined times are often used. As part of prevention, there are three machine maintenance intervals, namely daily care, monthly inspection, and general inspection.

A maintenance strategy is a planned way to upkeep devices, including “identification, researching and execution of many repairs, replace and inspect decisions”. Implementation of the strategy requires executable, tactical plans, according to the publication [9]. Maintenance strategy “includes a set of policies and actions that are used to “retain” or “restore” equipment as well as the decision support system in which maintenance activities are planned” according to the publication [10].

The maintenance strategy depends on parts that created the equipment. Check the oil level in the oil mark, and the coolant are checked during standard treatment. Besides, the visual and auditory test of the process is conducted by machines and accessories. Monthly testing entails inspecting the state of the moving parts, checking all functions of the unit, checking the clearance, checking the hydraulic and pneumatic components, and potential replacement of the filters and the exhaust fan cabinet. The general inspection shall require general inspection equipment. Inspection includes, for example, the inspecting of ball screw with the nut, checking the wiring, inspection of the bearings and spindle bearing, an inspection of the lubrication, replacement of hydraulic and pneumatic systems in the machine, and regulation of direct remuneration. Many of these activities are done by a maintenance technician. The goal of the maintenance strategy is to save maintenance costs and guarantee that all

maintenance-related procedures function smoothly. The output is a one-month to the one-year. The following picture Figure 1 shows the strategies of maintenance in an organisation [2].

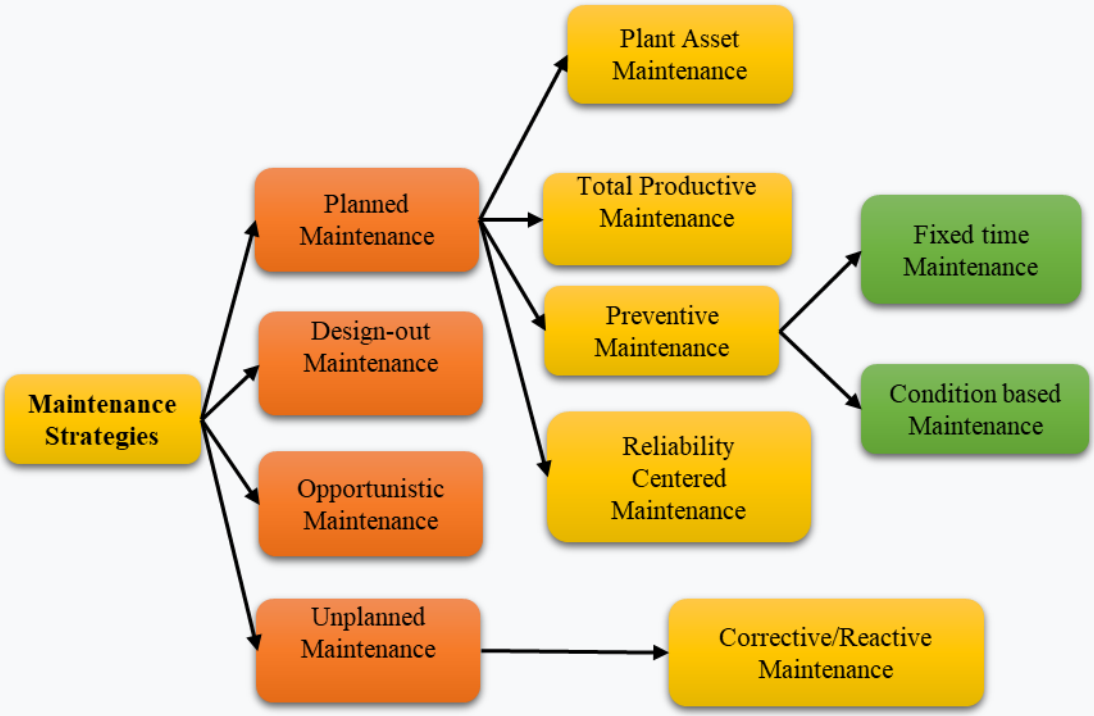


Figure 1: Maintenance strategies of an organisation [4]

2.3.MAINTENANCE MANAGEMENT

Definition:

"Management of a business (organization) involves the coordination of the efforts of people to accomplish the business goals and objectives using the available resources in an efficient and effective manner", in the publication [1], p.393.

Maintenance management is concerned with making decisions about PM and CM actions and the preparation and implementation of the tasks involved. It is a component of a company's overall management. A thorough understanding of general management is needed for a thorough understanding of maintenance management. The below are the central topics of maintenance management:

- Setting aim and objects
- Attending those aim and objects
- Decision making

Its goal is to focus on securing asset management and maintenance so that its operability and performance are as high as possible and maintenance costs are as low as possible. In fulfilling this goal, the integration of production and maintenance itself has often taken place [1]. The following picture Figure 2 shows that one example of maintenance management in an organisation.

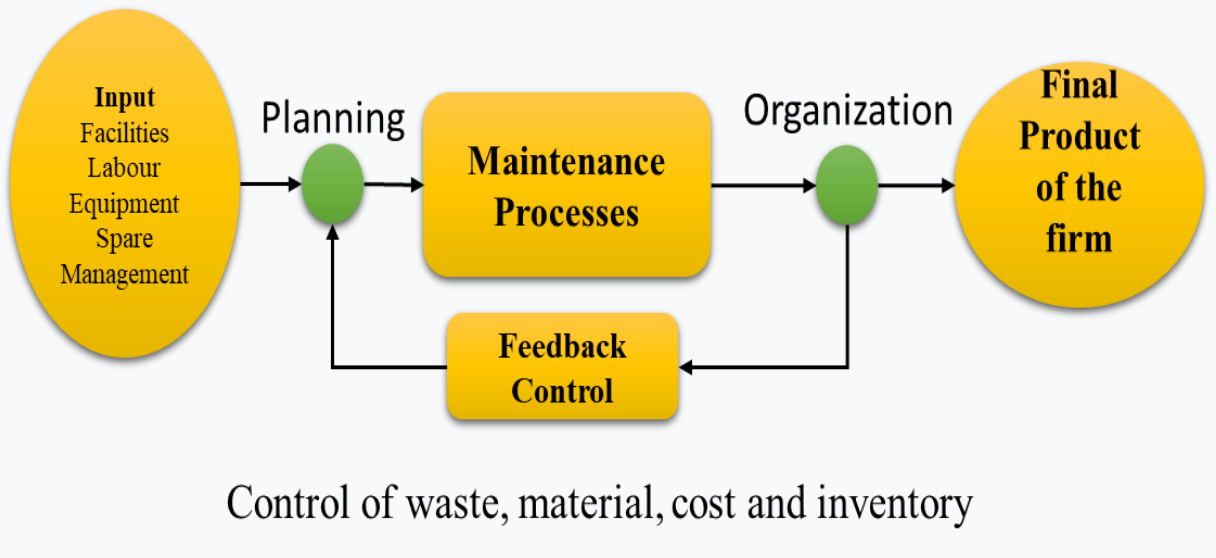


Figure 2: Maintenance management control [4]

2.4.DETERMINANTS OF A MAINTENANCE ORGANISATION

The structure of the maintenance company shall be decided after planning the type of maintenance. Maintenance organisation is highly determined by the type of centralization, decentralization, or hybrid that has been implemented [2].

2.4.1. CENTRALIZATION MAINTENANCE

This form of maintenance management is unique since all its services are focused on one position within the company. For an entire installation, a single schedule has been generated and administered nearly always by a familiar scheduling role, notwithstanding the number of professionals and contractors on site. This programmer communicates work on a field-wide basis, ensures that all fields and crafts know the priorities and events, and gather updates and manage work projections daily. In this situation, the scheduler will concentrate on the entire workforce per craft and charge the schedule according to priorities and needs but will leave particular managers to craft supervisors to work for a specific person [11].

2.4.2. DECENTRALIZATION MAINTENANCE

This form of maintenance organization seeks to align maintenance workers directly with other departments and organizations to carry out the necessary activities. This integration increases maintenance speed, a method for complex production units. When compared to other methods, decentralization can produce faster results. It is fit for larger units and organizations. Due to the company workers' dispersion, the downside is the need to buy more equipment and advanced instruments. There are also issues with management with a more significant number of workers [2], [1].

2.4.3. HYBRID MAINTENANCE

Hybrid maintenance created a combination of centralised and decentralised maintenance. The goal was to optimise organisation strengths while minimising the disadvantages created by their design. The centralised maintenance department in the organisation is in charge of doing more complicated or time-consuming work, the execution of which necessitates the use of costly and complex equipment, machines, and fixtures. As a result, highly trained workers with the appropriate skills and expertise are working here. Smaller groups or individuals serve within other departments. They solve immediate needs or carry out smaller, pre-planned activities [2].

2.5.APPROACHES TO MAINTENANCE PLANNING

Maintenance planning approaches are given below:

- RCM (Reliability-Centred Maintenance)
- TPM (Total Productive Maintenance)
- RBM (Risk Based Maintenance)
- FFM (Failure Finding Maintenance)
- TBM (Time Based Maintenance)
- CBM (Condition Based Maintenance)

2.5.1. RELIABILITY MAINTENANCE

The generality of the RCM principles and strategies, independent of technology, is applicable today to every method. In the RCM, maintenance priorities are specified according to roles and expectations of excellence for each item in its business setting. Its

implementation is an evolving activity that can always be evaluated as knowledge is accumulated.

Reliability maintenance is a mechanism to ensure that properties, in their current operating sense, continue to do what their users need. In general, it is used to establish specific minimum maintenance standards, changes in activities and policies, and the establishment of schemes and plans for the maintenance of capital. Efficient implementation of RCM would lead to improved cost efficiency, and uptime of the machine, and a better awareness of the organization's level of risk management. As a discipline, it helps owners of machinery to track, measure, forecast, and appreciate the operation of their physical properties in general [12].

Principles of RCM:

- The main objective is to ensure the machine's smooth operation. It is best to concentrate on comprehending the device as a collection of components, conducting the required functions, and ensuring that the its functionality does not decrease with time.
- All components' potential defects and their consequences are examined.
- Faults that endanger the output of the required system operation are given priority (in terms of resources expended).
- Successful maintenance actions are calculated based on the previous steps to avoid defects [13].

2.5.2. TOTAL PRODUCTIVE MAINTENANCE

In the 1951s, preventive maintenance operations started in Japanese firms. They wanted to use the existing workforce instead of hiring costly professional employees. Maintenance was carried out by the manufacturers (workers) directly. TPM helped them identify the approaching fault more effectively or diagnose the damaging feature of the machine more rapidly. TPM allowed maintenance engineers to concentrate on more complicated and critical activities. The long-term enhancement of the operation of machinery is possible by cooperation between operators and maintenance engineers. Increased productivity and production quality have been achieved. Operators have carried out maintenance activities and recommended system improvements, which have increased efficiency and minimized maintenance demands [14].

TPM was introduced to achieve the following objectives:

- Avoid wastage in a quickly changing economic environment
- Production of materials without reducing the quality of the product
- Cost savings
- Produce a small batch quantity as soon as possible
- The product that is delivered to consumers shall be non-default [15]

Pillars of TPM:

- 5S
- Autonomous Maintenance
- KAIZEN
- Planned Maintenance
- Quality Maintenance
- Training
- TPM in Administration
- Safety

Among the above pillars, 5S is the most basic pillar of TPM.

2.5.3. RISK-BASED MAINTENANCE

"*RBM is a maintenance approach that integrates risk in maintenance planning through the identification and assessment of the consequences of maintenance risks*.", in the publication [1], p. 414.

The first step in this method is to identify certain risks, as implied by the definition. To identify them, a list will be created of possible failures and causes which will make it possible to create ways of reducing or eliminating them. Besides, the severity of the disorders identified will be assessed. The main goal is to focus on the most risk-critical equipment and parts. Together with three principal factors, loss of productivity, money loss, and human health loss, the total determined risk shall be identified. The method of fault tree analysis (FTA) is then developed for probabilistic fault analyses [1], [5].

2.5.4. FAILURE FINDING MAINTENANCE

Failure finding maintenance activities are designed to detect hidden faults usually associated with defensive functions, as pressure safety switches, trip transmitters, and so on. This sort

of machinery would not have to work until anything else has broken. This means that under standard operating conditions if this system is still running was not known, i.e., the failure modes are concealed. It is necessary to note that inability to locate maintenance tasks does not prevent failure, but merely detect it. Failure finding maintenance is undertaken at set periods usually resulting from regulations or risk-based methods [5].

2.5.5. TIME-BASED MAINTENANCE

The main aim of time-based maintenance is to secure parts from failure which have constant mean time failure. Time-based maintenance suggests that the loss is based on the age-related and simple life of service may decide. Time-based replacement is more affordable and still successful. It is necessary to note that in many sectors, businesses may have to conduct such activities to conform with regulatory enforcement criteria, which will usually be carried out at a set period. i.e., time-based repairs. However, and concerning maintenance-related enforcement, there are also ways for regulators to participate in, for example, risk-based approaches [16].

2.5.6. CONDITION BASED MAINTENANCE

The CBM method was introduced in 1975 to maximize the effectiveness of PM decision-making. It is a maintenance program that recommends maintenance decisions based on details gathered from tracking conditions. There are three major steps: Data collection, Data analysis, and Decision-making in maintenance. Two important elements of a condition-based maintenance program are evaluation and prognostics [16].

Any symptoms, circumstances, or signs that such a failure will occur precede any failure. For the tracking of device conditions, several CBM strategies may be used. And some of them are:

- Vibration monitoring
- Sound or acoustic monitoring
- Oil-analysis or lubricant monitoring
- Other techniques (electrical, temperature, etc.)
- Monitoring changes in certain parameters, such as: pressure, flow rate, and electrical power consumption [16]

2.5.7. COMPARISON OF APPROACHES TO MAINTENANCE PLANNING

The approaches described in this chapter to maintenance planning differ in large part in their difficulty and duration. The RBM method is straightforward and time-efficient. Its application is particularly appropriate for identifying processes and equipment critical to the organization's operations. The RBM procedure does not cover maintenance planning. The RCM method is used to plan or optimize a company's preventive maintenance activities. Maintenance plans and schedules have been developed, but not all maintenance is dealt with. However, TPM systems are - planning, improvement, the involvement of the operators, training of personnel, and maintenance of long-term quality. This is the most complex and time-consuming method and requires a high degree of motivation in the organization to implement it. Nevertheless, on the other hand, the current asset status is tracked, and further maintenance requirements are determined in the CBM technique. Maintenance is planned where there is evidence of declining performance or failure. And Table 1 below shows the comparison between other maintenance types.

Maintenance Type	RBM	FFM	TBM	CBM
Task Type	Inspection or Test	Functional Test	Replacement	Measurement of condition
Objective	Determined condition and conduct risk assessment to determine when next inspection	Determine if hidden failure has occurred	Restore or replace regardless of conditions	Restore or replace based on the measured condition compare to a defined standard
Interval	The time-based interval between task and scope of the task is based on risk assessment	Can be set based on risk assignment	Fixed time or usage interval (e.g.: 1month/5000kms)	The fixed time interval for condition measurements

Table 1: Comparison of approaches to maintenance planning [Source: own]

2.6. TRENDS IN MAINTENANCE ORGANISATION

In recent years, the approach to the care of technically demanding maintenance tools has changed significantly as the supply of various diagnostic support devices grows. The aim of maintenance is primarily to maintain the functionality of the equipment, i.e., the state in which the equipment performs the function expected of it, including monitoring the return on investment. For complex sophisticated technical units, it is no longer enough to use only common operational maintenance procedures. It is necessary to include such phenomena that allow for analysis on the principle of the assumed state [17].

The latest trend in the field has become a combination of predictive maintenance and preventive maintenance, based on the operating conditions of the equipment. Predictive maintenance uses direct monitoring of the current state of the equipment, its operating conditions, to plan activities related to maintenance, efficiency, and other indicators to eliminate failures or efficiency losses of production equipment. The inclusion of predictive maintenance in a comprehensive maintenance management program thus makes it possible to optimize the availability of operating equipment, significantly reduces overall maintenance costs, and, conversely, increases the quality and productivity of work [17].

Finally, an important factor in this trend is the minimization of unplanned outages and accidents of all equipment in the plant. The predictive and preventive approach, which currently replaces conventional post-failure maintenance, is therefore crucial for eliminating the consequences of possible failures, for the smooth operation of equipment and maintaining its high operability, and for the efficiency of maintenance costs [18]. The results of the introduction of a predictive approach in maintenance, then in companies with a hitherto traditional concept of preventive maintenance, “by replacing the maintenance system after a failure, it is possible to achieve up to 40% savings in current costs, and in companies where no maintenance systems have yet been implemented, savings of up to 55 % can be achieved”, according to the publication [19].

3. MAINTENANCE IN THE ORGANISATION

The main goal of this work is to focused on individual organizations separately and analysed their organizational structures, maintenance features, material, and information flow, outsourcing, and make comparisons with established criteria.

3.1.ACC INDIA PRIVATE LIMITED

Formerly (**The Associated Cement Companies Limited**), it is one of India's foremost cement manufacturers. It is a division of Lafarge Holcim. On August 1, 1936, ACC Limited was established in Mumbai, Maharashtra. In 1994, ACC founded India's first commercial Ready Mixed Concrete (RMX) plant in Mumbai. Ready Mixed Concrete is one of India's largest RMX producers, with approximately 85 new plants in major cities such as Mumbai, Bangalore, Kolkata, Chennai, Delhi, Hyderabad, Goa Pune, and Ahmedabad.

The innovative efforts of ACC in implementing Ready Mixed Concrete (RMX) and promoting bulk cement handling facilities have been responsible for redefining the speed and efficiency of construction operation in metropolitan cities and mega infrastructure projects. Small building projects and individual home builders looking for high-quality assurance standards will now use ACC RMX to bring the same complexity and value to their design as any of India's large infrastructure projects at virtually no extra cost [20].

3.1.1. TYPE OF PRODUCTION

Ready Mixed Concrete, or RMX as it is popularly called, refers to concrete that is specifically manufactured elsewhere and transported in a Transit Mixer for delivery to the customer's construction site in a ready-to-use freshly mixed state. RMX can be custom-made to suit different applications. Ready Mixed Concrete is bought and sold by volume - usually expressed in units m^3.

There are two types of concrete plants:

- Dry mix plants
- Wet mix plants

Dry mix concrete plants

As the name implies, dry mix plants prepare dry recipes before transferring them to a transit mixer. All of the required ingredients, such as aggregates, sand, and cement, are weighed and then loaded into a transit mixer. The transit mixer is filled with water. Concrete is mixed inside the transit mixer as it travels to the construction site [21].

Wet mix concrete plant

In wet mix plants, the ingredients are measured separately and then applied to a mixing unit, which would homogeneously mix the materials before dispatching them into a transit mixer or a pumping unit. They are also known as central mix plants because they provide a much more cohesive product since they are combined in a central place in a computer-assisted setting, ensuring product uniformity [21]. In ACC, wet mix concrete has been used.

Raw Material

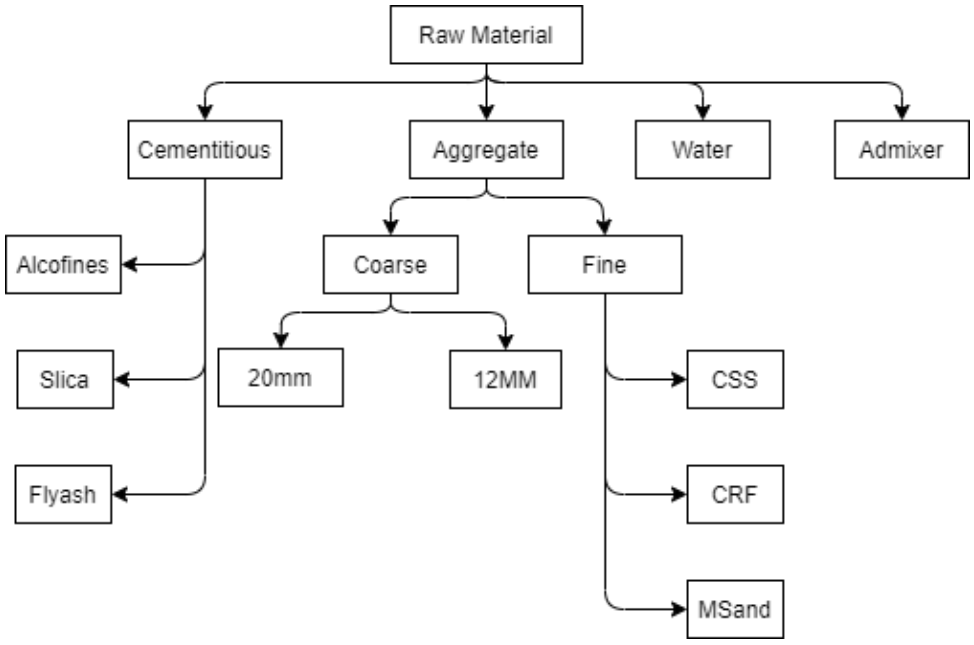


Figure 3: Raw Material flow of ACC [20]

The above Figure 3 shows that the material flow of the organisation. The organisation uses a different size of aggregates (12mm and 20mm) for various types of concrete.

Component of Batching Plant

A concrete batching plant comprises various parts and accessories that work together to manufacture high-quality concrete. The below are some of the main components:

Cement Silo: Cement silos are used to store vast amounts of cement that arrive in bulk trucks. It is usually equipped with safety features. A screw conveyor of appropriate diameter and length is located at the bottom, allowing cement to be transferred into the cement weigh hopper. A cement hopper is standard on many limited capacity machines. The hopper's opening is wide, making it easy to add cement that comes in bags. Bags must be set on top of the hopper, and when they are ripped, cement falls into the hopper. Cement hoppers also

have a screw conveyor for transferring cement to the weigh hopper. A weigh hopper usually has two holes on top for the inlet of two screw conveyors [21]. The cement silo shown in the Figure 4 below.

Figure 4: Cement Silo in The Organisation [20]

Aggregate Feeders: The aggregate feeding machine is one of the crucial parts of batching plant. Make it easier to feed coarse aggregates and sand. Bins are placed side by side. There are various bins available, each holding a different size aggregate or sand in a separate compartment. The explanation for separating each material (by size) is that each material would be measured separately according to the designated mix ratio [21]. The bins of the aggregates shown in the Figure 5 below.

Figure 5: Bins of Aggregates [20]

Aggregate Weigh Conveyor: The weigh conveyor is usually located under the aggregate feeders. It is suspended and supported by load cells. It aims to weigh aggregates one at a time and then pass them to the charging conveyor of the skip. Pneumatic cylinders are open and close to discharge aggregates to the weigh conveyor.

Ascending Conveyor: The ascending conveyor is responsible for transporting the weighted aggregates to the mixing machine.

Cement Weigh Scale: The cement weigh scale can contain a small amount of cement transported from the cement silo with a screw conveyor. Its job is to measure the aggregates until they are loaded into the mixing machine.

Water Weigh Scale: The water weighs the water pump feeds scale. It will keep water and measure it according to the recipe set in the control panel before adding it to the mixing machine.

Mixing unit: Mixing is the essential component and the core of the concrete batching plant. The mixer's task is to receive all of the ingredients and thoroughly combine them for a set amount of time. The concrete would then be discharged into a transit mixer or a concrete pump.

Air compressor: It is used to manage all pneumatic operations of the concrete batch mixer, such as the opening and closing of cylinders that control the feeder gates, the opening and closing of butterfly valves equipped with weigh hoppers, the opening and closing of the mixing unit doors, and many more.

Control panel: A control panel would control the machine's operation. The most recent computers are outfitted with PLC programming for ease of use. The control panel aids in the fast and precise calculation of ingredients. With the increasing demand for high-quality, precise concrete, it is critical to manufacturing high-quality products with minimal waste. In control panel have better control of all of the batching plant's parts.

Types of mixers

- Reversible drum type
- Single shaft mixer
- Twin-shaft mixer
- Planetary mixer
- Pan mixer [21]

Above these mixer pan mixer and twin-shaft mixer are used in the ACC

Pan Mixer

A mixer, generally filled by an opening at its top for concrete, in which blades rotate around the vertical axis, usually a mixing paddle along the horizontal axis, in mortar. The pan mixer is shown below the Figure 6.

Figure 6: Pan Mixer [22]

Twin-Shaft mixer

The paddle construction of the Twin-Shaft Mixer has been specially engineered for strength and abrasion resistance. Each Pallet group has been strengthened to prevent failure, and the concave arrangement extends the life expectancy. And the outer layer of the mixer is made up of Hardox wear plates.

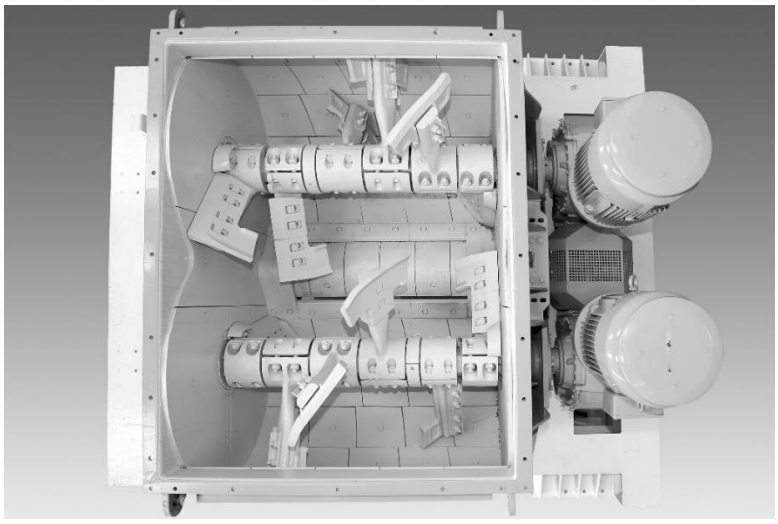


Figure 7: Twin-Shaft Mixer [23]

The Twin-shaft Mixer shows in the above Figure 7. Since the surface rigidity of Hardox wears plate surfaces is only around 3mm thick, the abrasion resistance of the plates decreases as they wear. Unlike Hardox, the rigidity of NI-HARD (A group of white cast irons alloyed with nickel and chromium to have high hardness and abrasion resistance) material is identical through every section and layer. The rigidity of the NI-HARD material does not

change so that the abrasion rates start to wear the sheets and are subject to the rigidity of the aggregates used.

3.1.2. ORGANISATIONAL STRUCTURE

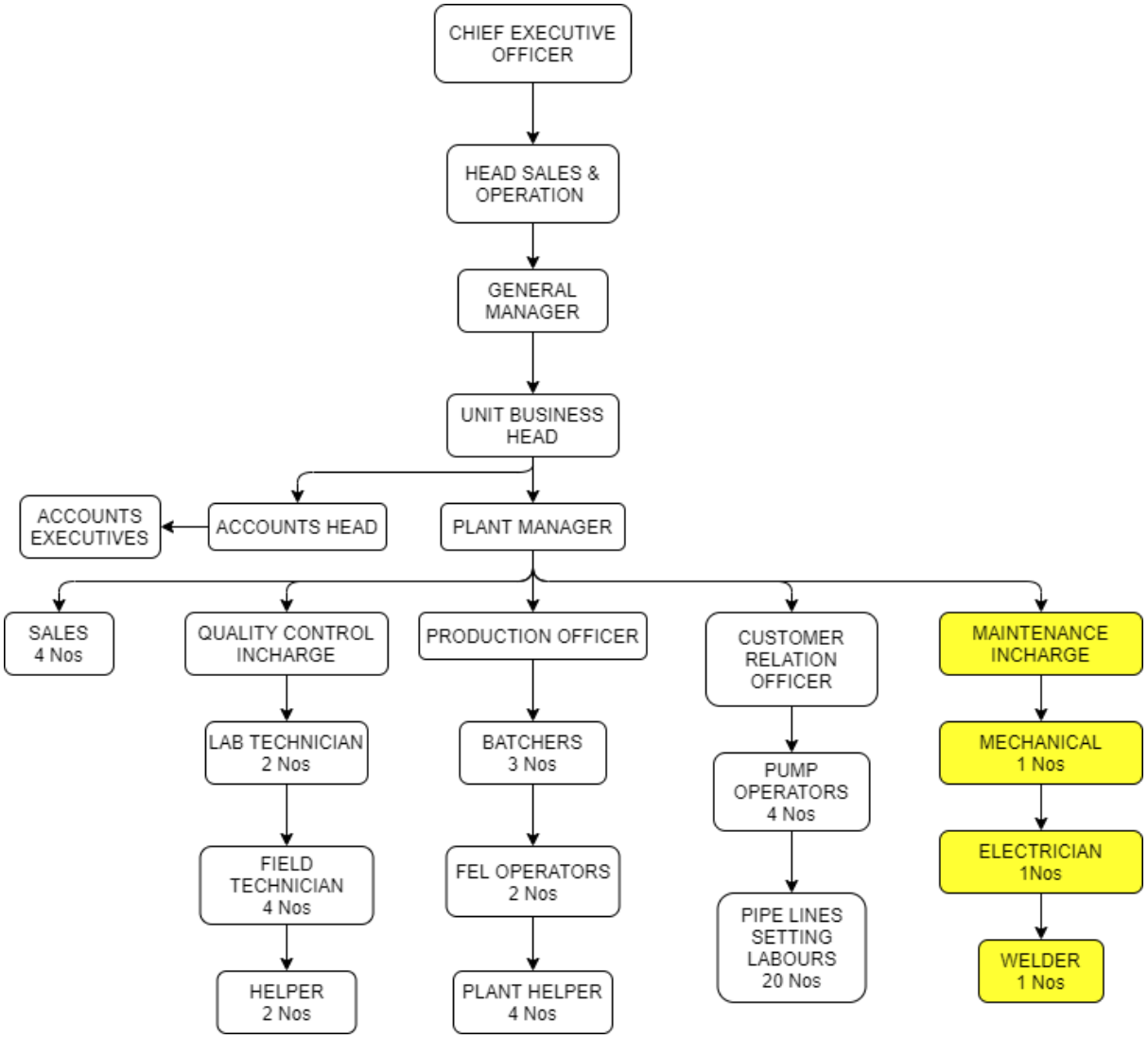


Figure 8: Organisation Structure of ACC [20]

The above Figure 8 shows the existing organisation structure in ACC. A company's hierarchical structure applies to its chain of command, which usually extends from chief executives' officers and general management to general employees. In other words, this arrangement refers to companies with a single chief and a chain of command behind them. In the maintenance department, there is maintenance in charge, followed by mechanical, electrical, and welder. The maintenance department comes under the command of the plant manager.

SI	Position	Own Employee	Contract	Total
1	**Plant In-Charge**	1	0	1
2	**Production Officer**	2	0	2
3	**Lab Technician**	2	0	2
4	**Loader**	2	0	2
5	**Maintenance**	1	1	2
6	**Batcher**	3	0	3
7	**Customer Relation Officer**	1	0	1
8	**Field Technician**	0	4	4
9	**Helpers**	0	6	6
	Total	12	11	23

Table 2: Man power in ACC [20]

The above Table 2 shows the employees details of ACC. The plant in charge is head of the plant and followed by the production officer, lab technician. There are about 12 direct employees of ACC and 11 contract basis employees.

3.1.3. ANALYSIS OF MAINTENANCE IN THE ACC

Type of maintenance

Monitoring the maintenance in ACC. The organisation has a daily preventive maintenance plan and does not have a proper maintenance schedule. Employee attrition and a lack of skilled labour are common issues that affect this industry. That was due to the industry's high level of competition. It is not easy to find new employees and retain existing ones. ACC mainly uses a corrective maintenance strategy. Maintenance of the machines takes place only after the failure. This will result in high maintenance cost and downtime in production. For maintenance, the company does not employ any specialized software. Users may insert maintenance specifications into an application, which acts as a software framework for all device user requirements. The downside is that there is no historical analysis of the different forms of maintenance undertaken, their expense elements, and there is no chance of

forecasting and looking for optimal variants, which is critical for successful organizational management.

Control panel

The control panel was controlled by schwing stetter sofware. In this software, the operator can see every movement inside the batching plant.

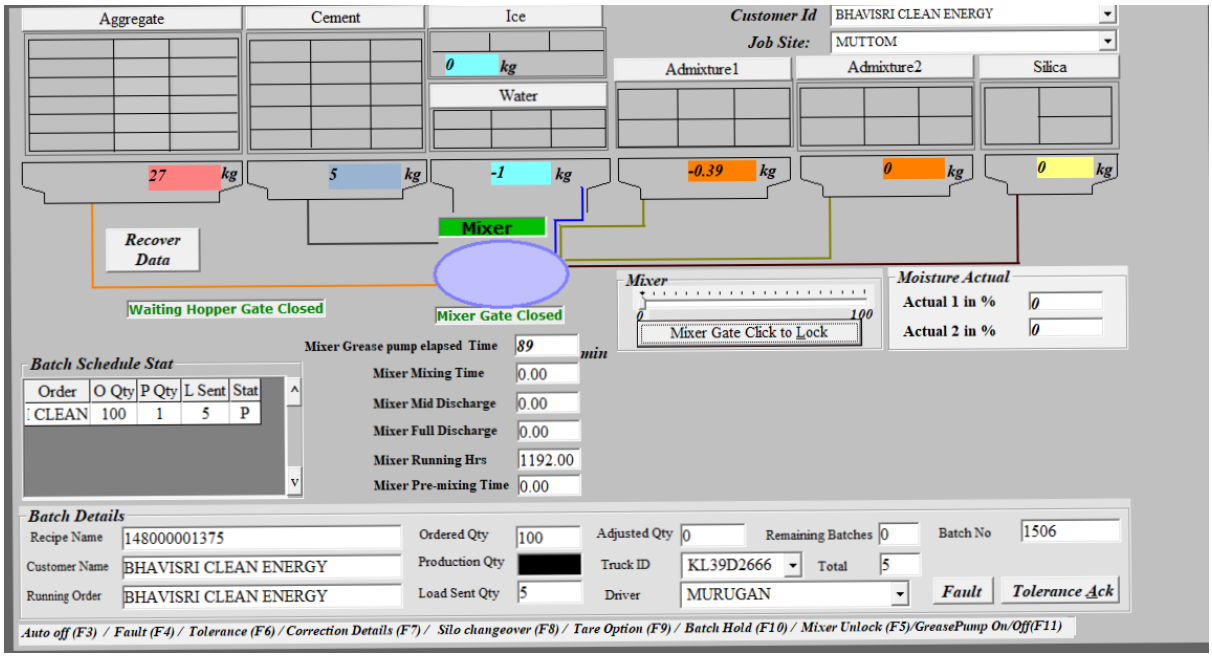


Figure 9: Schwing stetter software used in the organisation [20]

Above Figure 9 shows how much aggregate, cement, water, silica, and admixture mixed inside the mixer—and mixing time, mixer running hours and batch details like customers name, order quantity, transit-mixer number, transit-mixer driver's name.

Stock management

The organization's maintenance is not organizationally autonomous. It is entirely reliant on the investment assets of individual departments, which would then be used to save money on other operations. The organization uses SAP software primarily for asset management, control and quality tracking and procurement of spare parts.

The costs of spare components represent a substantial percentage of the total maintenance cost of this company. Around 500 distinct replacement components are available. The SAP system checks the minimum inventory of replacement components, and the system includes information on each item input. It produces an order if the inventory level of the item surpasses the stated limit. The order created is examined by the maintenance department's

Head and confirmed. In the process of maintenance, data on specific spare components are recorded in the system. Their consumption estimate is based on the suggested supplier values or our own experience with similar components. The review of consumption data generated by SAP software constantly adjusts this estimate. This organization applies no inventory management technique besides the technique mentioned earlier. Receipt and difficulty are recorded with a barcode scanner from the warehouse. Because the replacement components utilized here cannot be lost due to time, there is no set distribution mechanism.

3.1.4. NONCONFORMITIES FOUND IN THE ACC

i. Downtime in the production
ii. Accident investigation report
iii. Transit-Mixer workability inspection report
iv. Inventory control system

3.1.5. IMPROVEMENT IN ACC

The author's nonconformities found in the organisation and the solution and methods to resolve these nonconformities are given below.

i. Downtime in The Production

Due to the identified discrepancies, monitoring and recording took place in the organization. There is downtime in production due to neglected maintenance.

1: The pan mixer mother plate (outer layer of the mixer) is damaged in the below figure due to abraded, and it is patched with a mild steel plate. It is because of maintenance staff failed to notice the damage shown in the Figure 10 below.

Figure 10: Patchwork in mother plate [20]

2: The below figure shows a small hole in the mother plate, and the spot is temporarily fixed by some rod with clothes. In this case, same as before, the maintenance worker failed to notice the wear and tear of the NI-HARD surface inside the pan mixer, resulting in damage to the mother plate shown in the Figure 11 below.

Figure 11: Temporary Maintenance [20]

In the above cases, the mixer got abraded. The concrete mixing inside the mixer was leaked through the damaged mother plate. So, the maintenance worker came and fixed the damage.

3: Damage load cell in ascending conveyor so, an uneven weight of aggregate and m-sand send into the mixer results in changing the grade of the concrete. This type of faults occurs several times, and because of this, the customer rejects the transit mixer.

4: Sometimes, air leakage in the air pump due to the poor sealing at the air pipe joint. If there is a slight air-exposed, it will not affect the routine work. However, long-term air leakage will aggravate the air compressor's start and stop times and increase energy consumption.

To prevent this type of breakdown, it is recommended that the organisation to implement a proper preventive maintenance checklist.

Weekly Checklist for Batching Plant

Date: _____ Plant: _____

1. Check dues:	**Due**	**Not Due**	**Done**	**Not Done**
a. Mixer gear oil & Filter change	☐	☐	☐	☐
b. Skip, Screw conv., Belt conv. Oil change	☐	☐	☐	☐
c. Air compressor oil change	☐	☐	☐	☐
d. Cement feeder screw bearing service	☐	☐	☐	☐
e. Skip rope change	☐	☐	☐	☐
f. Bulk feeder oil change	☐	☐	☐	☐

2. Check the level of the weigher frame track and fixed track. They should be on the same level.

☐ OK ☐ Level corrected ☐ Not done

3. Check the pneumatic cylinder of aggregates for proper fitment & air leakage.

☐ OK ☐ Fitment rectified ☐ Leakage arrested ☐ Not done

4. Check the aggregate gates for wear or spillage.

☐ OK ☐ Gate replaced ☐ Spring replaced ☐ Not done

5. Check the skip rope & fittings for wear or damage.

☐ OK ☐ Changed skip rope ☐ Cardium compound applied ☐ Not done

6. Check the skip rollers for wear or bearing play.

☐ OK ☐ Changed bearing ☐ Changed rollers ☐ Not done

7. Grease skip flap bearings.

☐ Done ☐ Not done

8. Check the position of the skip rope drum for smooth take-off / landing. Adjust if required.

☐ OK ☐ Position adjusted ☐ Not done

9. Check the skip bucket for wear.

☐ OK ☐ Lining changed ☐ Not done

10. Check the oil level in skip gearbox.

☐ OK ☐ Oil topped up ☐ Not done

11. Carry out scale check of aggregate weigher.

☐ Scale check OK ☐ Re-calibration done ☐ Not done

12. Check the condition of mixing blades & arms.

☐ OK ☐ Mixing blades ____ no's replaced ☐ Mixing arm welding done

☐ Wearing packing ____ no's replaced ☐ Arms adjusted

13. Grease the mixing arms and discharge gate.

☐ Done ☐ Not done

14. Check the oil level of mixer gearbox.

☐ OK ☐ Topped up. ☐ Not done

15. Check the mixer discharge gate hydraulic cylinder for oil leakages.

☐ OK ☐ Rectified ☐ Not done

16. Check the condition of wear plates.

☐ Ok ☐ Outer wear plates ____ no's replaced ☐ Inner wear plates replaced

☐ Outer wear plates rotated. ☐ Bottom plates replaced ☐ Not done

17. Check condition of mixer cover lifting mechanism.

☐ OK ☐ Rectified ☐ Not done

18. Clean the inspection pockets of the screw conveyors & inspect the bearings.

☐ Cleaned ☐ Bearings OK. ☐ Bearings replaced ☐ Not done

19. Check the oil level in the gearbox of screw conveyors.

☐ OK ☐ Oil topped up ☐ Not done ☐

20. Clean the inspection pockets of silo to plant screw conveyor & inspect the bearings.

☐ Cleaned ☐ Bearings OK ☐ Bearings replaced ☐ Not done

21. Check the oil level of cement feeder blower.
☐ OK ☐ Topped up ☐ Not done

22. Check for cement leakage thru cement feeder screw gland.
☐ Ok ☐ Rectified ☐ Not Done

23. Carry out scale check of cement weigher.
☐ Scale check Ok ☐ Re-calibration done ☐ Not Done

24. Carry out scale check of water weigher.
☐ Scale check Ok ☐ Re-calibration done ☐ Not Done

25. Carry out scale check of admixture weigher.
☐ Scale check Ok ☐ Re-calibration done ☐ Not Done

26. Check for excessive leakage of water through water pump gland.
☐ Ok ☐ Rectified ☐ Not done

27.Clean the air filter of air compressor.
☐ Cleaned ☐ Not done

28. Check the oil level of lubricant in air compressor.
☐ OK ☐ Topped up ☐ Not done

29. Check the oil level of belt conveyor gearbox.
☐ OK ☐ Topped up ☐ Oil Changed ☐ Not done

30. Grease the bearings of the belt conveyor rollers.
☐ Done ☐ Not done

31. Check whether the belt conveyor guide rollers are rotating properly.
☐ OK ☐ Rectified ☐ Not done

32. Check the functioning of dust collector and dust extractor pneumatic cleaning of filters.
☐ Ok ☐ Rectified ☐ Not Done

33. Clean the deposits in the dust collector:
☐ OK ☐ Cleaned ☐ Not done

34. Inspect the positioning of all limit switches and sensors.

☐ Ok ☐ Corrected ☐ Not Done

Remarks:

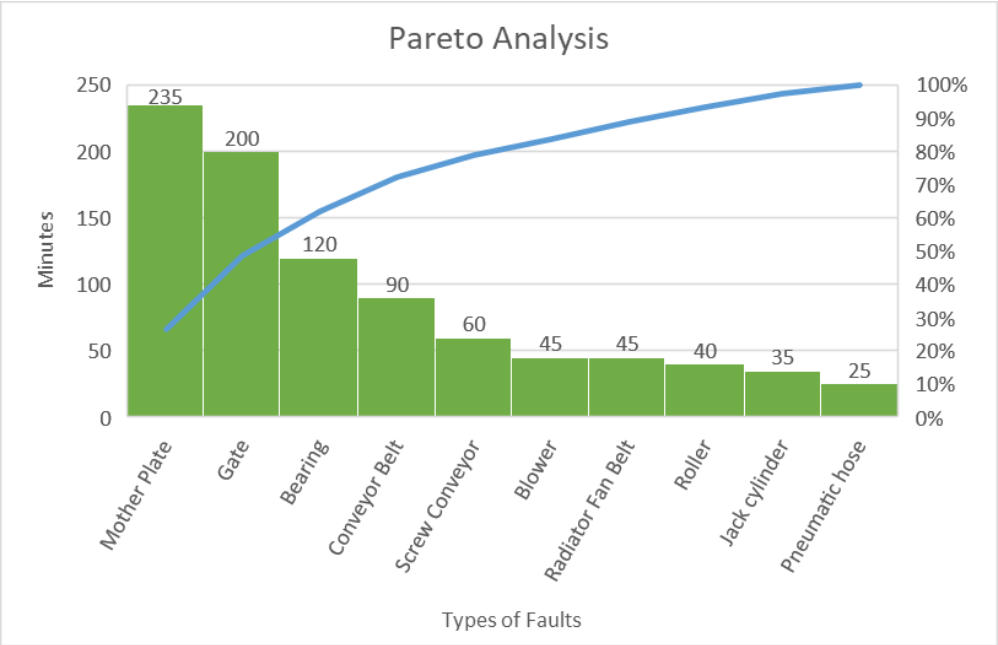
Checked by Technician**:** Reviewed by Plant In-charge**:**

Before implement maintenance checklist in ACC, the types of faults and their downtime is shown in Table 3 below.

Types of Faults	**MARCH**
Mixer	**Downtime(min)**
Mother Plate	360
Silo	
Screw Conveyor	45
Blower	30
Aggregate Bin	
Gate	180
Pneumatic hose	15
Jack cylinder	15
Ascending Conveyor	
Bearing	120
Conveyor Belt	90
Roller	30
Diesel Generator	
Radiator Fan Belt	45

Table 3: Production Failures [20]

In order to discover significant problems, Pareto analysis was then applied. This study is conducted under failure and downtime for all sorts of defects. The Pareto analysis approach was created in Graph 1. Of the ten elements, 5 represent 80 % of the defects, subject to considerable supervision.

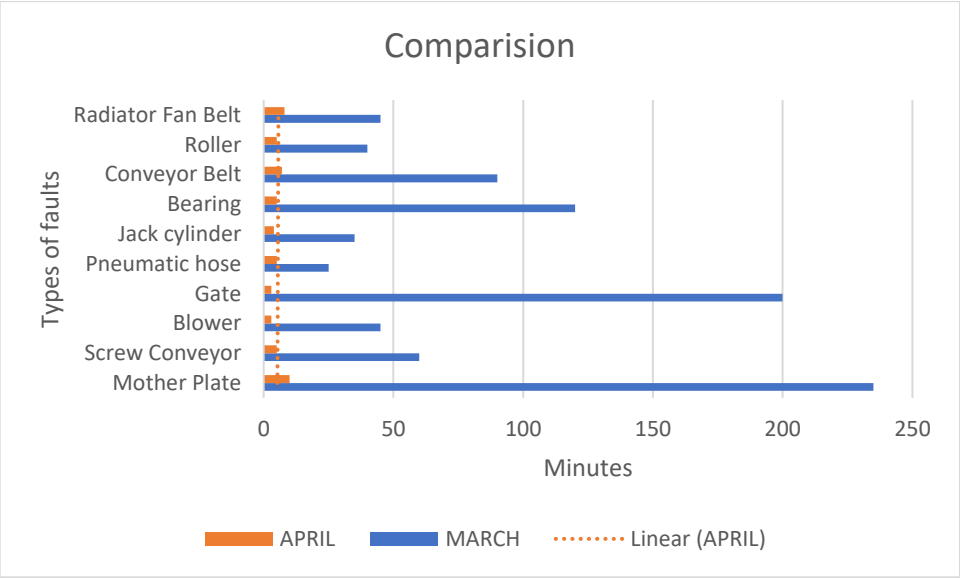


Graph 1: Pareto Analysis [20]

Graph 1 shows that the failures of mother plate, aggregate bin gate, bearing, conveyor belt, and screw conveyor were described as a significant minority. As a precaution, it is advised that:

- It is to check inside the mixer regularly if any wear and tear fount out immediately replace the NI-HARD layer inside the mixer.
- Check bins regularly should any damage be discovered in the aggregate bin. Take protective precautions to stop downtime.
- Pillow block should be checked every day before starting the plant. Enough grease should be applied to the bearing unit.
- The conveyor belt should be checked for signs of wear and tear and take preventative action if any are discovered.
- After batching, the screw conveyor should be emptied. When the cement was left inside the screw conveyor overnight, it solidified. To prevent downtime, avoid this sort of challenge.

The organisation follows the above-recommended checklist and instruction. The organisation found the faults before they happen and reduce downtime. The comparison Graph 2 is shown below.



Graph 2: Comparison of downtime in production [Source: own]

The Graph 2 shown here are only one example. After creation, the maintenance manager was contacted for any partial outcomes. Maintenance of the machines was recommended to the greatest possible extent as part of the measurement of the monitored nonconformities, and all activities outlined in the maintenance plan were carried out. The suggested improvements in maintenance procedures led to a change in the number of faults in manufacturing.

ii. Accident Investigation Report

By monitoring the organisation for the past two months, the accident that occurred was so many and most of the accident occurred because of the transit-mixer vehicle, and management did not take any preventive measures to avoid it in future. Moreover, for future improvement, a 5-why analysis was also created and shown Figure 12 below.

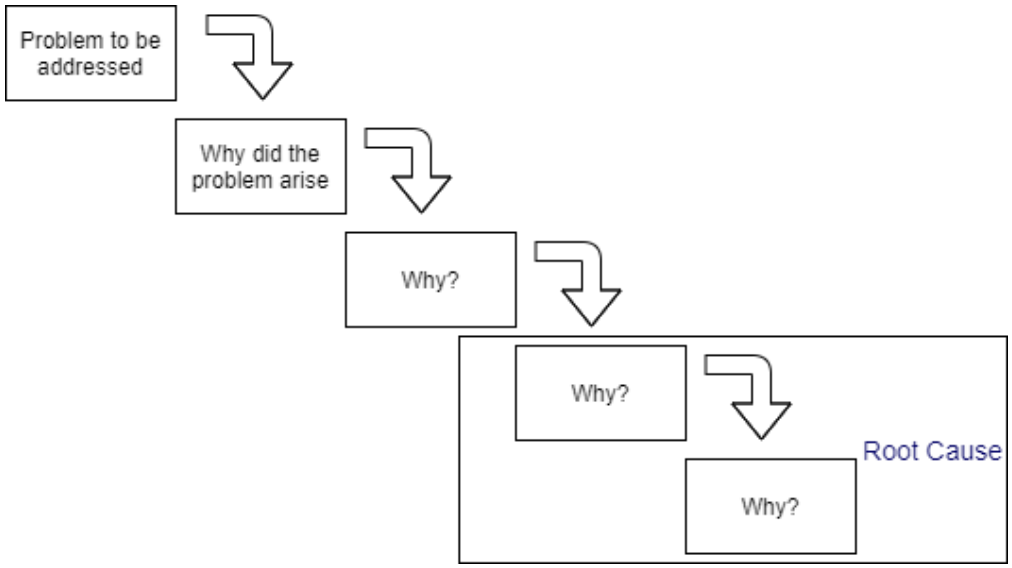


Figure 12: 5 Why Analysis [Source: own]

By using this analysis, the organisation found the root cause of the accident and take preventive measures. So that the organisation avoids the same accident happen it in future. It is recommended that the organisation report every accident that occurred and takes safety precautions by investigating it. Furthermore, follow the form shown in Table 4 below.

Detailed Accident Investigation Report No:-			
Date of Accident :		**Time of Accident :**	
Name of the Plant			
Location of Accident :			
Please Mark (**Tick √**)	**Plant** ☐ **Road** ☐ **Site** ☐		
Accident Type :			
Name of the Injured Person :		**Age :**	
Employee Status :			
Working Hours :			
Name of Contract Agency :			
HSE Induction Date :			
Description of Accident / Dangerous Occurrence :			
****Photographs of Accident:**			
Treatment Required for the Injured Person – YES / NO			
(If Yes Please Specify) – Minor First Aid / Referred to Doctor / Sent to hospital			
MAN DAYS LOST –			
Witness if any-		**Person Completing the form**	
Cost Of Accident :-	**Status of Injured Person :**		
Cause of Accident –			
Corrective Action -			
Actions to be taken to avoid the reoccurrence of the Accident – (Preventive Action)			
Remarks by Manager / Plant Head - **Signature and Date**			
** Photograph / Sketch is Mandatory.			

Table 4 : Sample accident investigation report [Source: own]

The above Table 4 report is filled immediately after the accident occurred by the plant in charge or production manager.

iii. Transit-Mixer Workability Inspection Report

In the organisation, the RMX is transferred to the site using Transit-Mixer. Furthermore, when there is a problem with the transit mixer's drum, the quality of the RMX is affected, and customers frequently complain regarding the quality. It is recommended that the organisation inspect all the transit-mixer vehicles to avoid the quality of the RMX inside the transit vehicles. So, the proposal for the organisation to implement the sample inspection form is shown in Table 5 below.

SI	Vehicle Number	Vender name	Date of Inspection	Empty Weight	Drum Condition	Remarks
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Technician:			**Plant In-Charge:**			
Date:			**Manager:**			

Table 5: Sample Transit-Mixer workability inspection report [Source: own]

The sample transit-mixer inspection report technician must enter the vehicle registration number, vendor name, date of the inspection and empty weight of the transit mixer. And mainly inspection the drum condition of the mixer. If the technician found any damage or faults inside the drum, immediately record the remarks and reject the vehicle. Furthermore, this report is supervised by the plant in charge and the manager. By using this report, the organisation can control the complaint from the customer regarding the quality of the concrete.

iv. Inventory Control System

Find the following factors to improve inventory control:

- Creating specific requirements to assist, categorize, and classify spares (marking parts with words such as "essential" will aid in parts inventory prioritization).

- Reviewing all spare parts regularly depending on time shift, replacements, or substitutes, among other factors.
- Regularly reviewing spares to see if there is surplus stock for specific parts will help to reduce the total product costs.

Using a CMMS with a parts inventory module is a great way to keep track of the inventory levels and avoid the need for annual inventory reviews assuming that anyone who needs spare parts keeps track of stock levels.

Stock level management

All stores-controlled items should have stock levels defined by the respective stores. These levels shall be used to establish material restocking requirements for re-order when the stock level falls below the re-order level.

Following formulas shall be used for defining the various stock levels:

- **Minimum level of inventory** = Reorder level – (Average rate of consumption x Average lead time) (1)

- **Maximum level of inventory** = Reorder level + Reorder quantity – (Minimum consumption x Minimum re-order period) (2)

- **Re-order level** = Minimum level + (Average rate of consumption x Average lead time) (3)

- **Average inventory level** = (Maximum level + Minimum level) / 2 (4)

To recommend the organisation to use the above formulas, by implementing it, the organisation can manage the stock level and re-order in advance if any spare required [24].

3.2.JAYALAKSHMI PLASTICS

Jayalakshmi plastics is a small-scale industry located in Madurai, India. Jayalakshmi plastic is a manufacturer of PET bottles and plastic buckets for paints since its establishment. The owner itself runs the company, so every money which spends this company is by his trade. Currently, the company has 23 employees and the operation is divided into three eight-hour shifts. Moreover, they have about two blow moulding machines for producing PET bottles and two injection moulding machines for the buckets. The manufacturing character relies on the customer's needs and is thus manufactured in bits, small series, and large series. The company plans to increase manufacturing capability further—consequently, a strategy to evaluate the management status of the company. The recommended enhancements are planned to help the company stay competitive, satisfy growing customer requirements, and ultimately draw new customers. All images used in the following description of the production process are drawn from the company's internal documents.

3.2.1. TYPE OF PRODUCTION

This company specializes in the production of

- PET (Polyethylene terephthalate) bottles
- Plastics Bucket for paints

PET (Polyethylene terephthalate) bottles

The PET bottle is a new, hygienic package of choice for many food items especially carbonated soft drinks and water. The reasons behind its success are its glass-like clarity, its ability to maintain carbonation and freshness, and its durability to weight ratio, which enables the production of lightweight, high capacity, clean and resistant containers. The proportion of the box weight relative to the contents makes for a very desirable sales economy, decreasing overall costs. In this company, they produce PET bottles using a blow moulding machine shows Figure 13 below.

Figure 13: LESHAN-K Series Blow Moulding [25]

The K series (economic) blow moulding machine from LESHAN will work with PE, PP and, EVA. The manual, semi-automatic, and automatic operating modes are available on the K series blow moulding system. And the product is different for various types of customers. Imported materials are used in pneumatic, hydraulic, and electrical parts, making them durable and long-lasting.

Plastic Buckets For Paints

This company specializes in the manufacture of unbreakable Paint Buckets. They are a quality-conscious business, so they make sure their paint bucket meets international standards. For this, they used high-quality raw materials and cutting-edge technology to create them. All of these unbreakable paint buckets are well regarded by customers and highly sought after in the industry due to their superior quality, style, shapes, and sizes, and they using Hitech injection moulding machine-TWX 4080 for plastic buckets shows below Figure 14 below.

Figure 14: UWA Tongyong Injection Moulding Machine-TWX 4080 [26]

Due to its vast injection capacity, the UWA Tongyong high-speed plastic injection moulding machine can have a higher injection rate than a standard machine. The manufacturer can make plastic buckets with a length of up to 880mm. Plastic baskets can be made out of PP, PC, PVC, ABS, LDPE and, HDPE. Moreover, HDPE is mainly used in this organisation. According to Chemical Safety Facts, HDPE materials are stable and are not known to transfer any contaminants into foods or beverages, rendering this plastic a low health risk variety. Quick and precise injection technology allows for accurate injection control and speed. The injection moulding system is very stable and sensitive.

Plastic injection moulding process

In the production of this technology, raw material - plastic granulate is filled into the hopper of the injection moulding machine, from which it is poured into the chamber, where it is pressed into the cylinder by a plasticizing screw. After cooling, the mould was opened, and the product is removed from the mould and placed on a conveyor to operate the machine. The whole cycle is repeated over and over again.

Injection moulds with their size and number of impressions (number of parts that fall out in one mould stroke) meet the requirements for the future product and the required production capacity. As the number of prints increases, the production capacity increases, and the product's price decreases, but the production of the mould is more expensive to afford. This technology is most widespread for plastics processing but requires large series of products (in the order of tens of thousands). Only with such series is it possible to calculate the higher

costs of mould production into individual products. Most common plastics can be processed by injection moulding.

Consistency of technology

From here, the pieces travel to logistics, or immediately to the customer. Logistics management is set up using the JIT ("Just-in-time") method, which aims to reduce storage capacity.

This arrangement, therefore, shows the direct dependence of the company's products on the injection moulding machine. This is also related to the high requirement for reliability. Due to the absence of larger storage space, a temporary warehouse, the so-called Partial Area, has been created at the moulding department. The temporary storage of plastic parts is set up as a prevention in the event of a sudden failure of the machine or mold, to ensure a certain number of parts for the customer at all times. After a while, the plastic material loses its properties and for this reason, the warehouse works with the FIFO system. In this way, loss of quality of the overall product is avoided.

3.2.2. ORGANISATIONAL STRUCTURE

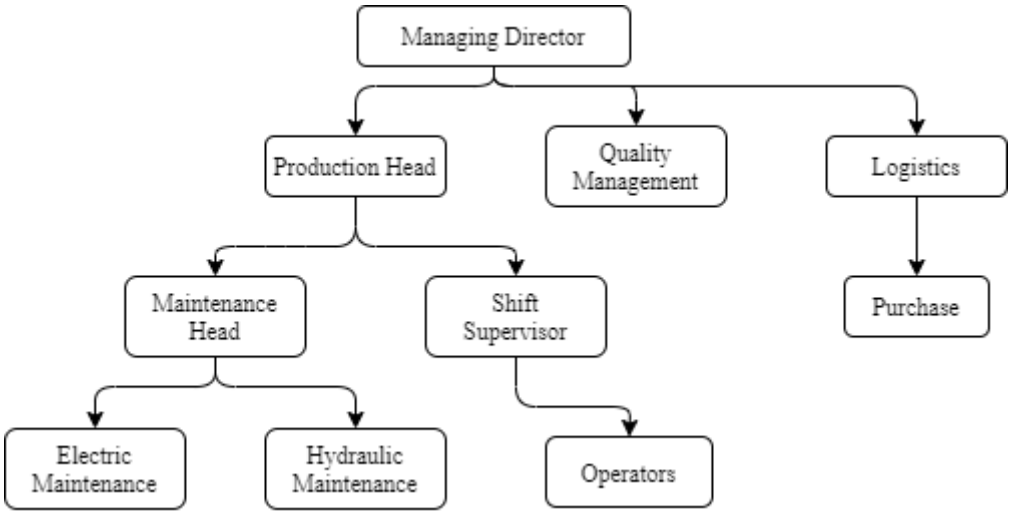


Figure 15: Organisational structure of Jayalakshmi Plastics [Source: own]

The above Figure 15 shows that the organizational structure is linear between the production head, shift supervisor. Looking at this partnership, everything appeared to be the way it should be. There were no separate instructions or scenarios which the operators could not manage. Indeed, the effect is an improvement in the workload of operators.

3.2.3. ANALYSIS OF MAINTENANCE IN JP

Maintenance in Jayalakshmi Plastics includes preventive checks of the machinery about every six months. JP works on three shifts per day. This results in a high requirement of reliability. Efforts to comply with this provision are accompanied by routine frequent inspections. The word regular inspection shall be interpreted as an act of proactive maintenance, not the compilation of data for predictive maintenance records. A well-known concern is the belief that there is no need for money to be spent on prevention and that it is an excessive expense. However, resolving subsequent complications only in the case of a loss is inefficient and frequently involves orders of magnitude of higher costs than the prevention costs themselves. Any operations that are part of the regular checks cannot be carried out meanwhile the system is running. This is all work related to the cleanliness of the machine, its operating space, or the lubrication of individual parts. According to the official opinion of the group, the idea of carrying out regular checks is not specified, because it is not possible to precisely decide whether it is carried out while the system is working or before the start of manufacturing. Work is based on the premise that repair is done before the start of development and is not produced at that point.

INJECTION MOLDING MACHINE MAINTENANCE

Monitoring the organization's function reveals that maintenance of the company's assets takes place only after failure. It requires only long-term operations such as oil change but only after the date that the manufacturer recommends. The organization does not have a formal operation or maintenance schedule. The turnover of workers and the shortage of skilled labour is a common issue and impacts this business. It was owing to the high degree of competitiveness in the industry. It is not easy to find new workers and to attract existing ones.

The machines are usually serviced after a breakdown. The operators themselves carry it out. If they cannot fix the error, an external technician specializing in the machine's form will assist them. An external technician is responsible for significant repair activities. As part of maintenance management, there is no paperwork. Events and their solutions have not been documented. The system was operating, and repair training is periodically performed once a year.

Operations are usually conducted as part of the routine inspection to improve work safety, improve product efficiency, and keep the machine working. Optical barriers, central stop

switches, or status markers for working fluids are used to simplify the efficiency of these functions. Furthermore, routine care is taken to ensure that the environment is clean. Individual checks are conducted in various time sequences.

OUTSOURCING

In several cases, the company uses outsourcing to avoid having to acquire specialized equipment.

- PLC service (programming support)
- Removal of waste
- Service of tanks with glue
- Nitrogen supplementation

The decision to define these maintenance activities outside the company reduces the overall maintenance costs. Selected activities are performed faster, cheaper and safer by specialized maintenance service providers. There is a chance that the number of workers will be reduced, allowing the organization to focus on its interests.

3.2.4. NONCONFORMITIES FOUND IN THE JAYALAKSHMI PLASTICS

i. Maintenance after failure
ii. Defective parts at the end of the manufacturing process
iii. There are no records of any faults and their resolutions
iv. Overall equipment effectiveness
v. Untidy workplace
vi. Safety Measures
vii. Unskilled Labour
viii. Spare parts Management
ix. QMS in maintenance
x. Temporary storage for the product

3.2.5. IMPROVEMENT IN JAYALAKSHMI PLASTICS

Based on the review of the existing maintenance schedule currently laid out in Jayalakshmi Plastics, preventive inspection is based on the manufacturer's recommendations and currently does not have all the necessary data for its optimization. The daily inspection is performed at regular intervals with a weekly schedule, where these intervals affect the time utilization of the adjuster, the person performing routine maintenance according to the plan,

and especially the production time of the machine. The introduction of a measurement device improves access not only in the firm surveillance of given parameters but also, above all, in the absence of the human element. It is the human aspect that is essentially the source of error and imperfect regulation.

i. MAINTENANCE AFTER FAILURE

The schedule developed are meant to address the organization's existing maintenance deficiencies. Since resolving them, it is proposed that a maintenance process management framework be implemented.

DAILY MAINTENANCE

- The machine should be cleaned thoroughly
- Toggles should be wiped and cleaned with a clean cloth until they are free of grease and dust
- Checked the melt accumulation at the nozzle and should be cleaned if necessary
- Grease lubricating systems for pipes should be checked.

WEEKLY MAINTENANCE

- Be sure there is enough grease in the grease pump
- Safety equipment should be examined
- The nozzle should be centered

It is recommended to proposal the organisation follow the below Table 6 to avoid maintenance breakdown.

Maintenance Type	Per Shift	Per Week	2 Weeks	Per Month	3 Months	6 Months	Per Year
Hydraulic operating oil level	✓						
Air control	✓						
Running Condition of hydraulic pumps	✓						
Check and cleaning of nozzle	✓						
Checking Injection Moulds		✓					
Control Unit filter check			✓				
Checking the battery			✓				
Clean and apply oil to guid rod				✓			
Replace of filter cartridge					✓		
Cleaning of filter on the injection control valve					✓		
Service of screw motor bearing						✓	
Replacing of air filter							✓
Cleaning of oil tank							✓
Hydraulic oil change							✓
Replacing of filter in the cleaner							✓
Cleaning the oil filter							✓
Technician:		**Manager:**					
Date:							

Table 6: Maintenance Schedule [Source: own]

In the above Table 6 shows the maintenance checklist for the organisation, and the tick mark shows that the type of maintenance has to be done for a specific time interval. For example, the hydraulic operating oil level has to be checked every shift. Moreover, injection mould is checked every week.

ii. DEFECTIVE PARTS AT THE END OF THE MANUFACTURING PROCESS

Temperatures in injection moulding units should preferably be kept stable. Temperature variations caused by the manufacturing cycle result in product form defects. The temperature control unit for injection moulding machines is advised to keep the system at the right temperature.

Figure 16: Mould Temperature Controller [27]

The above Figure 16 shows the mould temperature controller. The mould temperature controller circulates cooling fluid through the mould's cooling circuits to provide heat flux equilibrium with each loop. Separate mould temperature controllers are commonly used for each mould. This configuration enables better process management and processability.

iii. THERE ARE NO RECORDS OF ANY FAULTS AND THEIR RESOLUTIONS

The organization follows the guidelines outlined below Table 7 to remove the failures. The organization uses TPM to adjust the preventive maintenance based on the performance of field operations rather than from the equipment manufacturer. The TPM allows for the coordination of findings, the adaptation of maintenance types, and the training of employees.

Operation	Executer	Method
Register the failure	Operator	Fill out the form at the position of the failure
Repaire the machine	Maintenance worker	Manage the interventions and the spare parts
Confirm the cause and suggest preventative measures	Maintenance worker and supervisors	Pareto analysis
Forms for maintenance should be created or updated	Maintenance worker	Forms for preventive maintenance should be updated and validated
Make use of the update form	Operator and maintenance worker	Proceed to the next phase of maintenance, determine the training requirements, and prepare the operator

Table 7: Method of Records of Faults [Source: own]

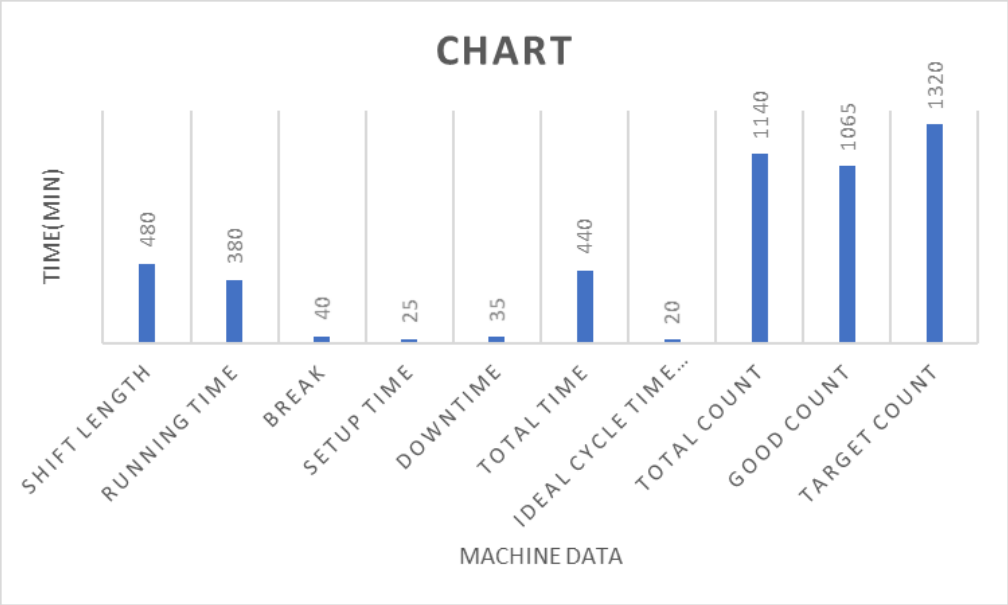
iv. OVERALL EQUIPMENT EFFECTIVENESS

Due to the identified discrepancies, the organisation monitored and recorded discrepancies in production—the overall equipment effectiveness was slightly low because of the downtime and damaged part at the end of the production. OEE value of the organisation before implementing sensors

Machine Data	**Values (Min)**
Shift Length	480
Running Time	380
Break	40
Setup time	25
Downtime	35
Total Time	440
Ideal Cycle Time per part	20
Total Count	1140
Good Count	1065
Target Count	1320

Table 8: Machine data from the organisation [Source: own]

Above table 8 shows the time consumption in the organisation in 8 hours shift, a total of 480 minutes in these 40 minutes are standard break and setup time of the machines is like 25 minutes. In some case, parts jam inside the moulding chamber results in downtime of 35 minutes. So, the total running hours of the machines are 380 minutes. The ideal cycle time per part is about 20 seconds. The bar chart for the following data is shown in Graph 3 below.



Graph 3: Machine data in JP [Source: own]

The formula for calculating the overall equipment effectiveness of the organisation is:

- $$Overall\ equipment\ effectiveness = availability * performance * quality \quad (5)$$

The overall equipment effectivenesss value of the organisation before implementing sensors are shown in Table 9 below.

Variables	Formula	Result
Availability	Run time/Total time	86%
Performance	Total count/Target count	86%
Quality	Good count/Total count	93%
OEE	**Availability*Performance*Quality**	**70%**

Table 9: OEE value of the organisation [Source: own]

CHECKING THE OIL LEVEL

On the injection moulding machine, the working oil level is examined at two stages. In the first, the lubricating oil level is reviewed. The hydraulic oil level is used in the follow-up

inspection. The need for visual inspection is removed using sensors to verify the amount of these two working fluids.

Figure 17: Oil Level Sensor[28]

The above Figure 17 shows the oil level sensor. The oil level sensor is mounted inside the cylinder. Its primary function is to calculate the volume of oil inside the cylinder. If the oil level is low, an alert light can illuminate.

CHECKING THE AIR PRESSURE

The machine cannot work until the air pressure is adjusted correctly. The new maintenance schedule calls for pressure control per shift. Visual monitoring can be eliminated by using a pressure sensor **PQ3834** for pneumatic applications. The sensor also contains an LED monitor for faster reading of current values on the machine.

Figure 18: Pressure Sensor [29]

Above Figure 18 shows the pressure sensor. These pressure transducers feature a constant-area sensing device that responds to the force given to it by fluid pressure. The applied force will cause the diaphragm within the pressure transducer to deflect. The internal diaphragm's deflection is monitored and transformed into an electrical output. This permits programmable controllers to monitor the pressure.

VIBRODIAGNOSTICS ON PUMPS

The most recent suggestion to alter the injection moulding machine's maintenance schedule is to install a mechanism to monitor the pumps' vibration. This check is required to the frequent problems with increased vibrations, which result in the wear of the inner rings for the connection of nozzles, or the risk of corresponding pump exhaustion, the spike in vibration can be predicted in advance with continuous monitoring and significant harm can be avoided and the sensor shown in Figure 19 below.

Figure 19: Vibration Sensor [30]

The above maintenance plan is designed to transfer daily controls practised only through the human senses to control using scanning systems. At the same time, two new controls can be integrated into the new maintenance system to ensure a trouble-free operation of the machine. Implementing the sensors in the organisation to solves the current problem, which results in frequent production shutdowns and necessary repairs.

For sensors implementation

The installation of multiple sensors on each unit is needed for actual use. Individual segments must be wired together, and power for sensors, buses, and other accessories must be available for maximum functionality.

Oil level sensor = 6000 INR (1800 CZK)

Pressure sensor = 7500 INR (2200 CZK)

Vibration sensor = 20000 INR (5800 CZK)

Equipment	oil Level Sensor	Pressure Sensor	Vibration Sensor	Total
Inspection	Lubricant level	Controll of air pressure	Hydralic pump vibration	
Price(INR)	6000	7500	20000	33500
Time Saving(Min)	2	3	4	9

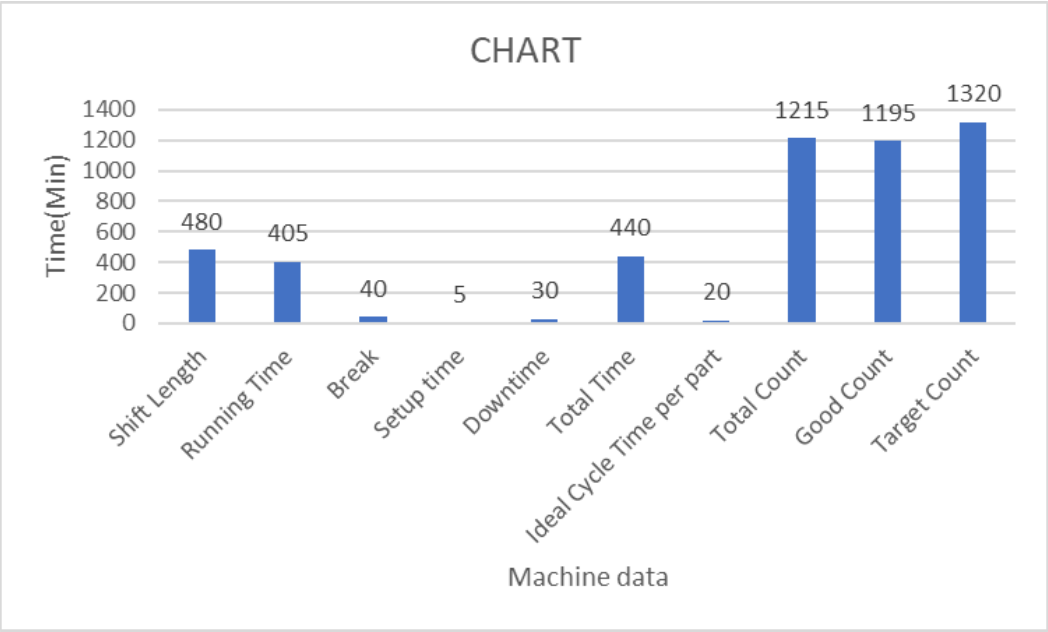
Table 10: Price of the Sensors and time saved [Source: own]

The above Table 10 shows the total cost of one injection moulding machine's machinery is 33,500 INR. This is a gross price that does not include the cost of the service software, connecting cables, and, most importantly, the work done (it is expected that the maintenance department will install the device in the case of a time crunch).

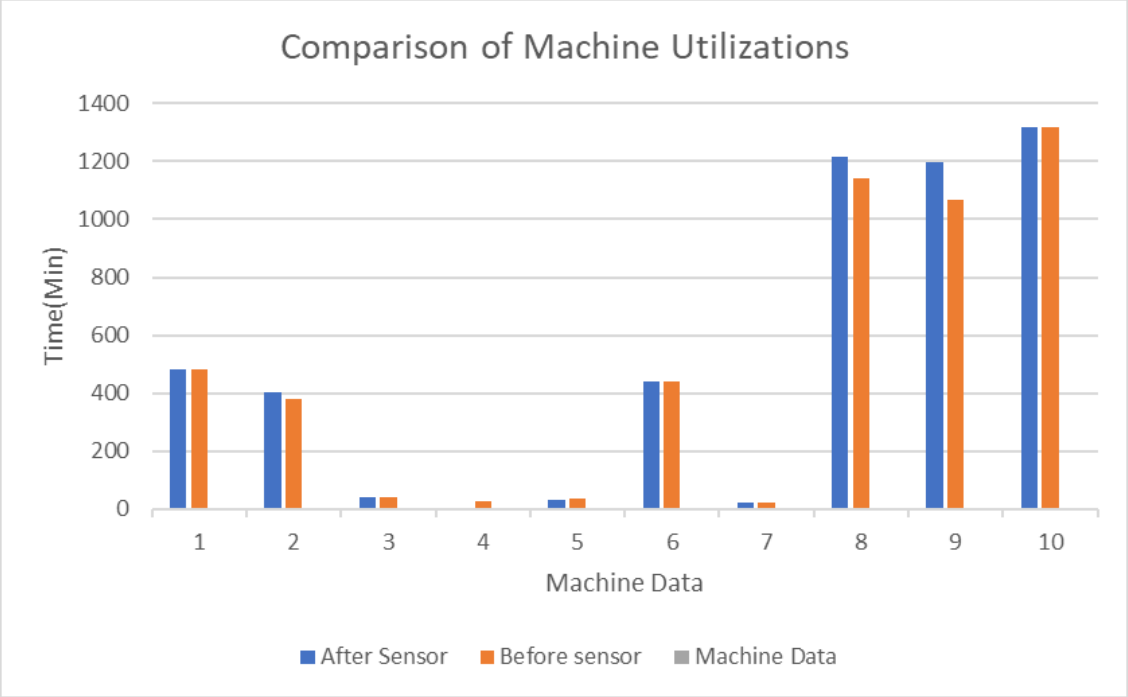
Machine Data	Values (Min)
Shift Length	480
Running Time	405
Break	40
Setup time	5
Downtime	30
Total Time	440
Ideal Cycle Time per part	20
Total Count	1215
Good Count	1195
Target Count	1320

Table 11: Machine data after implementing sensors [Source: own]

Above Table 11 shows that the machine utilisation after implementing sensors, the setup time and downtime decreased because of the sensors, so the machines' total running time and productivity also increases. The bar chart for the following data is shown in Graph 4 below.



Graph 4: Machine utilization after implementing sensors [Source: own]



Graph 5: Comparison of machine utilizations [Source: own]

Variables	Formula	Result
Availability	Run time/Total time	92%
Performance	Total count/Target count	92%
Quality	Good count/Total count	98%
OEE	**Availability*Performance*Quality**	**83%**

Table 12: OEE value after implementing sensors [Source: own]

The above Table 12 shows the comparison of the machine's productivity before and after implementing the sensors. The availability and performance increased by 6%, and the quality increase by 5%. By using the formula, the OEE value is calculated and increased by 13% compared to the previous OEE.

v. UNTIDY WORKPLACE

It is recommended the organisation follows 5S standards.

5S is a lean manufacturing tool. An essential step to pursue a successful Lean Manufacturing process is implementing the 5S.

The 5S methodology is used for setting up and maintaining the quality of the working environment in an organisation. Such organisations can manage and organise inefficient ways that require fewer human efforts, space, time, and capital to make products with minor error and make a well-ordered and clean workplace.

5S system is used to decrease waste and optimise productivity and quality by monitoring an organised environment and using visual pieces of evidence to get more firm results. Using this 5S technique gives an effective way to improve safety standards, health, housekeeping, and environmental performance.

The 5S's are

- SEIRI – Sort or Organize
- SEITON – Set in Order or Systemize
- SEISO – Shine or Clean
- SEIKETSU – Standardizing
- SHITSUKE – Sustaining and Self - Discipline to Maintain It

SORT - unused tools, aids, and accessories are sorted. This results in a cleaner and clearer work environment. All site operators should be involved in deciding whether to decommission equipment.

SET IN ORDER - each tool and material must have a clearly defined place in the workplace. If the worker is used to taking and storing tools in the same place all the time, the efficiency of the process will increase.

SHINE - A clean workplace and tools also help increase efficiency. Besides, a clean environment helps to detect faults, such as oil leaks.

STANDARDIZE - To be able to effectively perform the previous steps repeatedly, it is necessary to standardize these tasks. If employees know the scope and frequency of activities performed, it is easier to manage and control these tasks.

SUSTAINING - the purpose of the method is to complete the first four steps in the long term. Creating a work system at the workplace in cooperation with its staff and regular inspection of individual workplaces are essential prerequisites for the operation of the 5S method [30].

vi. SAFETY MEASURES

Any part of the plant must adhere to safety protocols, switches for emergency shutdown. Everyone who works in the plant should wear protective equipment such as gloves, safety shoes, safety glass. Electrical wiring should be checked for insulation.

vii. UNSKILLED LABOUR

It is essential to ensure the adequate qualification of maintenance staff qualified to conduct maintenance for the expected improvements in the maintenance management structure to work optimally. It is proposed that a curriculum of routine professional training be developed. This will require thorough system operator training as well as routine maintenance training.

viii. SPARE PARTS MANAGEMENT

It is to recommend the organisation to implement small spare parts inventory to implement spare parts management. And below some proposals for the organisation.

- Replacement of pieces that have reached the end of their mechanical or warranty existence.
- Exchange due to a technological limitation, such as a system failing to follow the requirements needed for service during the technical inspection.
- Workpiece damage during application (damage found during service, during routine maintenance)
- Damage to the workpiece during storage (quality loss), for example, replacement of parts suggested by the manufacturer or an authorized individual in the technical documents concerning the warranty term.
- Individual components such as gaskets, screws, filters, and so on.
- Components assembled by the retailer from different parts and ready for installation.

ix. QMS IN MAINTENANCE

It is to recommend the organisation to follow ISO (International Organization for Standardization).

ISO 9001 is a collection of QMS (Quality Management System) standards. These guidelines offer instructions and resources for businesses and organisations that wish to satisfy the quality demands and specifications of their customers.

x. TEMPORARY STORAGE FOR THE PRODUCT

The finished product from the injection moulding machines travels to logistics or immediately to the customer. Logistics management is set up using the JIT ("Just-in-time") method to reduce storage capacity.

This case shows the direct dependence of the company's products on the injection moulding machine. This is also related to the high requirement for reliability. Due to the absence of more extensive storage space, a temporary warehouse, the so-called Partial Area, has been created at the moulding department. The temporary storage of plastic parts 10was developed as a preventative measure in the case of a sudden breakdown of the system or mould to ensure that certain parts are still available to the consumer. Since the plastic content loses its properties after a while, the warehouse uses the FIFO method. In this way, loss of quality of the overall product is avoided.

4. RISK AFFECTED MAINTENANCE IN THE ORGANISATION

Organisational maintenance risks can be evaluated from a variety of perspectives. First, the hazards that may have an impact on how specific tasks are carried out. Second, maintenance is one of the most dangerous operations in organisations, particularly in breakdown maintenance, when defective machines whose function is critical to the given process are fixed. Checks and testing of equipment while it is in operation, are also dangerous. As a result, it is critical to assess the dangers and take the required precautions.

The risk affecting maintenance in ACC are:

- During the loading operation, operators are exposed to dust comprising elements like silica, cement and aggregate.
- People subject to high-temperature materials and surface vessels, most commonly produced by scalding, exposed to unintentional conditions.
- Operators use a trailer pump to get the ready-mix concrete to the top of the floor through a pipe. Object storage improper quickly lead to a fall injury.
- Transit-mixer delay due to traffic conditions.

The risk affecting maintenance in the JP are:

- Avoid safety precautions.
- Inadequate financial budget.
- Bad ergonomics.
- A lack of personnel.
- Inadequate qualification.
- Material of inferior grade.
- Ventilation.

It is necessary to establish a "safety culture" in three categories of factors: human, technological and organizational. It is mainly focused on assessing maintenance risks and then developing appropriate solutions to remove, mitigate, prevent, or protect against such risks. In general, a health and safety management system that includes risk assessment, risk management, and monitoring procedures is designed to prevent workplace accidents. It primarily identifies hazards and individuals at risk, analysing and prioritizing risks, deciding on preventative action, executing, and monitoring reviewing [31].

Risk management in organisation maintenance guide for three contents:

- Safety planning
- Identifying hazards
- checklist of workers

To obtain safe maintenance, it is necessary to follow the five essential guidelines listed below:

- Develop a detailed plan,
- Make the work environment safe,
- Use suitable personal protective equipment,
- Work as planned,
- Accomplish a final check [31]

5. PROCESS APPROACHES AND MAINTENANCE

Another aspect of this effort is assessing the condition of maintenance concerning the process approach. To that goal, factors that should help to improve and clarify the evaluation have been chosen.

Currently, both the organisations do not have a credential proving compliance with the ISO 9001 standard. The organisation's maintenance quality control framework is not entirely developed. In this region, risks have not yet been assessed. Maintenance processes are not defined, nor is the process map generated. Maintenance operations have not yet been recorded, nor has the efficiency of maintenance systems been assessed and analysed. As a result of these conditions, no improvement methods have been introduced. Organisations and their maintenance management were examined in the following areas in compliance with the ISO 9001 standard. [32], [33].

- Organisation
- Leadership
- Planning
- Support
- Operation
- Performance evaluation
- Improvement

Management is carried out following individual operations rather than processes. Organisations do not map maintenance processes. Several disagreements accompany organisational functioning. Based on the analysis of their current situation, they recommend adopting a process management approach. To ensure the proper operation of the displayed processes, it is necessary to identify the process's owner, monitor its features, and take the necessary measures based on their evaluation. In the given organisations, functional maintenance management can be replaced by process management in the short term. The proposal process map for the organisations is shown in Figure 20 below:

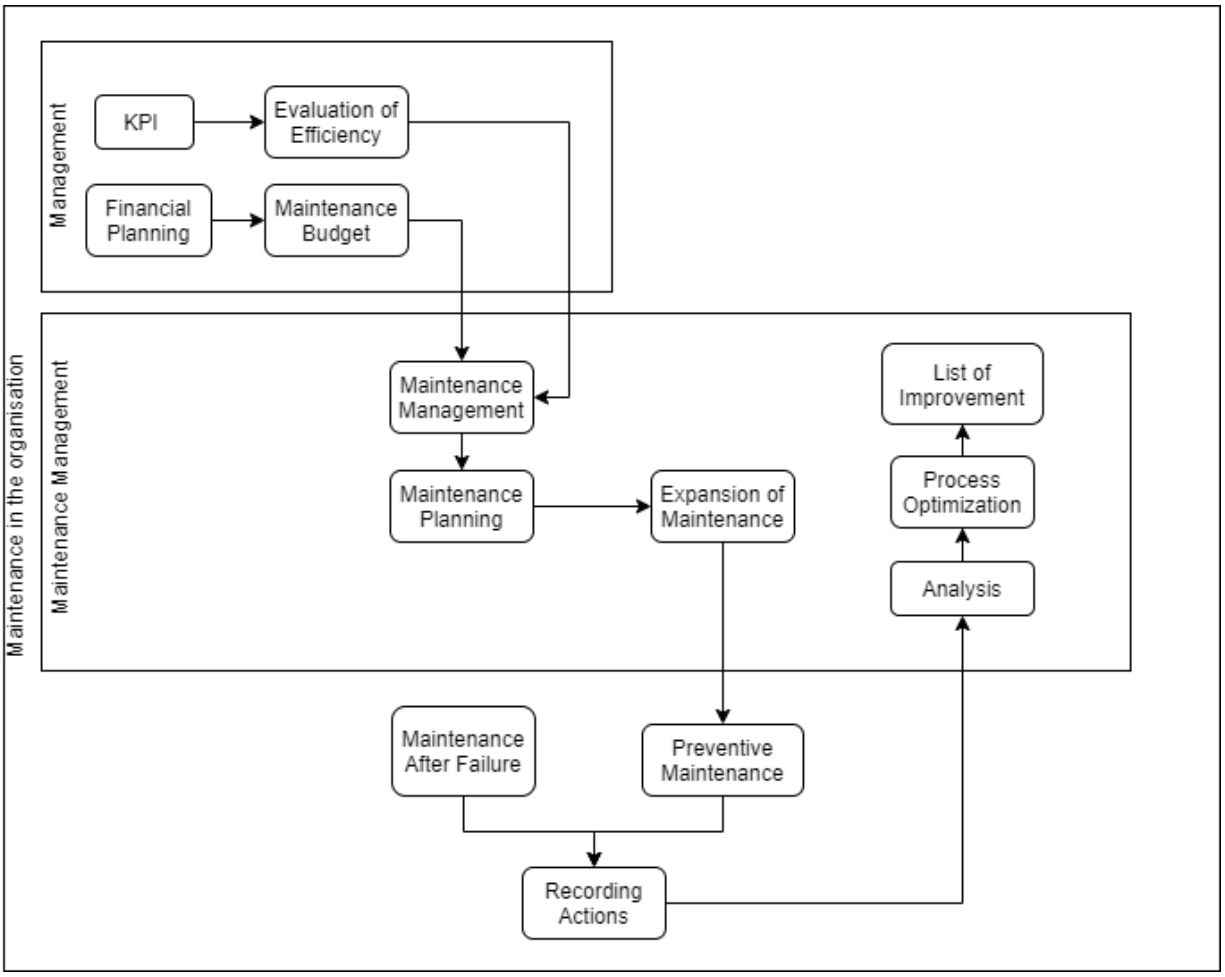


Figure 20: Process Map for the organisations [Source-own]

The organisation is currently run using systematic methodology concepts. Management is carried out under human procedures rather than procedures and do not map maintenance systems. A series of disagreements characterise organisational functioning. Based on their current situation, it is advised that they adopt a process management approach.

6. RECOMMENDATION FOR ORGANISATION

In both organisations, several nonconformities found, and recommendations have been made. Firstly, it is a solution to the nonconformities when the organisation is monitored. A suggestion to modify maintenance management, minimise the number of failures and downtimes and recommendations to improve management processes is included in the scope of the solution. According to the study of the relationship between maintenance in the organisation and process management, organisations should execute processes according to generated process maps, define personnel accountable for processes, analyse characteristics of primary processes, number of produced pieces, production times, and continually improve processes.

Organisations were advised to evaluate the benefits of implementing automation elements based on the relationship between maintenance in the organisation and the new production concept. Above all, weigh the potential costs against the value of the savings that will result from their implementation. The use of this solution to automation of maintenance is advantageous. It will also provide benefits in introducing predictive maintenance and the resulting more straightforward evaluation of the necessary interventions.

A list of documentation was created for organisations:

- Weekly maintenance checklist
- Pareto analysis
- 5Why analysis to found the root cause of the accident
- Transit-Mixer workability inspection report
- Improve inventory control system
- Increase in overall equipment effectiveness
- Method of records of faults
- 5S implementation
- Process map

Because of the standard's scope, it is suggested to conduct a thorough study of the organization's current situation and implement the appropriate documentation and processes.

7. CONCLUSION

The scope of the thesis includes ideas to modify maintenance management, minimise the number of failures and downtime, and optimise organisational procedures. Maintenance and administration are essential components of every enterprise, whether it is a manufacturing or trading firm. To ensure reliable service, both organisations must take care of their properties. Maintenance eliminates the dangers of its breakdown, which may be fatal. This diploma thesis outlined maintenance and administration in the literature part and discussed the fundamental forms of maintenance, maintenance types, maintenance strategies, methods of the maintenance organization, approaches to maintenance planning, methods of planning, and trends in maintenance and technology developments.

In the practical part, two organizations were added, and their operations were examined. The current maintenance schedule lacks well-specified requirements for carrying out maintenance. Based on the monitoring of activities in organizations, it was discovered that the administration of maintenance and the organizations themselves were carried out under practical management standards. During the research, theoretical knowledge was applied to achieve the goals of the task. Initially, a maintenance study was conducted on the status of the organisation. Information was found which is significant for placing the company in perspective. In this examination, two elements were highlighted. The first was the downtime due to neglected maintenance, and the second the use of a process approach in maintenance. Nonconformities in the companies were discovered and analysed. Following that, suggestions for their solution were made.

The significant benefits for the organisations described in this diploma thesis are to change in the approaches to maintenance. By implementing the proper checklist in ACC, the organisation can reduce downtime by more than 60 %. Moreover, 5why analysis was created to find the root cause of the accident and take preventive measures to avoid the same accident happens again. Meanwhile, in JP, the overall equipment effectiveness is increased by 13 % by implementing sensor in the organisation. The maintenance management guidelines, particularly the use of a process approach, are the next step in improving process efficiency.

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