

Aircraft Ground Support Equipment: A Framework for Maintenance Strategies

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Abstract

The airline industry encompasses a wide range of businesses, called airlines, which offer air transport services for paying customers or business partners. Airline industry can be classed as just one sector of the wider aviation industry. There are a number of services that may be done on a plane when it is parked at an airport terminal gate, and they are known as "aircraft ground handling. The number of passengers using airports continues to rise, pushing such facilities to their maximum capacity. Without the substantial services provided by the Ground Handlers, these brick and mortar infrastructures would not be able to continue to exist. Ground Support Equipment (GSE) is an industry term that refers to support equipment typically found at an airport that is used to service the aircraft between flights. The primary goal of GSE maintenance is to deliver the holder or user with safe and operable equipment that is also presentable, while incurring as little expenses as possible and experiencing as little downtime as possible. The laws that oversee airport operations must be complied with by any maintenance programs that are begun on GSE. Introduced equipment standardization, processes standardization, parts standardization, inventory management, asset management, maintenance KPIS, life of equipment and impacts on performance and reliability. Too little maintenance may lead to expensive breakdowns, poor system performance, and reduced dependability. Regular maintenance improves dependability but raises costs.

Keywords: aviation industry, airline industry, ground handling, GSE, GSE maintenance, standardization, inventory management, hazards, asset management, salvage value, book value and depreciations, maintenance KPIS, impacts of maintenances & reliability

1. Introduction

Air transport and aircraft constitute a specific category of services, which are characterized by a high level of operational safety in comparison to other modes of transport and means of transport. Much emphasis is placed on safety and continuity of service. GSE ensures fluidity of air transport. If the aerodrome operating technique delivers on its operational phase required technical effects, undeniably it requires appropriate maintenance. The work outlines the basic maintenance division and its impact on the function and performance to the individual type of service at the airport. The goal of maintenance is to lengthen the useful life of the equipment or at the very least, to push back the average time before the next breakdown, which may result in expensive repairs. In addition, it is anticipated that efficient regulations about maintenance would be able to cut down on the number of service outages that occur, as well as the many unfavorable effects such interruptions have. A high degree of dependability and the intended result were the goals of the research, which aimed to offer methods and policies for the maintenance of aviation GSE in order to accomplish those goals. The aviation industry being so diverse and congested with time bound activities, where time being commodity matter a lot avoiding unnecessary waste processes. Mostly focused here in the paper GSE directly intact with the Aircraft ground handling operation.

Standardized processes needed to incorporate the coverage of maintenance need avoiding business disruption. GSE maintenance is backed by a highly JIT inventory processes with lean submission of all the logistics and spare parts considerable need of maintenance. Parts delays in the early stage delays the overall scheduled maintenances specifically in preventive maintenances, which particularly goes against the business if failed arrest on time. The most considerable objectives of the maintenance are: Cost control, Improved quality, planned maintenance work, personal safety particularly operating equipment on airside, production downtime, aircraft operational delays avoidance, GSE's useful lives extensions, budget allocations and controls on forecasted consumptions, organizing and developing policies and procedures, resources allocation, team management, coordination with all stakeholders, and compliance to recommended regulations (Including ISAGO, IATA) etc. The equipment unless maintained on time during the early life failures extends to useful life retractions with a shortest wear out phases, that is why it is highly desirable following recommended instructions and guidelines from the OEMs based on ISAGO regulations avoiding such circumstances. Safe equipment will have no or less complications on operational end of the ground handling and not only boosting ground handling performance but expedites overall safety performances. Study is totally based on experience, observation, reviews and documentations.

1.1 Background, Applications, Outcomes and Study Motivation

GSE is the support equipment found at an airport, usually on the apron, the servicing area by the terminal. This equipment is used to service the aircraft between flights. As the name suggests, GSE is there to support the operations of aircraft whilst on the ground. The role of this equipment generally involves ground power operations, aircraft mobility, and cargo/passenger loading operations. The primary goal of GSE maintenance is to offer owners and users with the same functional and visually appealing equipment at the lowest possible cost and with the least amount of downtime. Airport operations must also be regulated by GSE maintenance programs. Most of the GSE are automotive with dominant shares of electrical, hydraulic, pneumatic controlled systems. Extending excellent maintenance strategies with low cost repairs will reflect more cost effect which is eager to obtain. Without a GSE maintenance plan, your employees have no direction. Because of this, constant and unexpected equipment downtime will become the norm. A maintenance plan for airport GSE will prevent this. A comprehensive GSE preventive maintenance plan, when scheduled and followed, takes the guesswork out of tasks. It ensures that all employees are following the same standards for inspection and instructions for maintenance. This means that all involved will know precisely which GSE will be down for maintenance or inspection, and at what time. So, you wind up with minimal disruption to your employees' workday and your hanger's overall efficiency. When all of your employee begins to follow a regular GSE plan, the operational reliability and productivity of your equipment will naturally increases. The maintenance place work by addressing issues before they develop into serious problems. This support the early detection of equipment components that are showing the beginning signs of failures, so you will see a consistent level of reliability and productivity from each and every piece of equipment in your fleet. Things that used to negatively impact your equipment's performance, like hydraulic contamination or inadequate fluid levels, are drastically minimized when standards and maintenance plans are put in place. This means your GSE and vehicles are now running at their peak operational conditions, equating to a measurable bump in their efficiency. At the end of the day, the most significant advantage to putting a maintenance plan in place for GSE and vehicles is the considerable cost savings you will see. From inspecting your tow bar less tug to lubricating air plane jacks and engine compartments, every little bit will help to improve the efficiency and operating ability of your equipment. You will begin to notice a dramatic decrease in unexpected repairs, operational expenses and unscheduled downtime, all resulting in an overall reduction in costs. When we invest in preventive GSE maintenance, we experience a significant impact on your productivity and thus your company's long-term return on investment (ROI).

2. Literature Review

Wang, Lim (2021) Studied to reduce ramp accidents and enhance aircraft ground handling by: 1) "Track GSE in actual time and with great precision to readily get their locations and velocities and precisely report possible aircraft-GSE collisions. 2) GSE was planned optimally based on real-time data to make optimum use of GSE. S. Saggarr and A. Matta are the authors of this research (2021) "this effort focuses on optimizing the planning and real-time distribution of certain resources that are utilized to turn around an aero plane between two consecutive flights. Sznajderman, Ramírez-Díaz, Di Bernardi, C.A (2021) Studied to look into the possibility of constructing a hybrid apron with a predetermined number of parking spots by taking into account how the management model influences the average amount of time that each aircraft is delayed as well as the total amount of gaseous emissions that are produced by aircraft and GSE combined. According to research conducted by JENOV and KOK (2017), "the primary concern at airports is the security of passengers and employees, as well as the

efficient operation and upkeep of all technological apparatus and technical means used for ground handling of aircraft. As a result, the primary purpose of this article is to provide the procedure for the management of the repairs of GSE. ak (2016) “found that maintaining the aircraft GSE at airfields of the Armed Forces of the Republic of Poland in a condition of operational readiness affects whether or not the body that performs its maintenance and repair had enough means and resources. In this article, the distinguishing elements of the maintenance model applied to GSE components that are utilized for aircraft ground handling are discussed in detail. Fan H (2014) Showed via research that as the figure of aircraft flying missions increases and as the electronic and digital capabilities of aviation ground support facilities continue to advance, CBM will inevitably become the dominant form of maintenance management. Analysis on the materiel support process taking into consideration the failure of support equipment was reported in the study that Yan Wang (2011) conducted. Using a priority queuing system as a foundation, a virtual customer who represents broken support equipment was made to have a higher priority in terms of receiving assistance. A maintenance process model that takes into consideration the breakdown of support equipment was created. When compared to more conventional models, the results of the failure of the support equipment were disclosed. D. Nguyen (2011), D. Nguyen (2012), Yan Wang (2011), Yan Wang (2010) “Researched that the electrical GSE is a crucial part of the L&T marketing effort (EGSE). The EGSE is a combination of hardware and software that gives the L&T team the ability to test and validate the spacecraft while it is still on the ground. Liu, Wang, & Su (2021) Studied with the terms of the rebate warranty contract, the vendor is obligated to provide a refund to the purchaser in the event that the total number of product failures or the amount of time necessary for a single repair exceeds the specific constraints outlined in the agreement. Pintelon and Vereecke (2006) conducted research on the topic in order to develop a framework for determining and evaluating the effectiveness of a business's maintenance strategy. This may be of use in the operational and tactical management of maintenance. When compared to other activities such as manufacturing and business, the amount of strategic literature on maintenance is quite limited. A great deal of apparatus and methods have been conceived of and put to use in different domains. However, there has never been an attempt made to test the applicability of such tools to the maintenance role. The subject of maintaining an appropriate inventory of Naval aviation GSE was studied by Jacquette and Richard Morey in 1969, and the study discusses the implications of their findings. The work that was done for the Aviation Supply Office may be found reflected throughout this report. This article takes automobile maintenance spare parts as the research object, and proposes a distributed multi-level spare parts inventory algorithm based on centralized control to address the problems of low satisfaction of the automotive maintenance spare parts warehouse and poor effectiveness of spare parts inventory control”. This study was conducted by Li (2020) and takes automobile maintenance spare parts as the research object. The characteristics of automobile maintenance spare parts supply, vehicle maintenance spare parts supply, and vehicle maintenance spare parts inventory management are introduced, and the current status of automobile maintenance spare parts inventory management is analyzed. The functions of inventory cost and projected inventory cost were determined by applying the criteria of centralized ordering and mutual allocation. In order to facilitate centralized ordering and the inventory of mutual spare parts, a mathematical model was developed. According to the findings of the trial, the algorithm not only has the benefit of a high satisfaction rate of vehicle maintenance spare parts library, but it also enhances both the efficiency and the accuracy of the process. The names Tabares and Drouin (2021) “that efficient and timely ground handling of aircraft at airports is essential to the continued viability of the aviation industry This study makes a recommendation for a ground handling management structure that enables the automation of operations in order to meet the increasing demand for this service. This article by Chang, Bandyopadhyay, Biller, and Xiao (2007) discusses the procedure for planning the maintenance personnel, as well as the part that simulation plays in carrying out this procedure. The concept of feedback control is being used here in order to solve the staff planning issue. This research will assess the tradeoffs that exist between the staffing levels of maintenance personnel and the throughput of a manufacturing line in order to better serve its intended function. According to the research done by Gullo and Kovacevic (2021), “Condition-based Maintenance (CBM) is not the same as Time-based Maintenance (TBM). CBM has the potential to significantly cut down on the number of man-hours that are required for asset maintenance. Instead of doing extensive overhauls over long periods of time, maintenance is only carried out when it is absolutely necessary and just on the parts of the asset that need repair. As a result, this allows firms to function with less needs for employees. CBM provides businesses with a wide range of opportunities to cut down on the need for scheduled maintenance downtime. According to Sekolah Tinggi Teknologi Kedirgantaraan Yogyakarta (2023), Punctuality in the field of aviation is an important focus in work. Serving aircraft movements, the GSE unit performs an important role in it, so that the unit requires to always carry out work discipline. In order to minimize the errors, the discipline carried out by GSE officers is

very important in handling the movement of aircraft, vehicles and goods that cross the apron area. This study aims to determine the factors that influence the work discipline of the Ground Support Equipment unit.

3. Research Methodology

A scientific inquiry is what we refer to as research. The process of exploring for new knowledge and methods of thinking in any field of study is referred to as a "investigation," and the name "investigation" refers to this process. In light of this, we might define research as the process of looking for new information. Discovering new facts, relationships, and rules that control business phenomena is, of course, the goal of any business organization that exists today. However, it is necessary to do ongoing verification of previously established ideas, particularly in an ever-changing commercial setting. Comprehended and established work performance and maintenance strategies in accordance with OEM specifications in order to carry out and provide a well-maintained inventory management system that supports fleet maintenance. Both the airside and landside activities that make up ground handling services and operations are designed to service parked aircraft in the time gap between two future flights. These services also include the processing of passengers, their baggage, and cargo. The breadth of services that are offered may vary based on the airline as well as the airport that the airline flies to and from. Many different firms and parties, who are often engaged in the activities that are going on at the same time, can be the ones to carry out the ground handling chores. Aside from the operations of numerous businesses, aircraft handling may be impacted or even disrupted by a number of different parties. These parties include airport authorities, the provision of security services, board control, and even an airline itself. A major influence on ground handling operations may also be caused by airport operating, security, and safety protocols, in addition to the activities that various stakeholders complete on time. The performance of ground handling is also significantly influenced by the infrastructure in and of itself. It includes the arrangement of the ramps, the configuration of the luggage system, the size of the warehouses, and other aspects of the airport. During the turnaround operations, GSE has to be accessible and dependable at all times. Because of this, the primary goal of GSE maintenance is to provide the owner or user with safe and functional equipment that is also aesthetically pleasing, while incurring as little expenses as possible and experiencing as little downtime as possible. To prevent delays in ground handling and ensure compliance with rules that govern airport operations, maintenance programs that are launched on GSE must also comply to regulations. Because of this, the proper management of GSE maintenance has become an important problem with two distinct goals: to lower the operating costs of GSE and to avoid unforeseen breakdowns. The real maintenance system for aviation GSE is too sophisticated to be studied directly and, as a result, has to be structured. This is due to the large number of components that make up the system. The purpose of the study should determine the structure of the organization and the maintenance techniques, and the strategies should accurately depict the complexity and interdependence of phenomena that arise throughout the process of really operating the system. The Ground Support Equipment (GSE), technical people, technical operating means, plans and techniques of maintenance, and linkages between specific system components are all included in the technical maintenance subsystem. This subsystem is primarily responsible for ensuring the refueling of aircraft, as well as the delivery of electricity, gases, and consumable liquids to aircraft, as well as the operation of specific equipment, the inspection of the aircraft's technical state, preventative maintenance, repairs, and so on. A rise in the need for aircraft technical maintenance services is caused by the dynamic expansion of air transport overall, including both civilian and military aviation. Maintenance of this kind have to be carried out in a manner that is not only expertly done but also accomplished quickly and at a low cost. As a consequence of this, the GSE for the aircraft should be in adequate operational condition and have an adequate reserve of service life. In order to maximize the existing resources in a practical manner, standardize the processes to an optimal level while having a limited personnel, and overcome maintenance challenges while achieving the goals set for the project. The study is based on observation, record keepings, reviews, practical experience, tacit knowledge and documentations.

3.1 Flow Chart Representation of GSE Maintenance Methodology

A flowchart is a picture of the separate steps of a process in sequential order. It is a generic tool that can be adapted for a wide variety of purposes, and can be used to describe various processes, such as a manufacturing process, an administrative or service process, or a project plan or maintenance strategies.

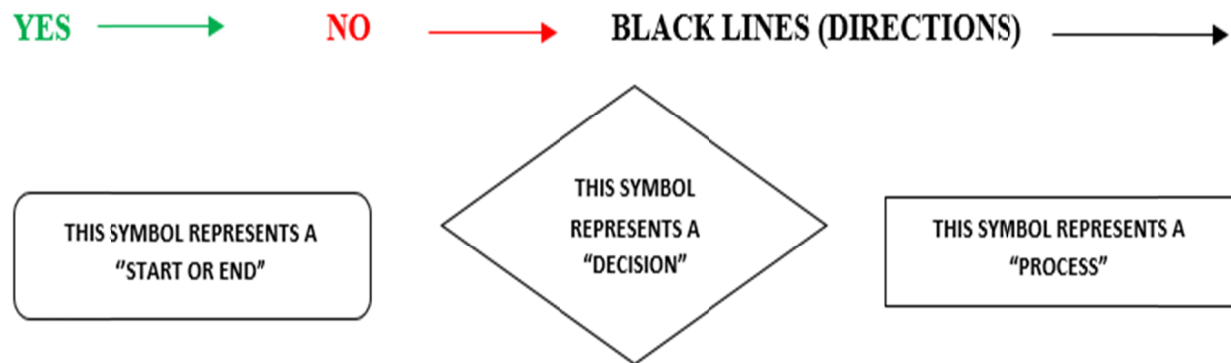


Figure 1. Symbols, Color Codes and Representation

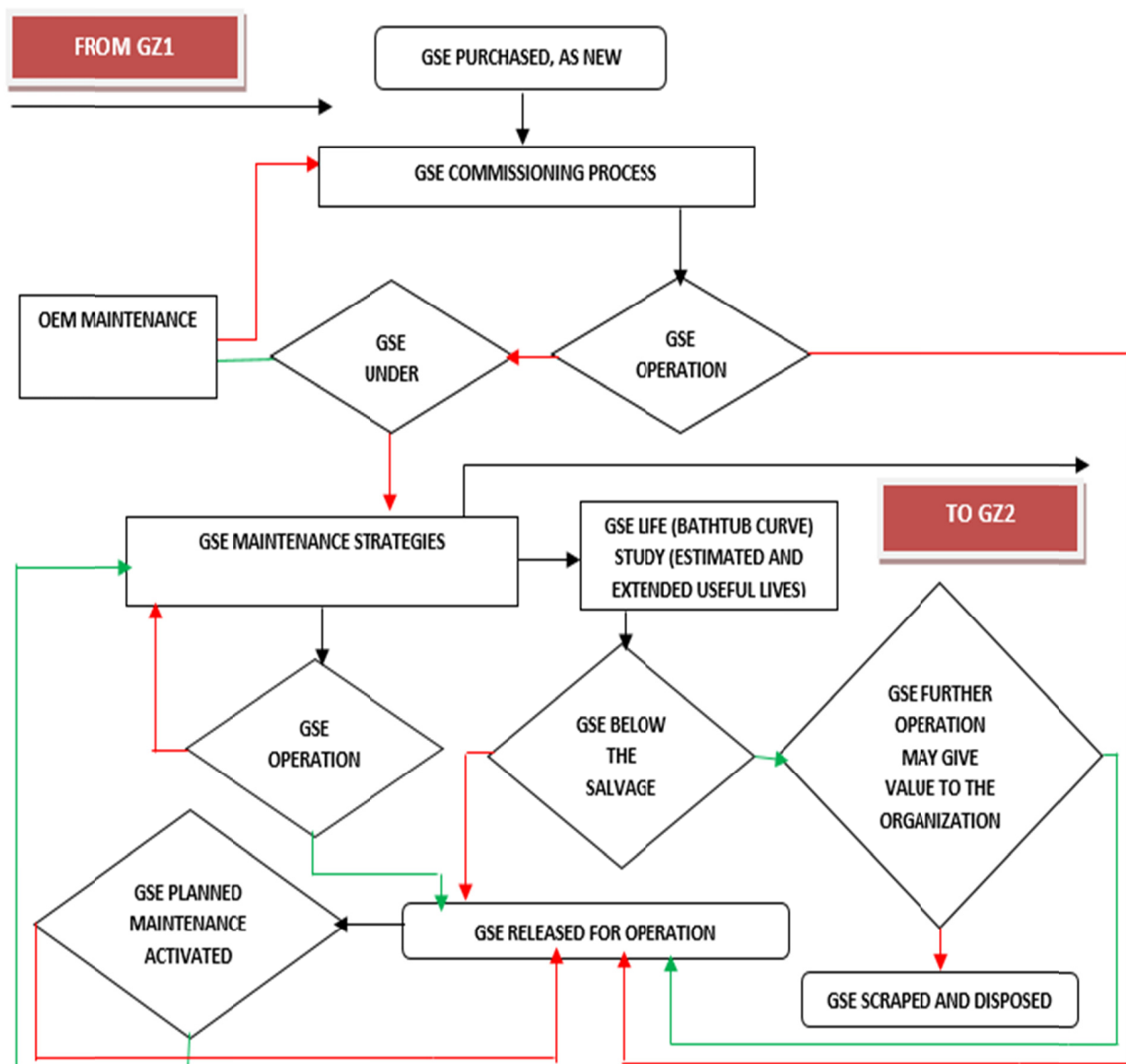


Figure 2. Flow Chart, GSE Purchasing Till Disposal

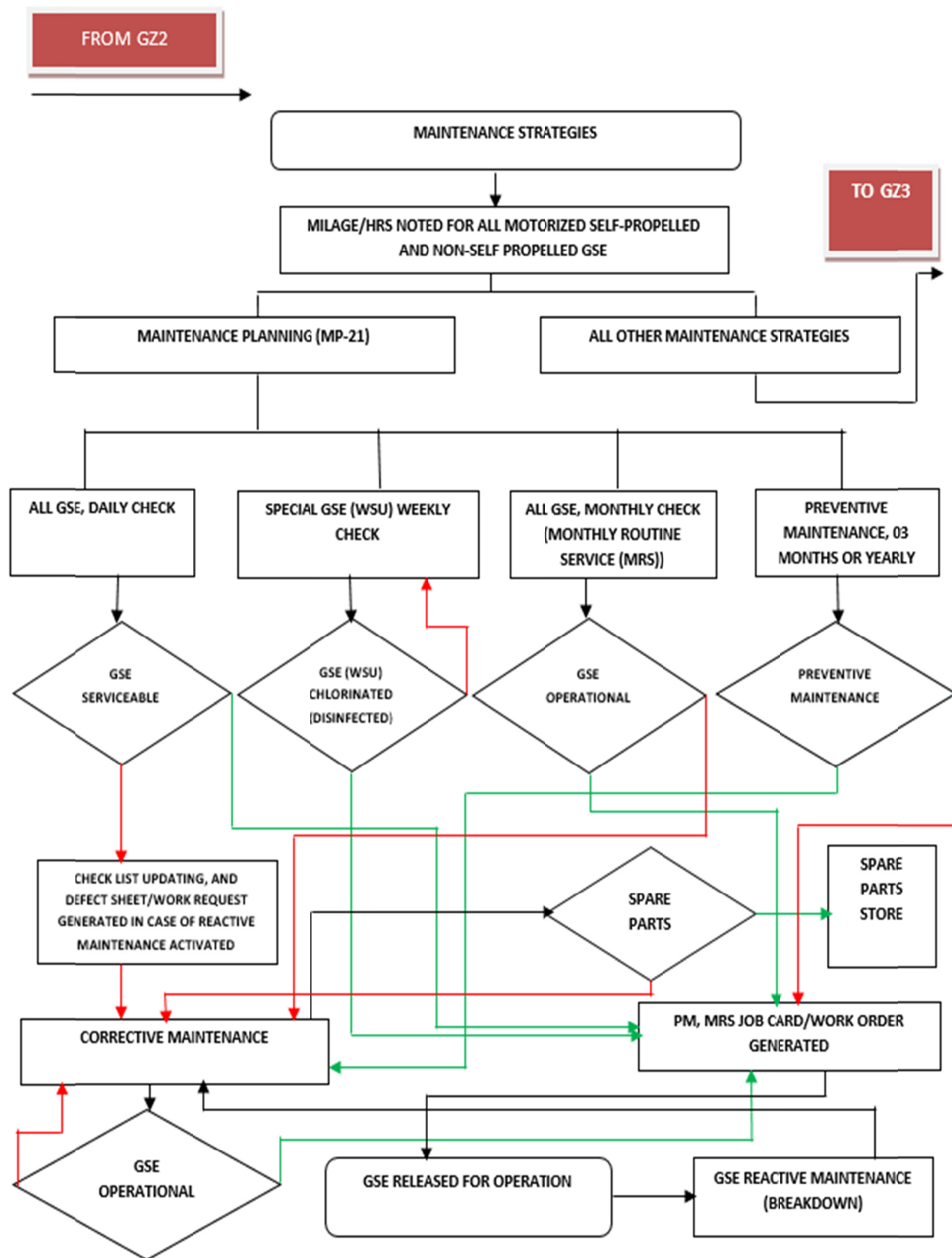


Figure 3. Flow Chart, GSE Maintenance Strategies

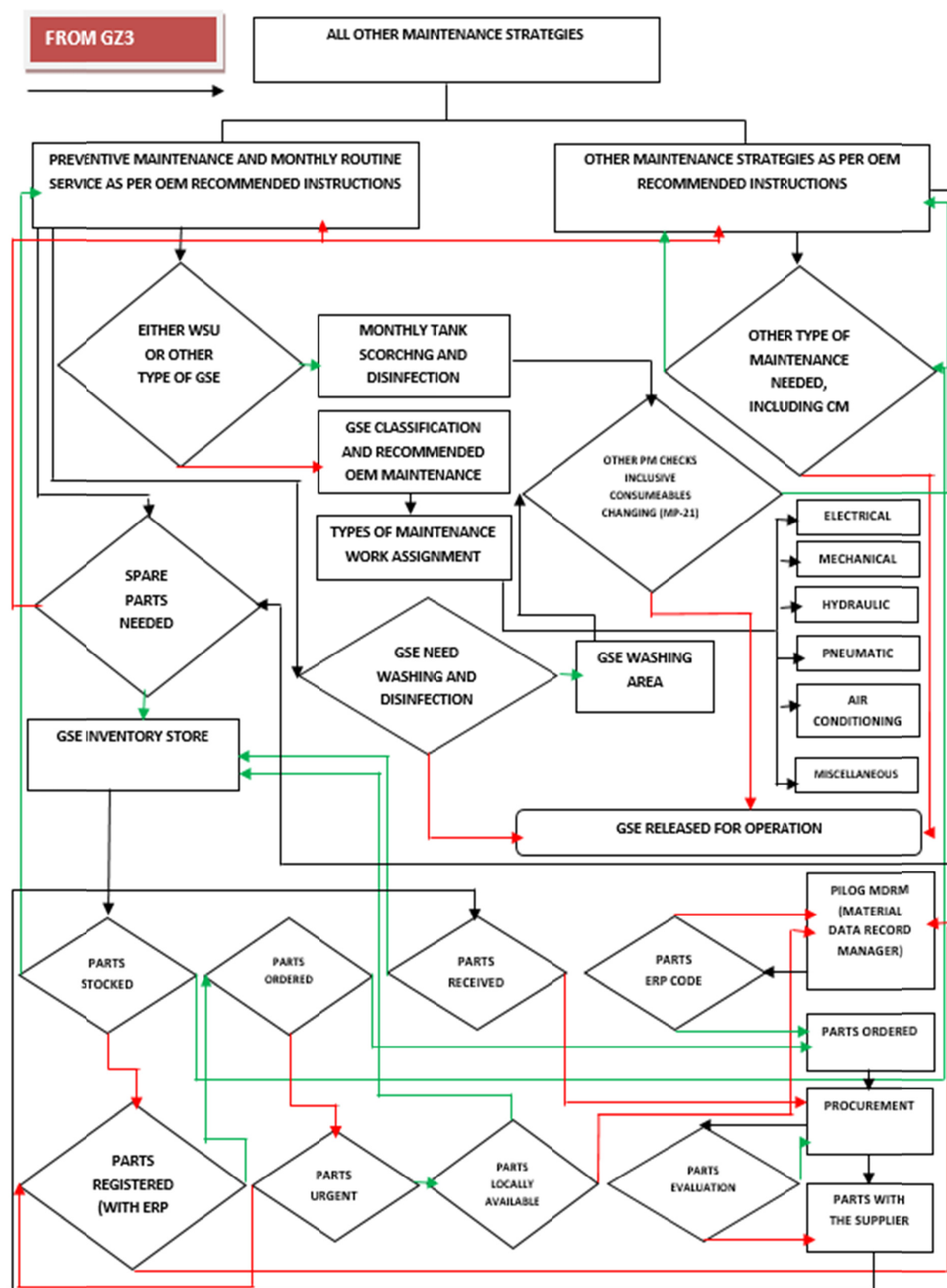


Figure 4. Flow Chart, GSE Maintenance Strategies

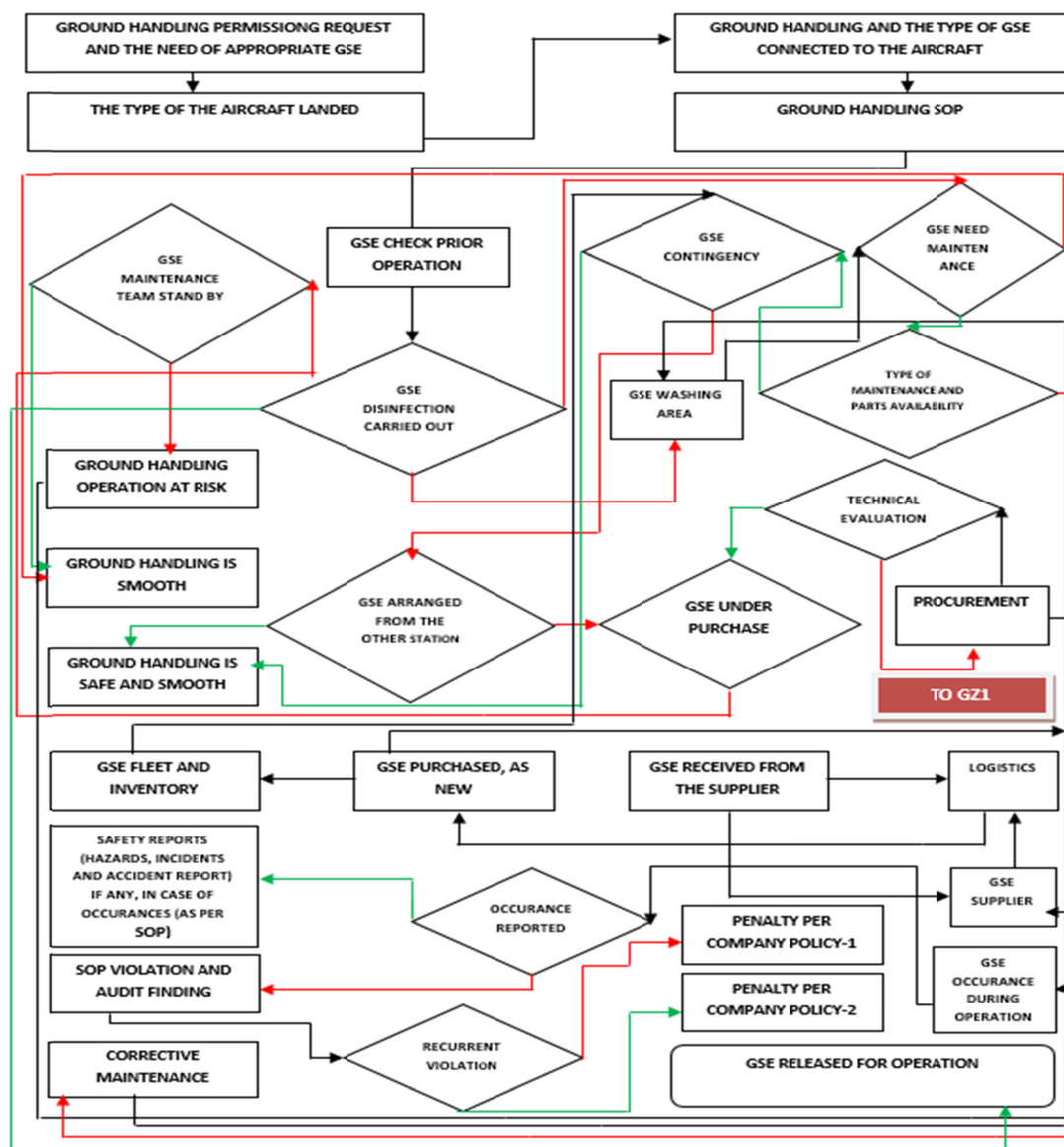


Figure 4. Flow Chart, GSE Engagement with the A/C and the Type of Maintenance Strategies

3.1.1 Flow Chart, GSE Purchasing Till Disposal

In this stage of the flow chart the GSE when purchased as new undergone commissioning processes post which released for operation with no issues in operational activities vice versa checked for warranty repairs. In case of no express terms contractual obligation warranty term or warranty expires the GSE incorporated with indoor maintenance strategies or in line with directions. During maintenance implications the life of GSE studied for useful life both for estimated and extended as undertaken and studied in excel file subject 6.0 GSE maintenance. In case of equipment life below the salvage and still giving value to the organization with safety measures considered with appropriate ROI to business, recommended to count for extension to useful life per in lined business directions and stayed on operation end vice versa scraped and disposed for tendering. Reactive maintenance activates when arrested fault while daily checks and undergone maintenance strategies else stayed on operation end standby.

3.1.2 Flow Chart, GSE Maintenance Strategies

Maintenance strategies in this stage of the study are subdivided into Maintenance planning MP-21 and All other Maintenance strategies. The appormentioned strategy is further elaborated in excel file subject 6.0 GSE maintenance for daily, weekly, monthly and yearly based maintenances and where logistic and parts inventory management involves as well. Pilog MDRM, ERP-I procurement, Procrurement, Logistics and Inventory assists

in contignet parts sourcing. For each type of work request/from EAM (Enterprise Asset Management) Workshop Module or manual job request/defect sheet there generates CM work order on EAM Workshop Module system or manual job card/in the form of PM or CM. Equipment post final check released for operation or vice versa re directed to maintenance in case of other defects suspected. Prior maintenance initiates, Milage/Hrs for each GSE taken to predict the the type of PM. During this stage of the flow, the type of services assigned to the maintenance personnels. Post work completion and prior release to operation, equipment washing and disinfection processed as well.

3.1.3 Flow Chart, GSE Engagement with the Aircraft and the Type of Maintenance Strategies

In this stage of the flow chart, while GSE connecting to the aircraft the operational team seeks the equipment physical appearance and inspection check based on the type of fleet requested in landing the aircraft from the concern business stakeholder. In case of equipment needed which is not part of the current fleet, shall be requested from othe stations avoiding business disruption or in case of equipment presence with defect, maintenanc personnel attended effectively with presence on stand bye vice versa ground handling could have been risked. Near misses and occurances reported with the level of risks or prior occurances as hazards avoiding safety violations.

4. Research Approach and Design

The technique of naturalistic inquiry known as qualitative research tries to gain an in-depth understanding of social phenomena by researching them in the context of their natural environment. It is based on the personal experiences of human individuals as meaning-making agents in their day-to-day lives and puts a focus on the "why" rather than the "what" of social happenings. The focus of qualitative research is on many research methodologies, and it utilizes an interpretative and naturalistic approach to the analysis of its subject matter. This shows that qualitative researchers look at things in their natural surroundings, attempting to make sense of occurrences by interpreting them in terms of the meanings that people bring to them, and examining these things as they occur in their natural habitats. In contrast to the more frequent quantitative approaches, qualitative research takes a distinct approach to the collection of data, the interpretation of those results, and the compilation of reports. The research that was conducted for this project is not limited to a particular machine or GSE; rather, it is intended for the entire fleet of corresponding GSE that is used in the aviation industry. It was thinking about fleet management, recommended maintenance strategies, inventory arrangement, and the impacts on reliability as conducted in this research. As a theoretical foundation, a generic data set is compiled from a number of secondary sources. This data set is based on experience. Quantitative research, is used to quantify the issue at hand by creating numerical data or data that can be turned into useable statistics. Qualitative research, is considered exploratory and is used to identify patterns in people's ideas and views. Qualitative research is used to uncover patterns in thoughts and opinions. Both that knowledge is more subjective than objective, and that the researcher must learn from the participants in order to grasp diverse concepts, are two of the most popular assumptions. Through qualitative research, new product idea generation and development, investigating current or potential product/service/brand positioning and marketing strategy, understanding the strengths and weaknesses of products and brands, and comprehending the dynamics of purchase decision making are all possible outcomes. Investigative research is what's meant by the term "qualitative research." This approach is often used in the process of comprehending viewpoints and perspectives. It provides prospective solutions to a variety of issues and assists in the formulation of ideas and hypotheses for future measurable research. The qualitative technique, which makes use of analysis to go further into circumstances, is helpful for aiding in the development of new ideas and individual points of view since it digs deeper into the topic at hand. For the purpose of data gathering, this approach makes use of a number of different unstructured or semi-structured activities, such as group discussions, individual interviews, diary and notebook exercises, and the involvement of others. It entails paying attention to a person's gestures, postures, and body language and analyzing this data in order to determine issues and provide potential solutions to those issues. For this reason, the qualitative theoretical framework was something considered in this study. The majority of the material is assured to come from genuine sources, original equipment manufacturer manuals, and daily analysis based on practical experience. Legislations exist in the aviation sector to process maintenances in accordance with approved instructions from the International Air Transportation Agency (IATA), and there are also safety audits for ground operations (ISAGO). All of these methods use a mostly qualitative and theoretical approach to data retrieval, with the only exception of prescribed manuals, and there is no room for modification in the area of maintenance from non-OEM sources. The primary goals that will be addressed by this project are safety, aviation security, ground handling, equipment characteristics, capabilities, performances, and maintenances. When we talk about anything being valid, we're referring to the quantity to which evidence and theory provision the competence and

suitability of deductions based on score interpretations. As an aviation GSE maintenance company, it is our responsibility to guarantee that all maintenance procedures are carried out in compliance with the ISAGO check list and the IATA regulations. Para 2.1 Ground Service Equipment Maintenance (ISAGO Checklist-Station, GOSM Edition-10 and updated Edition with references ORM 2.1.1, ORM 2.2.1, ORM 2.2.2, Additional Guidance (ORM 2.2.1).

5. Area of Academic Consideration

The term "airline" refers to a diverse group of companies that together make up the airline sector. These companies offer airborne transport facilities to paying customers or business partners. These air transportation facilities are given for both passengers and freight, and the vast majority of the time they are carried out by jets. Career opportunities in the airline business include those in piloting aircraft, working as flight attendants, and ground crew. There is a common misconception that the phrases "airline industry" and "aviation industry" are interchangeable; nevertheless, these two words really refer to distinct aspects of the same sector. As was previously said, the term "airline industry" is used to refer to firms that provide air transportation services to paying consumers, while the term "aviation industry" refers to all enterprises that are associated to aviation.

5.1 Aircraft Ground Handling

The word "aircraft ground handling" is a term that is used in the aviation business. This word refers to the many services performed on an aero plane while it is parked at an airport's terminal gate. Among these services are also: Cabin Service, Catering, Ramp Service, Passenger Service, Field Operation Service. The aviation sector is one of the most competitive and sophisticated businesses in the world. There is an enormously complicated ecology on the ground that allows people to travel pleasantly, securely, and on time in a way that permits them to coexist in a restricted area for many hours at a time. This ecology revolves on airports. In terms of size, complexity, amenities, and the ability to manage large volumes of passenger traffic, when compared to the first airports, today's airports have certainly come a long way. Every year, up to 90-100 million people travel through some of the world's busiest airports. As a result, a large number of planes are arriving and leaving from these airports every day, each carrying more than 100 people from a variety of origins. As the number of travelers rises, so do the airports' capacity needs. The comprehensive services provided by Ground Handlers are necessary for these physical infrastructures to function. Travelers' entire experience is greatly enhanced by the efforts of Ground Handlers.

5.2 Ground Support Equipment (GSE)

The phrase "GSE" is a term used in the aviation business to refer to the support equipment that can normally be located at an airport and is used to maintain aircraft in between flights. When the GSE is not being used, it is often stored on a ramp that is located close to the terminal for easy access. The primary function of Ground Support Equipment (GSE) is to ensure the continued smooth functioning of the aircraft both after it has landed and before it takes off again. The use of GSE often encompasses a wide range of aircraft mobility, ground power operations, cargo and passenger loading activities. Included in the ecosystem of the GSE market are important firms supplying sustainable aviation fuel, private and small enterprises, technology providers, distributors/suppliers, and end users (airlines and airports). Significantly influencing the GSE market include investors, financiers, academic researchers, distributors, service providers, and airport and aerodrome authorities. Electric automobiles are a respite from mounting pollution and are better for the environment. according to study. Petrol or diesel-powered vehicles release hazardous emissions like carbon.

5.3 Ground Support Equipment Classifications

Table 1. Ground Support Equipment Classifications

By point of sale	By platform	By type	By power sources	By mode of operation
Equipment	Commercial	Mobile	Non-Powered GSE	Conventional/Manned GSE
			Powered GSE	Remotely operated GSE
			Non-Electric GSE	Autonomous GSE
Maintenance services	Military	Fixed	Electric GSE	Self-Propelled GSE (Motorized GSE)
			Hybrid	Non-Self Propelled GSE (Non-Motorized GSE)

6. Ground Support Equipment (GSE) Maintenance

Throughout the course of a piece of GSE's life cycle, maintenance encompasses all of the technical, administrative, and managerial tasks that need to be completed. The most effective way to avoid chaos at the airport is to take preventative measures to ensure that its facilities do not experience a breakdown of their equipment. There are two fundamental categories of maintenance. The first is preventative maintenance and the second is corrective or reactive maintenance (maintenance after failure). At regular periods, preventive maintenance is conducted. Preventive maintenance is carried out by replacing old and worn-out components and lubricating or cleaning them. In this instance, the maintenance or operations management unit of airports or other competent centers organize these actions. Monitoring the equipment's features, characteristics, and parameters at the airport is the foundation for preventive maintenance based on the device's technical state. The monitoring of these functions is either predetermined or continuous. No longer are the human senses of sight, hearing, touch, and smell adequate. Corrective (reactive) maintenance is maintenance that tries to fix equipment and machinery as quickly as possible in the event of failure. It is tasked with restoring equipment from a failing condition, modifying or replacing broken machine components at the airport. Unscheduled maintenance performed in the event of equipment breakdown. Subsequently, the maintenance is separated into urgent and delayed maintenance. Immediate maintenance is undertaken as soon as defects are discovered. Maintenance is a specialist activity that tries to enhance the technical aspects of a device and to improve or preserve the original characteristics of airport infrastructure. Maintenance is utilized to enhance the time and energy efficiency of airport machinery and equipment. When doing maintenance, it is essential to consider the health and safety of operation as well as environmental protection. Maintenance management is a procedure that requires the administration of all administrative and technical tasks associated with airport facilities over their entire life cycle. The objective of maintenance management is to restore the state of the equipment so that it can continue to fulfill its tasks at the airport at the lower most possible price and with the upper most probable quality and safety principles. Emergency maintenance is a kind of corrective maintenance that is performed after a problem has occurred. Since GSE maintenance and its significance have been reviewed, Original Equipment Manufacturer (OEM) maintenance consumables guidelines have been recovered in accordance with daily, weekly, monthly, and annual maintenance services. Once upon a time, each piece of equipment required a monthly routine inspection, which consisted only of predictive maintenance tests. Now, most GSEs are directed to do preventive maintenance every three months. All of these checks are in addition to daily inspections, which often result in a remedial action plan or predictive services in the event of discoveries. All of these facts are tabulated in the Excel File. For details please Click here



Excel Sheet:

(1) List, GSE

It is the list of all types of GSE and vehicles which are planned for Maintenance strategies in next stage of excel sheet-2

(2) Maint. Strategies, MP-21

In this sheet all types of maintenance strategies based on weekly, monthly and yearly basis incorporated depending on the kind of GSE and vehicles. Below are color codes justifying various kinds of planning depending on the kind of equipment from excel sheet 1.

Table 2. Color Codes showing type of maintenance strategies for GSE for the whole year.

COLOR CODES												
	Indicates MRS.		Indicates PM.		Indicates MRS for WSUs (Including tank scorching and water chlorination)		Indicates Weekly Water chlorination for WSUs		Indicates both PM and MRS for WSUs.	Indicates, the equipment is recommended scraped.	Indicates MRS checks for W/S heavy machinery.	Indicates OFF days (Friday & Saturday)

(3) Inventory for Consumables

A list of details generated for a year at least per recommended instructions from OEM, depending on the kind of equipment from excel sheet 1, forecasted consumption, and type of consumable.

(4) GSE Consumables Benchmarking

It is the list of all types of consumables for each kind of GSE in line with directions from OEM considering various types of maintenance strategies from excel sheet 2.

(5) Graphical Representation-05-36

This sheet Introduced a useful life in terms of estimated and extended useful life for a kind of GSE called Passenger step coded 05-36. Mileage/ Hours and Time both factors considered for each type of aforementioned life study in context to consumable used and business ROI in account from year 1994-2009 as estimated and 2009-2022 the extended useful life. The output extended to excel sheet 6 the next below.

(6) Graph. Representation Summary-1

This sheet explains graphical representation of useful lives for both ideal and real situation of a GSE/05-36 from previous sheet 5 as ROI considerations.

(7) Graph. Representation Summary-2/ Tabular Representation

This sheet further elaborates tabular representation into graphical representation of useful lives for both ideal and real situation of a GSE/05-36 from previous sheet 5 and 6 as ROI considerations and comparison of both ideal and real situations for estimated and extended useful lives.

(8) Planned Maint. Graph Representation

In this sheet, a planned maintenance from excel sheet2 is tabulated and elaborated graphically representing more viable understanding in failure conditions and burden over next months. This burden is shown with a loss in health safety violations on maintenance personnel overhead business losses including direct labor losses as paid overtimes in extra, operational delays maintenance imbalance and disruption. Failure in next month or reserve days of the month might cause reflection on audits findings and observations from external stakeholders and business partners.

(9) CM Performance Tables-V1

In this sheet of the excel file, Corrective maintenance have been tabulated for the ideal GSE estimated useful life of 15 years. A performance criteria for maintenance in down time and rating have been identified considering parts inventory as well. Performance criteria set have been consolidated with years per 260 working days for the estimated life of 15 years.

(10) CM Performance Graphs-V1

Previous from sheet 9, the tabulated data have been graphed in this sheet of the excel file.

(11) CM Performance Tables-V2

In this sheet of the excel file, the real estimated life of a GSE has been studied and tabulated, considering corrective maintenance in account only. Performance and occurrence criteria remained the same as per ideal.

(12) CM Performance Graphs-V2

Previous from sheet 11, the tabulated data have been graphed in this sheet of the excel file.

(13) CM & PM Performance Tables-V3

In this sheet of the excel file, since estimated life of 15 years with corrective maintenance is embedded with preventive maintenance strategies as well, so the life of the estimated time frame of 15 years extended for the next 13 year of extended life. The corrective maintenance remained the same as for sheet 11, but rather incorporated with the preventive maintenance strategies as well. This way the reactive occurrences of failures reduced in the estimated useful life and health of the machine extended for next 13 years ensured performance rating and business ROI.

(14) CM & PM Performance Graphs-V3

Previous from sheet 13, the tabulated data have been graphed in this sheet of the excel file.

(15) Comp Tables of Maint Strat

In this final sheet of the excel file, the comparison of the real cases of GSE is studied and tabulated considering corrective maintenances for estimated and extended useful lives for with and without preventive maintenance strategies

(16) Comp Graphs of Maint Strat

Previous from sheet 15, the tabulated data have been graphed in this sheet of the excel file.

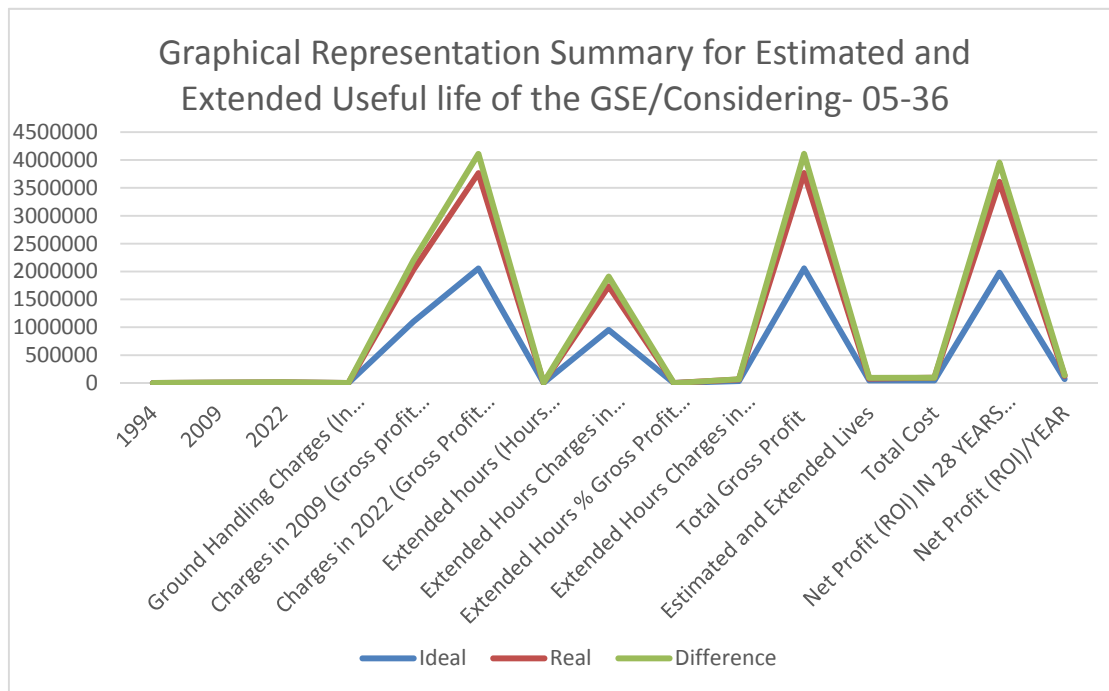


Figure 5. Graphical Representations of the Estimated and Extended Useful Lives of a GSE Named 05-36

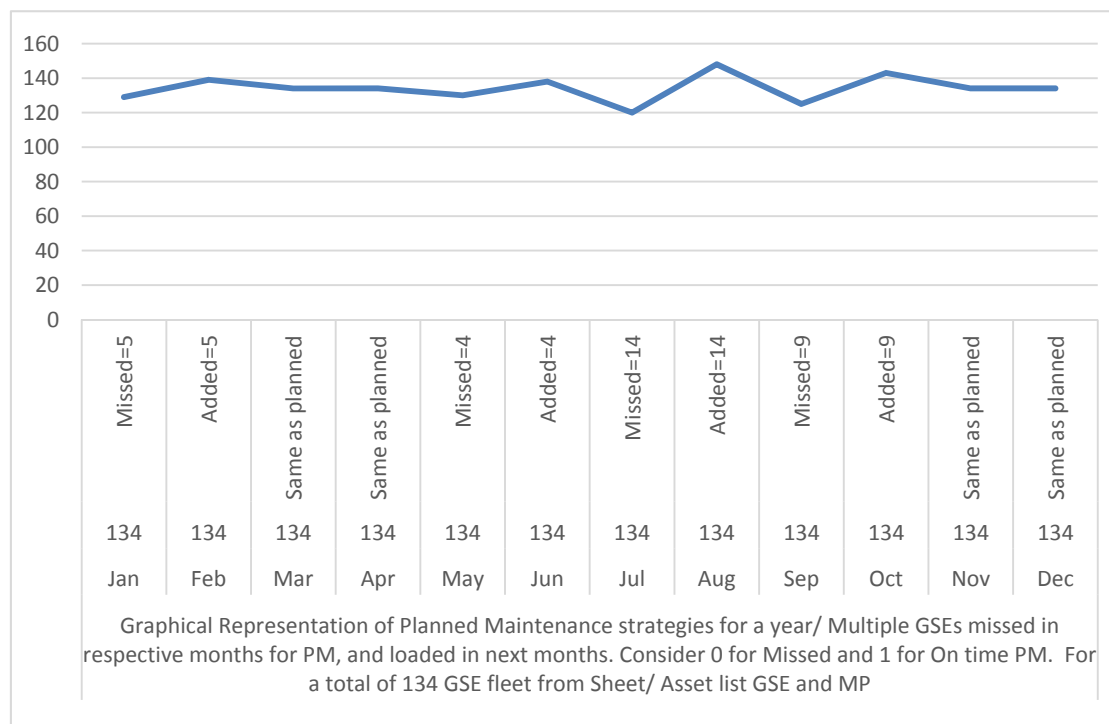


Figure 6. Graphical Representations of the Planned Maintenance Strategies

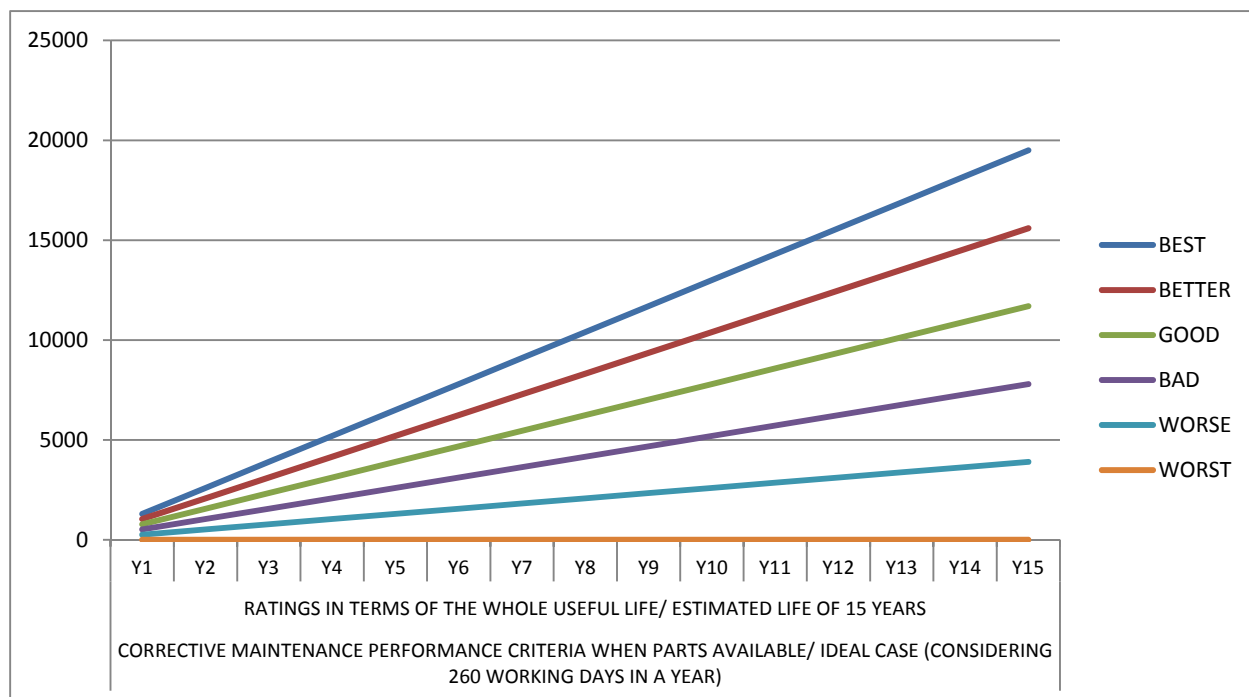


Figure 7a. Graphical Representation of an Ideal GSE with Corrective Maintenance Performance only, Considering Parts Inventory

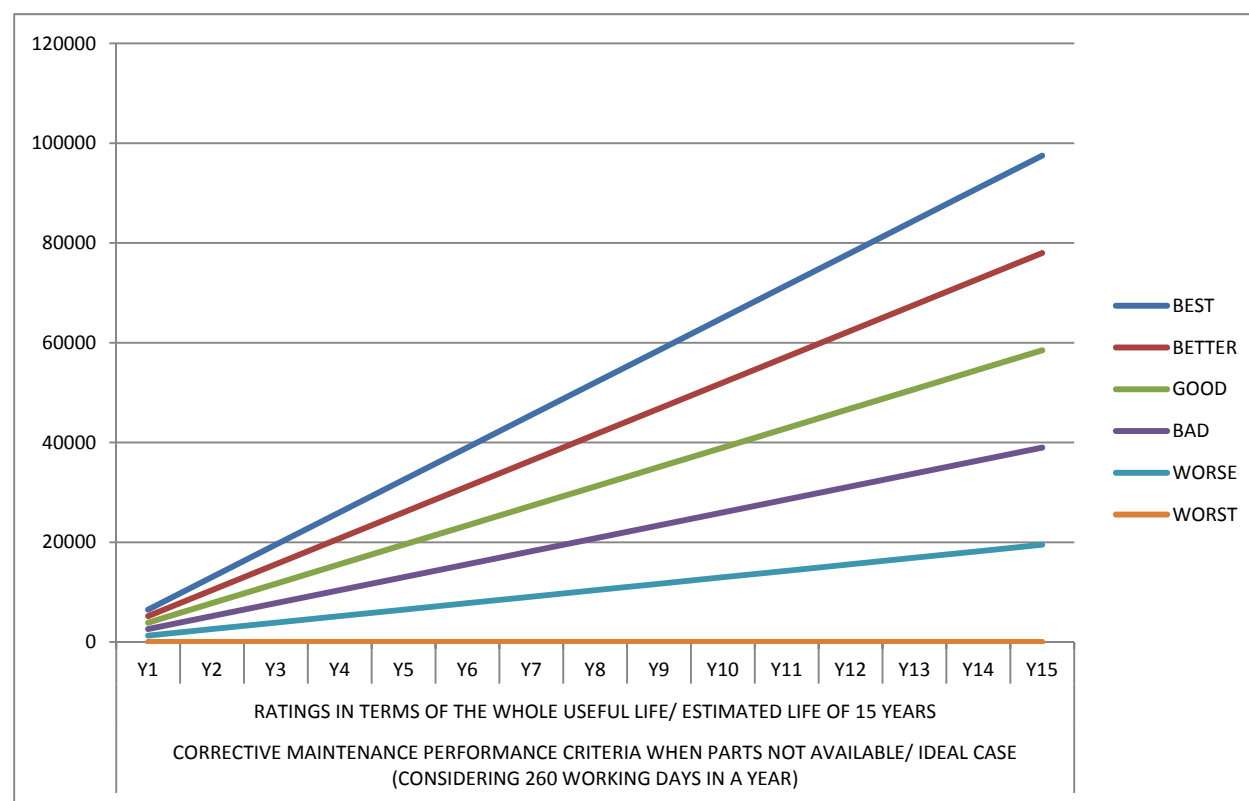


Figure 7b. Graphical Representation of an Ideal GSE with Corrective Maintenance Performance only, Considering Parts Inventory

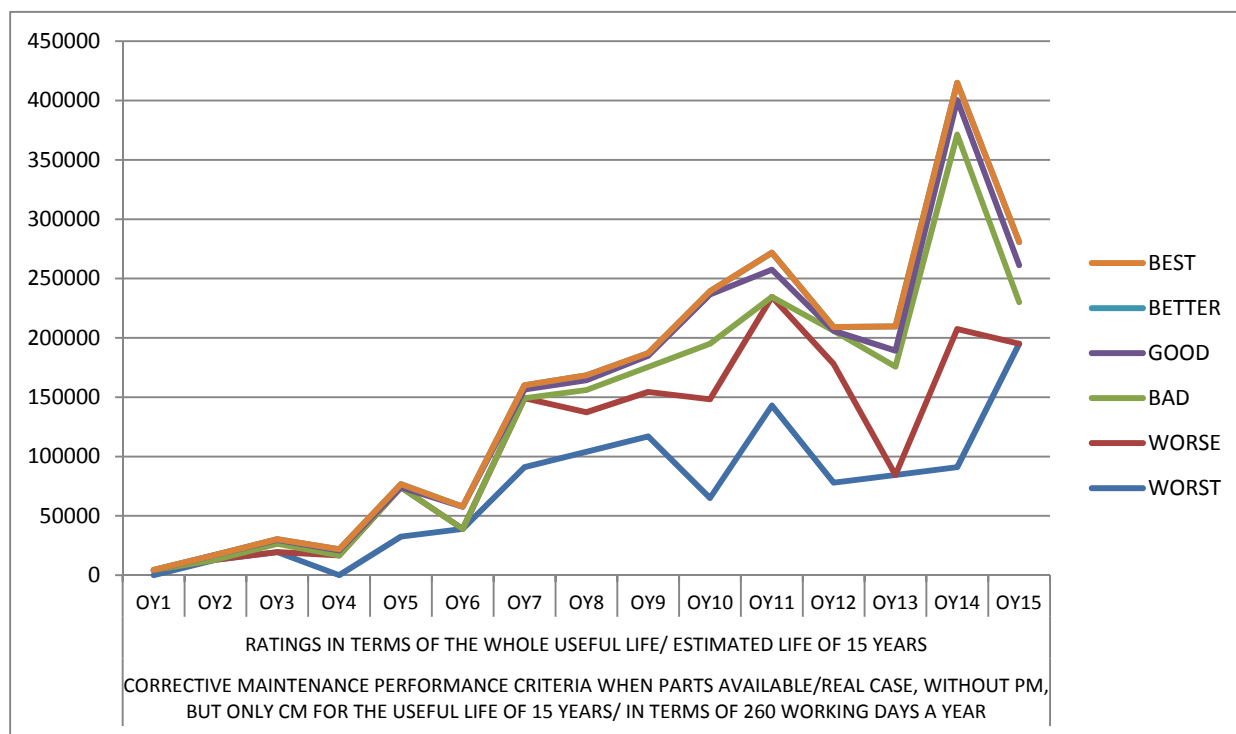


Figure 8b. Graphical Representation of a real GSE/05-36 with Corrective Maintenance Performance only, Considering Parts Inventory

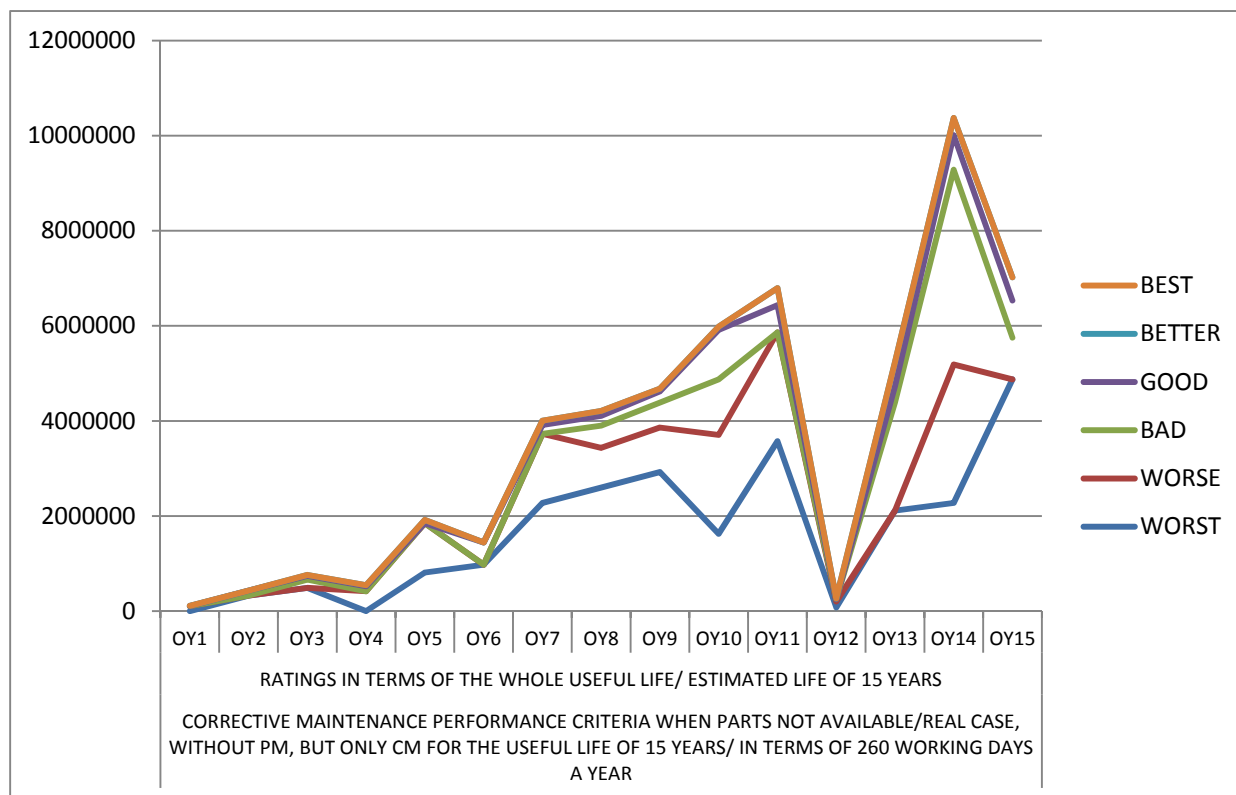


Figure 8b. Graphical Representation of a real GSE/05-36 with Corrective Maintenance Performance only, Considering Parts Inventory

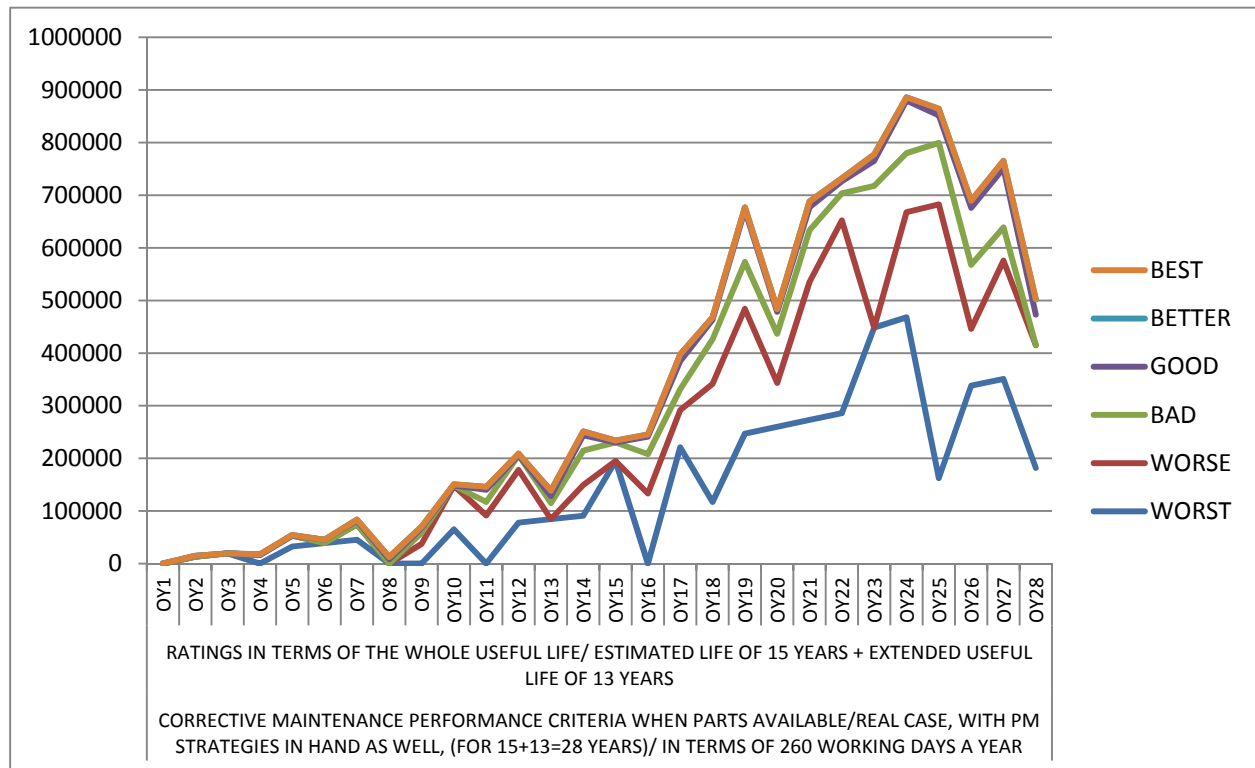


Figure 9a. Graphical Representation of a real GSE/05-36 with Corrective Maintenance Performance and Preventive Maintenance Strategies both, Considering Parts Inventory

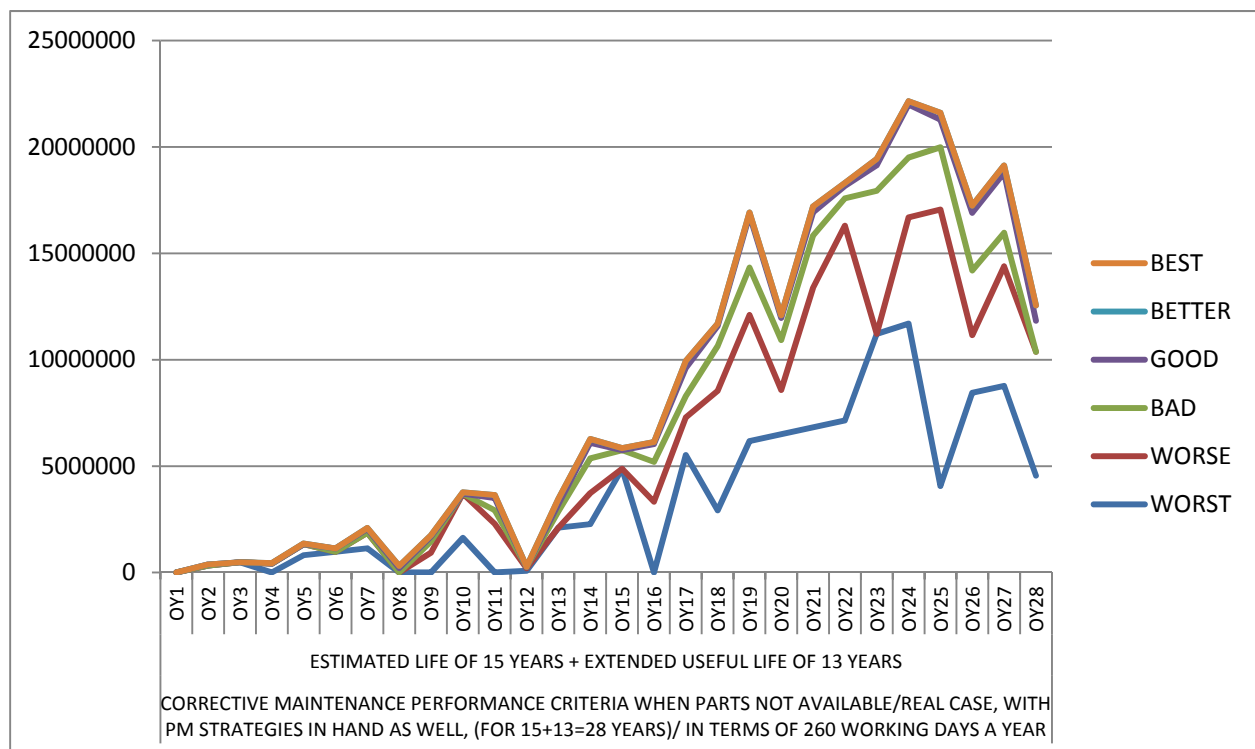


Figure 9b. Graphical Representation of a real GSE/05-36 with Corrective Maintenance Performance and Preventive Maintenance Strategies both, Considering Parts Inventory

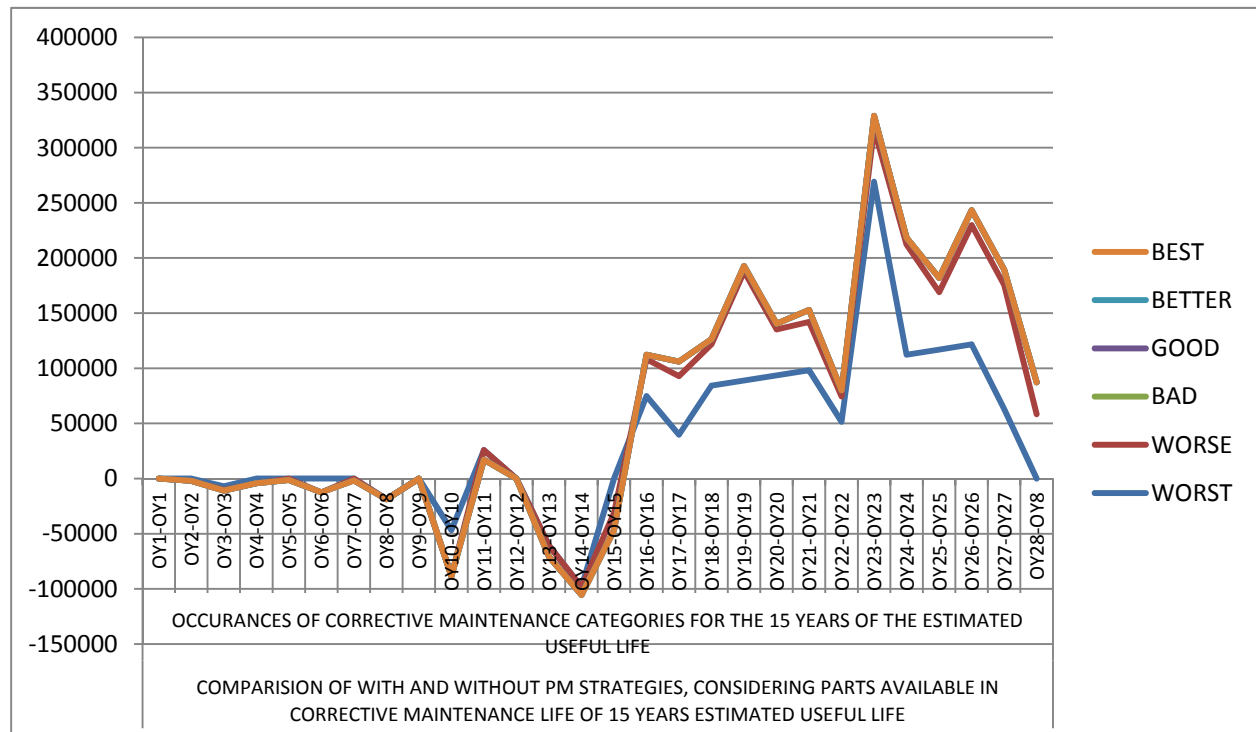


Figure 10ba. Comparative Graphical Representation and of a real GSE/05-36 with Corrective Maintenance Performance and Preventive Maintenance Strategies both, Considering Parts Inventory

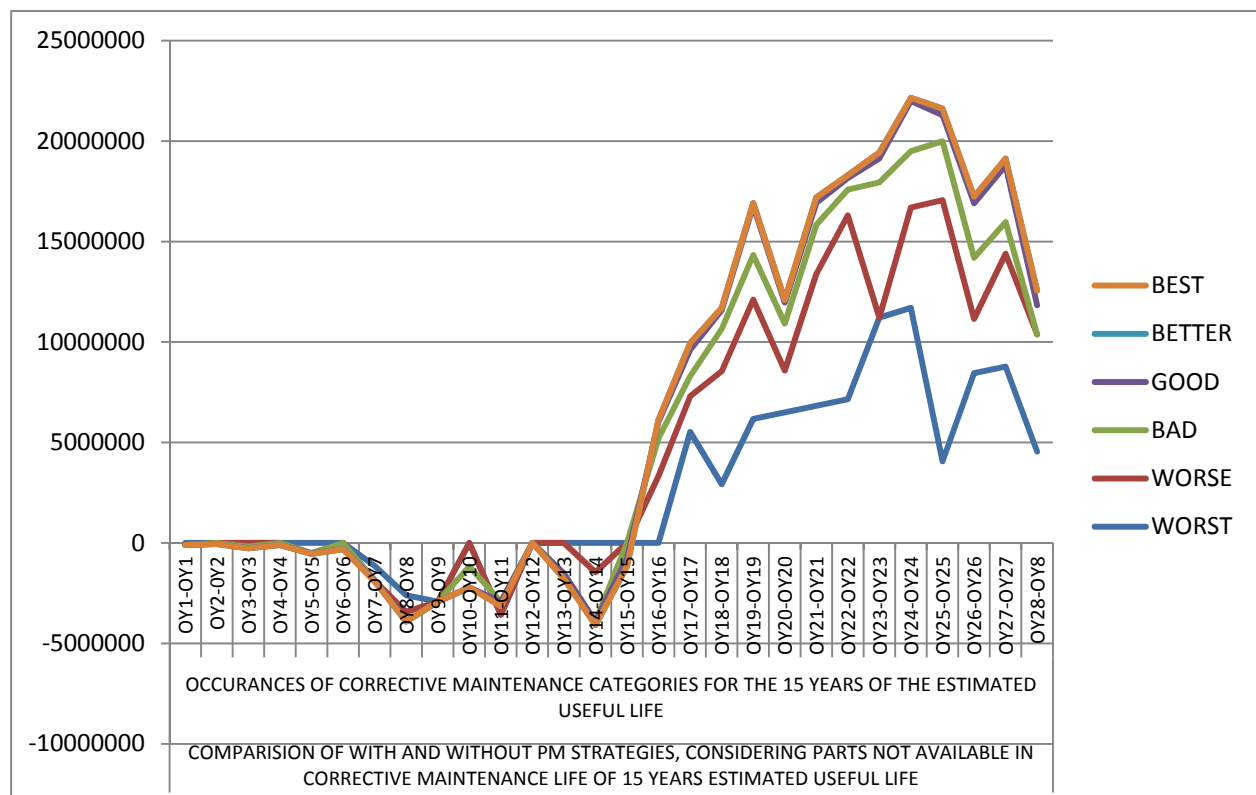


Figure 10b. Comparative Graphical Representation and of a real GSE/05-36 with Corrective Maintenance Performance and Preventive Maintenance Strategies both, Considering Parts Inventory

Table 3. Graphical Representations of the Planned Maintenance Strategies

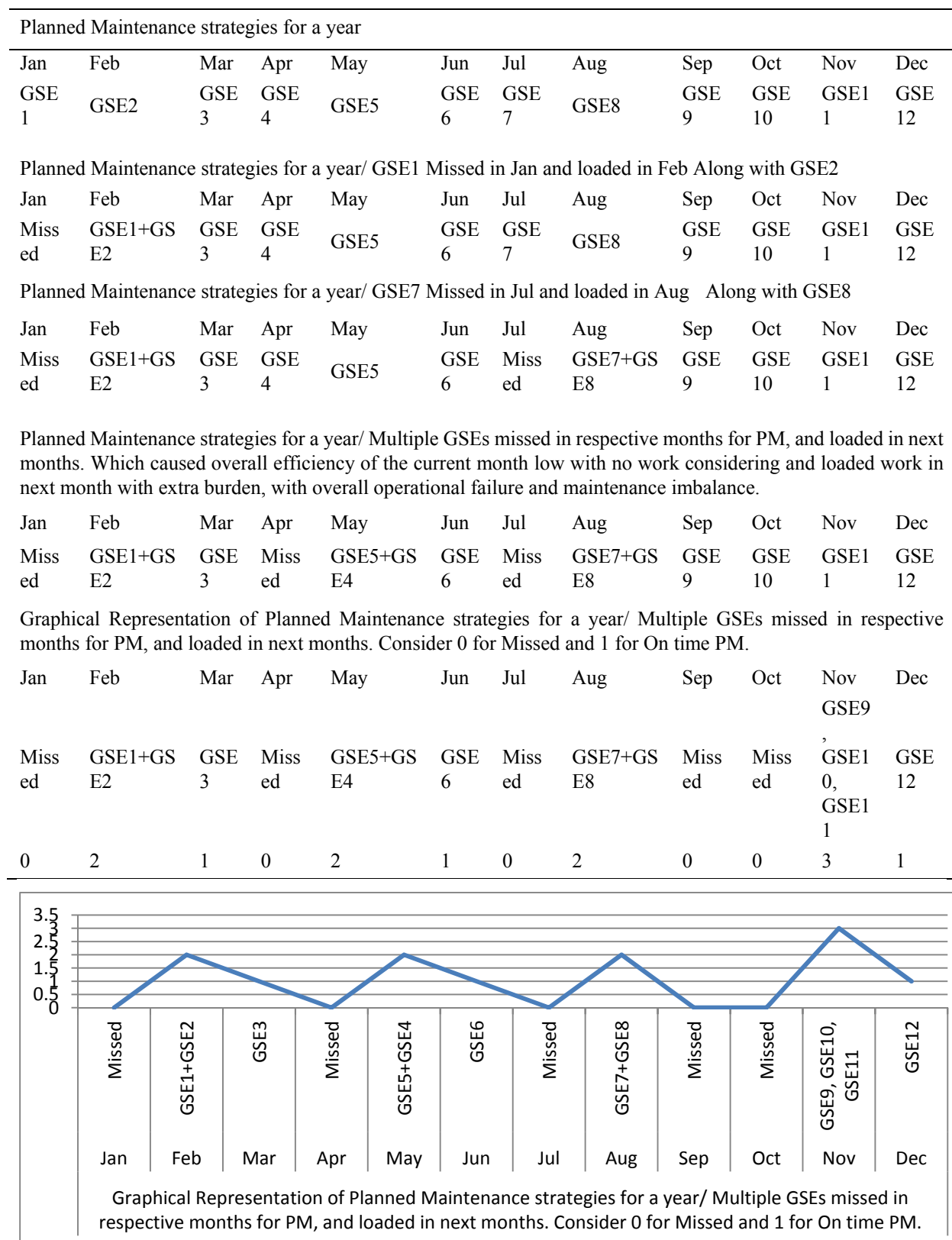


Figure 11a. Graphical Representation of Planned Maintenance strategies for a year

Table 4. Planned Maintenance strategies for a year/ From Sheet/ Asset list and MP-21

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
134	134	134	134	134	134	134	134	134	134	134	134

Graphical Representation of Planned Maintenance strategies for a year/ Multiple GSEs missed in respective months for PM, and loaded in next months. Consider 0 for Missed and 1 for On time PM. For a total of 134 GSE fleet from Sheet/ Asset list GSE and MP-21

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
134	134	134	134	134	134	134	134	134	134	134	134

Missed=5	Added=5	Same as planned	Same as planned	Missed=4	Added=4	Missed=14	Added=14	Missed=9	Added=9	Same as planned	Same as planned
129	139	134	134	130	138	120	148	125	143	134	134
5	-5	0	0	4	-4	14	-14	9	-9	0	0

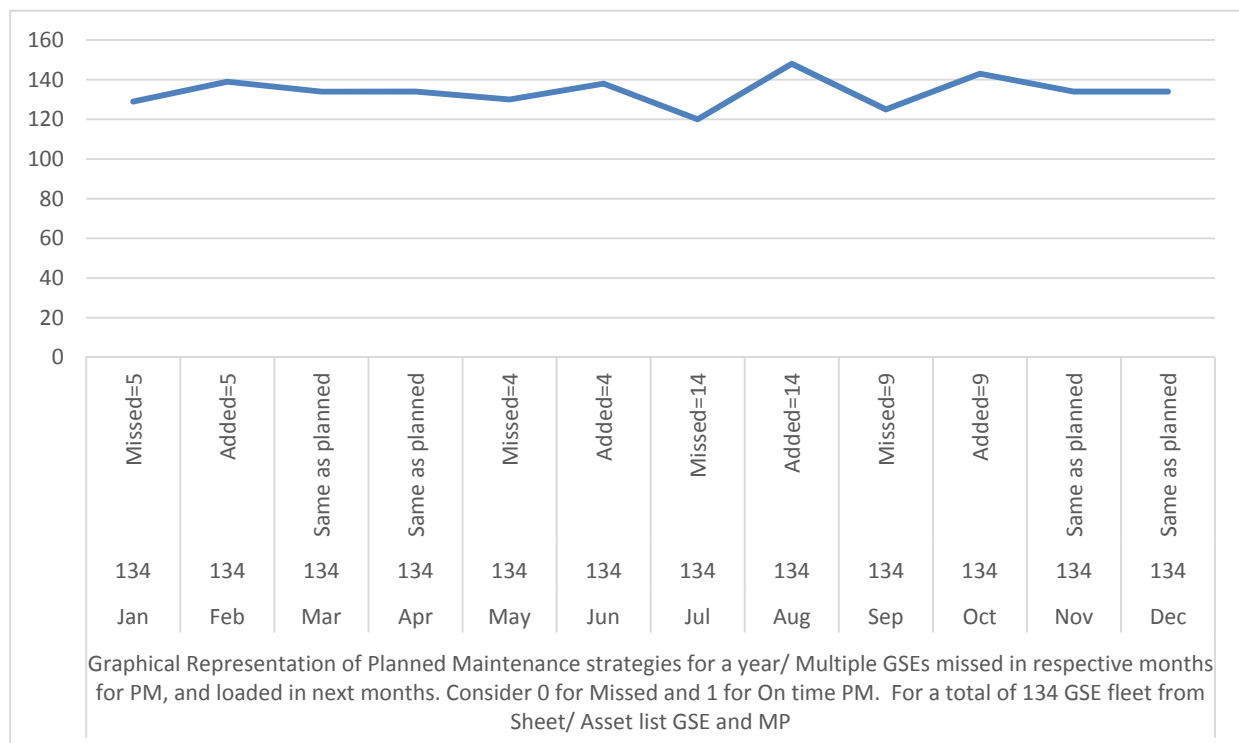


Figure 11b. Graphical Representation of Planned Maintenance strategies for a year

6.1 GSE Maintenance and real Time Tracking

The use of a GPS tracking device is becoming more popular as a method to get real-time information on the location of vehicles. A GPS tracking system that uses product hardware, open source software, and an easy-to-manage operator interface that can be retrieved over a Web server with Google Map or via software that is compatible with Google Earth. In order to acquire a position and send messages, the system is equipped with a GPS/GPRS module, as well as an 8-bit AVR microprocessor, an MMC memory card, and a temporary storage area for location information.

6.2 GSE Safety, Maintenance and the Types of Standards (ISO, IATA, SAE & EN)

Standards are internationally agreed by experts. Think of them as a formula that describes the best way of doing something. It could be about making a product, managing a process, delivering a service or supplying materials standards cover a huge range of activities. "IATA" rules are founded on the proposals that are enacted by regulatory bodies such as "ICAO" and the standards that are developed by industry working groups that are inhabited by member airline delegates and relevant industry organizations that operate in conjunction with IATA. "SAE" International is a globally active professional association & standards organization for engineering professionals in various industries. Their main focus is on the transport industries: automotive, commercial vehicles, and aerospace. European Standards (abbreviated EN, from the German name Europäische Norm ("European Norm")) are technical standards drafted and maintained by CEN (European Committee for Standardization), CENELEC (European Committee for Electro technical Standardization) and ETSI (European Telecommunications Standards Institute).

6.3 Asset Management and Maintenance KPIS

The process of growing one's total capital over the passage of time via the process of buying, monitoring, and trading assets that have the potential to increase in value is referred to as asset management. Standard ISO 55000 is an international regulation. Asset management, This International Standard is applicable to any and all kinds of assets, as well as any and all kinds of organizations of any and every size. An asset is any object, thing, or entity that has prospective or actual value to an organization. Assets may be physical or intangible, financial or non-financial; they can also be any combination of these. A collection of assets that have certain features that help to identify them as belonging to a certain group or class.

Salvage Value Formula

Salvage Value = Buying Value – (Yearly Depreciation × total year)

Salvage value or Scrap Assessment is the expected worth of an asset afterward its valuable lifespan is finished and therefore, cannot be utilized for the purpose for which it was intended. For example, if the GSE of a firm has a lifespan of 1 decade and at the end of 10 years, it's worth is only \$5000, then \$5000 is the salvage value. The worth of this item is also known as the scrap value. And keep in mind that this is merely a rough approximation. Nobody has any idea how much a piece of equipment or machinery will be worth once ten years have passed. It's possible that the item in question will wind up in a scrap yard as well. There are numerous procedures of devaluation spending and formulae for calculating the book worth of an asset. The most prevalent depreciation techniques include:

- (1) Straight-line
- (2) Dual declining balance
- (3) Components of manufacture
- (4) Sum of years digits

Accounting uses depreciation expenditure to disperse the cost of a physical item over its useful life. In other terms, depreciation is the loss in value of an item over time due to use, wear and tear, or obsolescence.

KPI = Key Performance Indicator

Leading and Lagging Indicators

A leading indicator anticipates future results and occurrences. A trailing indicator evaluates whether the desired outcome was attained in retrospect. Imagine you are driving a vehicle. Leading indicators observe the road ahead via the windshield. Through the rear glass, lagging indicators see the path you have previously travelled. Key performance indicators (KPIs) and key success factors (CSFs) are often misinterpreted due to their close relationship. The primary distinction between a KPI and a CSF is that KPIs represent the amount of achievement,

but CSFs identify the reasons behind success. CSFs are the reason for your achievement, whereas KPIs are the result of your activities.

KPIs monitor performance according to predetermined key success criteria.

KPIs are closely related to the company's overall objectives. Corporate, regional, and site levels set Business Objectives. These objectives identify the important actions (Basic Achievement Features) that need to be performed meritoriously for a certain procedure to be successful.

7. Impacts of Maintenance Strategies on Reliability

Reliability is the chance that a component (or a whole system) will fulfill its function for a specific amount of time in its design environment. Improved equipment dependability may decrease maintenance costs, eliminate opportunity costs associated with downtime, and guarantee that goods do not exceed allowable specifications. Historically, maintenance has consisted of a one-to-one, technical interaction with equipment in which something is repaired as it breaks. The difference between Reliability and Maintenance is that Reliability culture comprises everything equipment interacts with: technology, culture, design, and maintenance strategy. The purpose of maintenance and dependability is to preserve the system's functionality. Systems must be created and maintained to meet quality and performance expectations. Probability that a machine component or product will perform correctly for a specific period of time under defined circumstances. Maintenance is one method for maintaining or, if required, enhancing the degree of dependability of components and systems. Other alternatives involve raising system capacity, bolstering redundancy, and using more trustworthy components. The objective of maintenance is to prolong the lifespan of equipment, or at least the mean time before the next expensive breakdown. In addition, it is anticipated that good maintenance practices would minimize the frequency of service outages and the many negative repercussions associated with them. Maintenance has a clear impact on component and system reliability; if insufficient maintenance is performed, this may result in an excessive number of costly failures and poor system performance, thereby degrading reliability; if maintenance is performed frequently, system functionality may expand, but maintenance costs will surge dramatically. In a plan that maximizes efficiency, the two expenses must be balanced.

8. Remaining Work and Challenges

The continued use of traditional diesel GSE at airports has become a significant obstacle as a direct consequence of the implementation of electric GSE at these facilities. Electric GSE has to be charged on a regular basis. But the power grids that airports use to get electricity aren't big enough to charge all the different kinds of GSE. Doing so often causes the power grid to get too full. A study done in 2017 by MDPI Applied Sciences found that the use of large nonlinear loads like ground power units, PCA systems, and computer equipment, as well as the increased use of plug-in electric vehicle (PEV) chargers, could cause problems with power quality, delivery, and consumption at airports. This is because distribution transformers and switchgear systems could be overloaded. Appropriate maintenance personnel in accordance with the directions of GSE maintenance in accordance with the rules and instructions that are suggested, Electrified GSE change and labor resources, for example inclusive inventory management, international commerce, and delivery lead times, Electrified GSE a lack of trainings on both the operating side and the maintenance side from original equipment manufacturers that are in accordance with equipment performance and Absence of organizational and hierarchical management procedures, as well as failure to define genuine job descriptions and goals in accordance with specific requirements. Also needs to implement maintenance technology solutions to enable new processes such as predictive maintenance, and artificial intelligence introducing greater strategic benefits, and block chain technologies generating auto requests on maintenance and inventory set, those are a set of challenges which, ideally, should be rectified in advance GSE maintenance.

9. Conclusions

The airline sector covers a vast array of companies that provide air transportation services to paying consumers or business partners. In truth, the phrases 'airline industry' and 'aviation industry' have distinct meanings, despite popular misconceptions to the contrary. GSE is a phrase used in the aviation industry to describe the support equipment commonly located at airports and used to maintain aircraft between flights. When not in use, GSE is often stored on a nearby ramp for easy accessibility. The primary objective of GSE maintenance is to provide the owner/user with safe, serviceable, aesthetically pleasing equipment at the lowest possible cost and with the least amount of downtime. Initiated GSE maintenance plans must also comply with standards governing airport operations. According this research, there should be a comprehensive maintenance management programme for each type of GSE, in accordance with OEM recommendations, along with an excellent inventory management system, significant bathtub curves of equipment, and the necessary personnel to overcome fleet maintenance.

Using OEM-recommended guidelines and established monthly regular servicing and inspection rules enabled Munawala Ground Service to get ISAGO IATA accreditation, therefore validating its world-class maintenance methods. A significant portion of the difficulties in filling maintenance roles is attributable to the talent pool's lack of requisite knowledge, abilities, and experience. Need to address these difficulties by employing the appropriate staff and providing extensive, continuous training to grow knowledge to the levels expected by top industrial facilities. Every staff must follow proper maintenance procedures. For this reason, technicians were required to attend OEM-recommended training sessions. Safety and maintenance go hand in hand. Unfilled maintenance jobs or incompetent employees pose safety issues that must be addressed. As a result of the dearth of technical talent, an increasing number of facilities are turning to staffing alternatives to fill maintenance roles, bringing with them productivity and efficiency gains that boost the bottom line. Preventive and predictive maintenance are essential for ensuring that equipment operates according to specifications and produces optimal output. When maintenance is neglected or performed improperly, equipment performance suffers, production quality declines, and the equipment's lifespan is shortened. Post-standardization and maintenance planning, non-flight-engaged GSE will only be scheduled for preventive maintenance on a monthly basis, not in a monthly RS. It is assumed that equipment that is little used should be inspected on a daily basis in case of projected repair and should not be used in monthly regular services to save on labor and maintenance costs, but rather will be confined to preventative maintenance. During warranty periods, only OEM recommendations are advised for equipment maintenance, but after warranty expiration, self-generated maintenance may be performed in accordance with experience and international standards, not necessarily OEMs. LEAN processes, continuous improvement, waste reduction, and standardization of components and inventories will jointly aid in attaining process standardization and cost-cutting maintenance strategies. The study of whole-life asset management, salvage/scrap values, and techniques of depreciation, as well as maintenance KPIs, contributes to the achievement of maintenance performance as a whole. When equipment reaches the end of its intended life, considerable cost savings may be realized by focusing mostly on tailored maintenance, adopting local fixes, and avoiding OEM-recommended replacement components.

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