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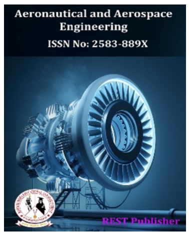


# Evaluating Key Factors in Autonomous Maintenance Using Grey Relational Analysis: A Focus on Weight and Data Analysis

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**Abstract:** *An autonomous maintenance strategy entails operators being in charge of regular equipment maintenance. It seeks to reduce equipment breakdowns and enhance general performance. Operators have daily responsibilities that include cleaning, lubricating, and inspecting equipment. This proactive strategy enables early abnormality detection, permits prompt repairs, and reduces unplanned downtime. Autonomous maintenance promotes a sense of ownership, raises equipment reliability, and makes the best use of maintenance resources by enabling operators to maintain equipment. The potential for autonomous care to transform medical procedures makes it important for study. Autonomous maintenance enhances overall equipment performance by enabling production and maintenance teams to schedule, carry out, and audit routine maintenance work. This method makes it possible to quickly identify and fix issues, which improves the availability, effectiveness, and quality of equipment. Researchers can help to improve maintenance strategies and operational efficiency in a variety of industries by researching the application and efficacy of autonomous maintenance. A mathematical method called Grey Relational Analysis (GRA) is used to evaluate the relationship between a group of variables. Even in the case of uncertainty or insufficient data, it measures the level of resemblance or correlation between variables. GRA enables a more thorough examination by taking into account both the trend and dispersion of the data. GRA assists decision-makers in identifying influencing factors and informing judgements based on the relative relevance of variables by calculating grey correlation coefficients. Weight took the first place and Data Analysis took the last place. In this paper, Autonomous Maintenance Weight took the first place and Data Analysis took the last place.*

**Keywords:** *Total Productive Maintenance (TPM), Autonomous maintenance, Database Management, Data Storage, Data Analysis and MCDM.*

## 1. INTRODUCTION

An important component of Total Productive Maintenance (TPM), autonomous maintenance (AM) refers to operators taking care of their own machinery and equipment. It attempts to enable operators to assume accountability for routine maintenance jobs that guarantee the equipment's general effectiveness and efficiency. In an AM setting, operators are taught and equipped with the skills needed to carry out standard maintenance tasks like sanitation, assessment, grease, and small repairs. Its goal is to stop equipment deterioration, identify irregularities, and quickly fix them to prevent breakdowns and unscheduled downtime. AM implementation has many advantages. In the beginning, it aids in changing maintenance attitude from an emergency response to an active one. Potential issues can be identified early by engaging operators, allowing for prompt responses and lowering the likelihood of serious breakdowns. This boosts output and lowers manufacturing losses. Second, AM encourages operators to have a sense of pride and ownership. They become more invested in and dedicated to the machinery they use, which leads to greater attention to detail. As users and maintenance people work together to maintain equipment reliability, this results in greater teamwork and collaboration. AM also helps operators to improve their skills. They get a greater comprehension of the machinery, how it functions, and probable failure modes when they take an active role in maintenance duties. This information can be put to use to increase operating effectiveness, optimise maintenance schedules, and support efforts to design and create new equipment. Autonomous maintenance, to put it briefly, is a proactive strategy that provides operators responsibility of standard maintenance activities. Organisations can increase equipment dependability, decrease breakdowns, and foster a culture of cooperation and continuous development by integrating operators in the maintenance process.

# 2. AUTONOMOUS MAINTENANCE

The initial phases of total production maintenance (TPM) research have largely been ignored by the maintenance and reliability literature. However, more contemporary writing has started to touch on these issues. In order to decrease the mean and variation of production cycle time, McCone and Weiss carried out an examination of the business decision to make investments in scheduled autonomous maintenance. By including regular upkeep as a result variable which helps in lowering the incidence of equipment issues, their model improves on earlier models. In order to properly manage cycle time, this module enables managers to decide on both the order amount and the time commitment for maintenance. The model's results show that investing in scheduled downtime to reduce projected cycle time is a good idea. Additionally, this model was expanded by McKone and Weiss to include the choice to invest in autonomous maintenance, inventory reduction, including safety stock and cyclical stock, and other factors. The findings of this study demonstrate that early TPM implementation can have a considerable positive impact on equipment performance. In conclusion, research from the past few years has shown how crucial financial concerns are in the beginning phases of TPM development. Studies by McKone and Weiss offer insightful information about the strategic use of scheduled autonomous maintenance to cut cycle times and inventory levels, thereby improving equipment performance [1]. The automotive sector is renowned for being demanding, calling for constant gains in efficiency from both vehicle makers and the suppliers who supply their parts. In the current economic climate, cost cutting, productivity growth, and cost cutting are all given a lot of attention. Companies are actively developing their products and operations to address these needs and boost profitability. The goal of this study was to enhance the maintenance procedures of a business that provides cooling ducts to the automobile sector. The main goal is to increase the availability of equipment, particularly for line AA3. These initiatives led to an 8% increase in overall equipment effectiveness (OEE) during the same time period [2]. Machine tool or FMS operators are responsible for continuing maintenance under operator-centered autonomous maintenance. But doing so calls for efficient management techniques, including training machine tool operators appropriately to assure their collaboration. To enable the transfer of some duties and activities form maintenance workers to operators, some modifications to maintenance engineering practises may be necessary. High levels of staff motivation must be effectively managed in order to be sustained. Through the provision of maintenance-related information in a manner that operators can simply comprehend and apply, this study endeavour seeks to assist machine tool operators. Recognising the value of storing all pertinent data concerning the state and efficiency of the mechanical system is essential for creating completely autonomous maintenance systems. To increase the effectiveness of maintenance, this data can be analysed. As they are freed from routine activities, skilled maintenance engineers may concentrate on more complicated problems and design maintenance strategies [3]. Advances in artificial intelligence have prompted research and development activities aimed at creating self-engineering behaviours on the element, subsystem, and system levels. As a result, the idea of autonomy has attracted substantial attention across a variety of industries. Innovative strategies that integrate crucial ideas like big data analytics, digitization, sensing, optimisation, information technology, and computer engineering are required to fully utilise the advantages of autonomy. Interest in implementing these ideas of automated maintenance, particularly automated predictive maintenance planning & built-in repair capabilities on the system level according to operational data, has increased with the rise of Industry 4.0, machine learning, and the digital twin. It is unclear, though, if current innovations actually attain autonomy or only automate already-existing procedures. In order to describe the present condition of technology and potential future possibilities, this article presents an overview of recent advancements in autonomous care. It examines the function of the digital twin as a tool for making decisions, taking into account both its requirements and the ways in which AI may help. A proposed framework for incorporating digital twin tactics into care models is also covered. The study concludes by considering the implications of autonomous care as an environmentally friendly technology and possible future developments [4]. The existence and control of autophagy processes in hematopoietic stem cells (HSCs) are poorly understood. Unknown is the function of FIP200 (a 200-kDa FAK-family interacting protein) in hematopoietic cells and mammalian autophagy. In this study, we show that severe anaemia and infant death result from selective deletion of FIP200 in hematopoietic cells. FIP200 was discovered to be essential for the cell-autonomous maintenance and operation of foetal HSCs. HSCs lacking FIP200 were unable to restore the health of radiation-damaged patients. Despite the fact that FIP200 deletion did not increase HSC death, it did boost HSC proliferation. The enhanced mitochondrial mass and amounts of reactive oxygen compounds seen in foetal HSCs when FIP200 was absent point to the protein's critical role in autophagy [5]. A maintenance plan called total production maintenance (TPM) aims to increase the availability and dependability of production machines and equipment. The use of autonomous maintenance (AM) practises is crucial to TPM's success. AM includes training operators to do normal maintenance operations with the assistance of technicians and engineers in addition to planned maintenance activities. The method of introducing AM at a Malaysian semiconductor manufacturer is described in this research report. The four methodological steps of initial preparation, training and motivation, five-step implementation, and audit are offered as a framework for the AM process. The corporation uses the framework in a crucial production line. AM reduces the likelihood of unanticipated equipment failures by empowering employees to do inspections, cleaning, lubrication, adjustments, and simple repairs on the equipment they are responsible for. AM makes production operators' duties and tasks more clear, empowering them to maintain their equipment on their own without needing assistance from the maintenance department [6]. The importance for preserving the efficiency of equipment increases in the setting of high-quality manufacturing. Automation of machine performance maintenance is the main area of research, particularly in highly computerised production systems that employ cutting-edge information technology. The usage of combined and remote support software and hardware is required for digital maintenance of manufacturing equipment. Its goals are to get real-time updates on the status of the equipment, forecast changes in the equipment's circumstances, warn staff members of crises and dangerous situations, automatically maintain the equipment's performance, fix mistakes, and have control software debugged while it is in use. The ultimate objective of the e-MM (electronic manufacturing and maintenance) idea is to build an automated autonomous control system for machine tools. The application of autonomous self-control, which entails monitoring and changing machine tool components to preserve or restore efficiency using specialised tools and information links, while judging its condition and importance, is a suggested definition for such a system [7]. The goal of automated maintenance (AM), a preventative maintenance (PM) strategy, is to enhance the "man-machine" interaction by emphasising the efficient implementation of tasks including cleaning, lubrication, and tightening. From a managerial perspective, the literature that is currently available primarily examines AM as a part of total manufacturing maintenance (TPM). However, this study proposes an AM decision model that makes use of the Fuzzy Analysis Hierarchy Process (FAHP) technique to handle the technical elements of AM deployment. The approach seeks to pinpoint crucial elements and choose the proper AM activities. A case study employing a lathe machine was carried out to verify the model. The maintenance engineering group may successfully implement an AM plan for their manufacturing equipment by employing this approach. By identifying the most important maintenance components and choosing the best maintenance operations, the model's principal benefit is a reduction in maintenance costs and time [8]. Total Productive Maintenance (TPM) is a type of maintenance management strategy that seeks to enhance total equipment performance through the adoption of a thorough system with everyone's input. Operator-based tasks associated with TPM, referred to as autonomous maintenance, are significant, particularly in the early stages of TPM adoption. At this point, practitioners must decide how much time and money to devote to returning equipment to a baseline state, how frequently to clean and lubricate it, and how to carry out standardised equipment checks. Although TPM has been used by practitioners to enhance their performance, little research has been done to analyse TPM or offer recommendations for carrying out activities. In order to prevent equipment failure, lower product non-conformance, and require less inventory, this article focuses on examining the investment in scheduled autonomous maintenance activities [9]. There are two main categories for autonomous maintenance. The introduction of self-related technology or characteristics, including healing themselves, monitoring oneself, awareness of oneself, self-configuration, and protection from harm, into high-value systems is the first aspect. The second area focuses on automating maintenance processes within organisations, particularly employing autonomous robotics to support, direct, or take the place of current maintenance duties carried out by engineering professionals or workers. Furthermore, it can be difficult to decide which autonomous systems to deploy at any particular time due to the irregular nature of maintenance and the combination of planned and unplanned operations. This problem is more obvious if autonomous maintenance systems were incapable of multitasking and are restricted to specific tasks like inspection or manipulation. On the contrary, humans have developed the capacity to manage several jobs at once to suit growing workloads [10]. A robotic maintenance system that can identify and fix issues with cables that are either disconnected or improperly connected in networking devices or radio base stations (RBS) is developed. The system overcomes a number of technological obstacles, including connector handling and hardware issue identification. This study's primary objective was to create a specialised gripper system that was both affordable and effective for handling RJ45 Ethernet connectors. Three tests were run to gauge how well the gripper performed. In the initial test, 30 participants interacted with the robotic arm's gripper in telescopic action while providing qualitative comments. The gripper was also put to the test in automatic operation. The outcomes proved the system's dependability and excellent performance in telescoping and automated modes. The gripper's capacity to handle connectors properly was proved in a practical test, and responses to a questionnaire suggested that users had a good experience. A computerised test was also run to evaluate the gripper's strength under continuous use [11]. Rapid technical advancements in the current era are changing conventional manufacturing methods in the industrial sector. These changes have been largely driven by the emergence of IT-enabled services. With features including intelligent information processing, cutting-edge methods, and sophisticated communication systems, these advances seek to turn industries into savvy and intelligent businesses. Industry 4.0's increasingly automated and complex systems pose fresh difficulties for security, dependability, and safety. Putting in place an autonomous maintenance system (AMS) is essential to overcoming these obstacles. AMS is a crucial element of Industry 4.0 since it lowers maintenance costs and boosts business profitability. The process of maintaining an item's condition and functionality is referred to as maintenance. In the setting of Industry 4.0, autonomous machines need a proactive autonomous maintenance system that keeps track of and manages linked equipment using data management systems, data analytics, and sensor technology [12]. Managers, engineers, technicians, and operators across the production and maintenance divisions work together as an autonomous maintenance team (AMT). Planning, carrying out, and assessing regular autonomous maintenance chores is their key duty. These teams may include both internal and external members. The internal team would be in charge of organising, carrying out, and reviewing independent repairs, while the external team would be responsible for carrying out maintenance duties. To avoid any network system downtime, it is crucial that both teams communicate and work together successfully. All teams perform autonomous maintenance and interact when resolving issues with the network system. All routine maintenance chores and unanticipated incidents should be coordinated with the respective work groups. All teams must act right away to fix the problem if a network system fails. The lack of standardised protocols and coordination guidelines for network infrastructure recovery makes it difficult to coordinate and collaborate in such circumstances. Network system recovery is typically based on historical performance and working practises [13]. An investigation was done to see how automated maintenance (AM) will affect a CNC machine used to make automotive parts. The goal of the study is to detect and estimate equipment loss related to ratios of performance, availability, and quality. These measures were used to compare the production line's overall effectiveness of the equipment (OEE) before and after applying AM. The project started with the formation of an AM team and continued with 5S activities, anomalies (fuguai) identification, and resolution. Kaizen is a method of continuous improvement that is used to repair broken machine parts and components. To guarantee the engine's optimal performance, the AM team members created and frequently followed autonomous maintenance criteria, which included cleaning, lubrication, and inspection. After AM was implemented, daily OEE measurements were obtained, and pre- and post-AM data were compared. The data showed that following AM installation, the average OEE increased significantly, going from 65.8% to 80.4%. However, the outcome fell short of the company's expectations mostly because of the machine's senior age, which is close to the level of deterioration indicated by the bathtub curve [14]. In mobile wireless networks, free-space optical communication is important because it offers high-speed wireless communication, enhanced signal protection, and spatial reuse. It does, however, necessitate careful maintenance of line-of-sight and vulnerable mobility issues. In this study, we concentrate on two mobile autonomous nodes with FSO transceivers installed on rotatable heads that can rotate 360 degrees. Using a direct LOS alignment protocol, we create a prototype implementation of mobile nodes equipped with FSO transceivers and establish and maintain an FSO connection among them. By examining the outcomes of tests done with the prototype, the efficacy of this alignment process is assessed. The results show that optical wireless networks can be deployed in mobile contexts with little interference using mechanically steerable transceivers that and a straightforward auto-alignment system [15].

# 3. METHODOLOGY

### 3.1 GRA Method:

The Deng-developed Grey Relational Analysis (GRA) technique has been successfully used to solve a number of multi-attribute decision-making (MADM) issues, including identifying defects in silicon wafer slicing, power distribution system recovery planning, integrated-circuit indicating evaluation, and quality operate deployment modelling. GRA consists of a number of processes, the first of which is grey relative formation, which transforms the performance of every alternative into a comparable array. An ideal sequence for target is created from these sequences, and the grey correlation coefficient—the measurement of how closely each comparable sequence resembles the ideal target sequence—is computed. The grey correlation strength among the ideal sequence of interest and each similar sequence is then calculated using these coefficients. The ideal alternative is the one that most closely resembles the ideal goal sequence in terms of grey correlation [16]. In order to solve problems involving multi-criteria decision-making (MCDM), which are characterised by interval-valued triangular fuzzy numbers with unidentified criterion weights, this study will offer an improved Grey Relational Analysis (GRA) method. Scale values are frequently written as triangular fuzzy integers with interval values that represent linguistic variables due to the complexity and ambiguity involved with objective aspects. By using optimisation models influenced by the conventional GRA technique, the criterion weights are determined. When evaluating options and choosing the best one, the expanded GRA technique for MCDM offers a step-by-step process that takes interval-valued triangular fuzzy estimations, ambiguous criterion values, and unknown criterion weights into account [17]. In order to solve multi-criteria decision-making (MCDM) problems using interval-valued triangular fuzzy numbers and unidentified criterion weights, this study suggests an enhanced Grey Relational Analysis (GRA) method. These problems frequently involve complex and ambiguous objective aspects, which calls for the usage of linguistic variables stated as trigonometric fuzzy numbers with interval values. To find the unidentified criterion weights, the study develops optimisation models that utilise conventional GRA concepts. To evaluate options and choose the best one, the expanded GRA technique for MCDM employs interval-valued triangular fuzzy estimates, fuzzy criterion numbers, and unidentified criterion weights. Notably, the suggested method's high-quality alternatives are consistent with those found in earlier studies, proving its efficacy in resolving real-world MCDM issues [18]. The double-hesitant fuzzy set (DHFS), which allows for potential membership and non-membership sizes of components within the range ,is a useful tool for conveying uncertainty data in multi-attribute group decision making (MAGDM). In the MAGDM issues that are the subject of this study, the attribute values are stated as dual-reluctance fuzzy elements, and the attribute and decision weights are expressed by real numbers. The normalised Hamming distance for each of the dual reluctance fuzzy components is first defined in the paper. Then, a novel strategy for tackling MAGDM issues is put out that combines the Grey Correlation Analysis (GRA) theory with a dual-reluctance fuzzy environment. When data is partially or entirely unknown, optimisation models are added to establish attribute weights [19]. Decision-making information frequently incorporates ambiguity and uncertainty in multi-attribute group decision-making (MAGDM) realistic situations, which can be successfully expressed using linguistic term sets (LTSs). It is simple to transform these LTSs into probabilistic linguistic sets (PLTSs). The use of the Grey Relational Analysis (GRA) technique to resolve MAGDM issues with entirely unknowable attribute weights is examined in this paper. In order to figure out the attribute's weights objectively using the CRITIC technique, a function for scoring is first created. The best option is then chosen based on the calculation of the highest compared correlation level obtained from the Probabilistic Linguistic Positive Ideal Solution (PLPIS), taking into account both the largest grey correlation coefficient from the PLPIS and the smallest grey correlation coefficient via the probabilistic linguistic negative ideal. Consolidation (PLNIS). The applicability of the conventional GRA approach is increased by the suggested method. The GRA approach, which is well-known for its efficacy in MAGDM or multi-attribute decision making (MADM), works well for handling ambiguous decision-making issues. The applicability of the suggested approaches and methods using PLTSs in different practical domains or uncertain fuzzy cognitive situations should be further investigated [20]. The difficulties of interval-valued Pythagorean fuzzy information, such as interval-valued Pythagorean numbers that are fuzzy with attribute values and inadequate attribute weight information, are addressed in this work as multiple attribute group decision making (MAGDM) problems. An inventive Grey Relational Analysis (GRA) method enhancement is presented to address such issues. In order to integrate decision metrics, the interval-valued Pythagorean Fuzzy Socket Integral Average (IVPFCIA) operation is defined. It is inspired by interval-valued intuitionistic fuzzy sets. The ranked order for alternatives based on the amount of grey relation for both positive and negative optimal options is computed. With this strategy, interval-valued Pythagorean fuzzy data MAGDM issues can be solved using classic GRA methods [21]. In recent years, attaining sustainable growth has depended heavily on selecting the best energy producers in the power sector. The study uses a five-dimensional framework to evaluate energy producers and their sustainability, taking into account environmental, social, economic, technological, and organisational factors. A modified Grey Relational Analysis (GRA) method using grey numbers is utilised for ranking to get around the partiality of expert opinions. Interviews with specialists and academics from Iran's Renewable Energy System (SUNA) validate the suggested strategy in a case study that focuses on the country's energy industry. The findings demonstrate the applicability of the study and show that the most sustainable sources of energy are wind, solar, and natural gas [22]. Organisations require a comprehensive strategy that combines subjective and objective evaluations in order to handle the challenges brought on by growing globalisation and ensure effective staff selection. The purpose of this study paper is to create a fresh approach to choosing employees. Grey correlation analysis (GRA) and intuitive fuzzy multi-criteria group decision making are used in the suggested approach. It combines the individual decision-makers' viewpoints into a collective agreement using the intuitive fuzzy weighted averaging (IFWA) operator. The weights of the criteria are determined by intuitive fuzzy entropy. GRA serves to evaluate and select the best possible options. The simple fuzzy multi-criteria group decision-making strategy with GRA presented in this research addresses the drawbacks of conventional approaches and is intended for staff selection [23]. When patterns in the data are interchangeable, Grey Relational Analysis (GRA) serves as a highly helpful tool for handling complex relationships. GRA has many benefits, including the ability to provide computations that are straightforward and applicable and to base outcomes on actual facts. When tackling issues with manufacturing technology, GRA can be used to make the best choices. This method scales and normalises the experimental data (MRR and TWR) to a range between 0 and 1. The grey correlation coefficient is computed using the normalised data to reveal the link among the desired and actual data. TWR is regarded as the "lowest ideal" response type, whereas MRR is the "highest ideal" response. The authors used grey correlation analysis to undertake multiple-response optimisation in order to allay reviewers' concerns regarding the practical use of fuzzy logic in this work. An exhaustive literature study found that this strategy, which is renowned for its simplicity, usability, and favourable optimisation outcomes, has been widely applied in over 100 research articles. Because of this, the authors decided to use GRA in place of the Gray-Fuzzy approach for this inquiry [24]. Decision makers offer choice information in the form of interval-valued intuitive fuzzy numbers (IVIFNs) and two-level intuitive fuzzy numbers (IFNs) at various times in a hybrid multi-attribute decision-making (DHMADM) process. The Dynamic Intuitive Fuzzy Dombey Weighted Average (DIFDWA), Weighted Geometric (DIFDWG), and Uncertain Dynamic Intuitive FDIW.., weighted geometric (UDIFDWG) operators are new dynamic weighted aggregation operators (AOs) that we introduce in this study. These AOs are designed to handle interval uncertainty. These mathematical operators are employed to dynamically combine the provided data. To calculate the overall grey correlation degree for each option in regard to the positive and negative best choices (PIA and NIA), the integrated matrix is next put through two grey correlation analysis (IF-GRA and IVIF-GRA) methodologies [25].

### 3.2 Parameters:

**Database Management:**
Data must be efficiently and securely organised, stored, and retrieved through database administration. It entails duties including establishing and managing tables, identifying relationships, ensuring data integrity, improving performance, and assuring data backup and recovery, among others.

**Data Storage:**
Data storage is the practise of conserving digital information for usage in the future. To securely store and restore data as needed, real or virtual devices are used.

**Data Analysis:**
Examining, purifying, manipulating, and analysing data is the process through which significant patterns are found, conclusions are drawn, and well-informed decisions are made.

**Sensor Technology:**
Technology that uses sensors to identify and quantify physical phenomena like temperature, pressure, or light is known as sensor technology. These sensors offer vital information for several systems and applications.

**Weight (Wj):**
In an equation or algorithm, weight (Wj) denotes the significance or contribution made by a specific characteristic or parameter, reflecting its impact on the whole process of decision-making.

**Preventive Maintenance:**
In order to avoid breakdowns, extend equipment life, and maintain peak performance, preventive maintenance involves routine inspections, cleanings, and repairs. This lowers the risk of unanticipated failures and expensive repairs.

**Reliability centred maintenance:**
A maintenance strategy known as reliability-cantered maintenance (RCM) aims to maximise maintenance efforts while minimising failure rates by identifying and prioritising maintenance jobs according to their influence on system reliability.

**Condition based maintenance:**
The goal of condition-based maintenance (CBM), a type of preventive maintenance, is to continuously assess the health of a piece of machinery to identify when repair is necessary and to tailor maintenance procedures to those needs.

**Predictive Maintenance:**
A proactive strategy called predictive maintenance employs data analysis and prediction models to foresee equipment problems, schedule repair in advance, and save downtime.

**Opportunistic Maintenance:**
According to conditions seen during ordinary operations, opportunistic maintenance is a maintenance plan that entails carrying out repairs or maintenance chores whenever the chance presents itself.

## 4. ANALYSIS AND DISCUSSION

**TABLE 1.** Autonomous maintenance

| | Preventive Maintenance | Reliability Centred Maintenance | Condition Based Maintenance | Predictive Maintenance | Opportunistic Maintenance |
|---|---|---|---|---|---|
| **Database Management** | 31.08 | 139.53 | 29.15 | 25.15 | 19.05 |
| **Data Storage** | 28.12 | 142.97 | 33.69 | 27.30 | 22.06 |
| **Data Analysis** | 33.15 | 122.58 | 30.23 | 23.10 | 36.05 |
| **Sensor Technology** | 23.17 | 128.28 | 24.60 | 20.15 | 15.06 |
| **Weight (Wj)** | 35.63 | 168.13 | 27.96 | 18.89 | 24.36 |

Table 1 Shows the Autonomous maintenance which incorporates Alternate Parameter: Database Management, Data Storage, Data Analysis, Sensor Technology, Weight (Wj) and Evaluation parameter having Benefit criteria: Preventive Maintenance, Reliability Centred Maintenance, Condition Based Maintenance, Predictive Maintenance, Opportunistic Maintenance.

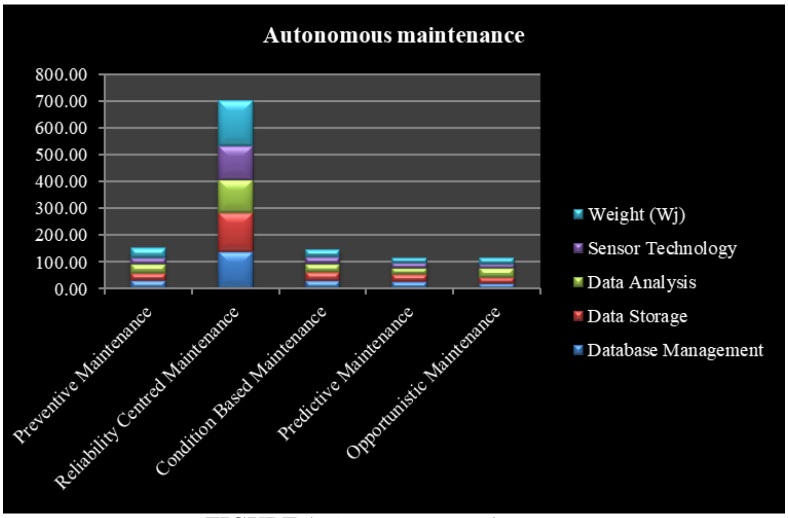


**FIGURE 1.** Autonomous Maintenance

Figure 1 shows the graphical representation of Autonomous maintenance which incorporates Alternate Parameter: Database Management, Data Storage, Data Analysis, Sensor Technology, Weight (Wj) and Evaluation parameter having Benefit criteria: Preventive Maintenance, Reliability Centred Maintenance, Condition Based Maintenance, Predictive Maintenance, Opportunistic Maintenance.

**TABLE 2.** Normalized Data

| | Preventive Maintenance | Reliability Centred Maintenance | Condition Based Maintenance | Predictive Maintenance | Opportunistic Maintenance |
|---|---|---|---|---|---|
| **Database Management** | 0.634831 | 0.372119 | 0.50055 | 0.255648 | 0.809909 |
| **Data Storage** | 0.397271 | 0.44764 | 1 | 0 | 0.666508 |
| **Data Analysis** | 0.800963 | 0 | 0.619362 | 0.499405 | 0 |
| **Sensor Technology** | 0 | 0.125137 | 0 | 0.850178 | 1 |
| **Weight (Wj)** | 1 | 1 | 0.369637 | 1 | 0.556932 |

Table 2 Shows the Normalized Data For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method.

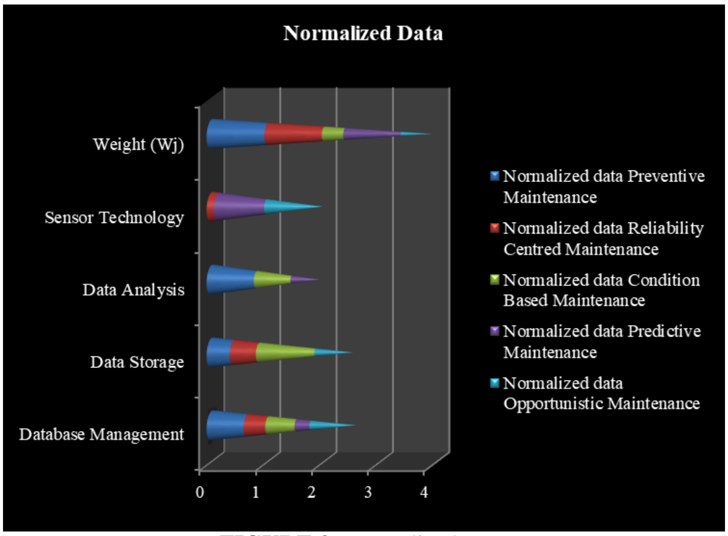


**FIGURE 2.** Normalized Data

Figure 2 Shows the graphical representation of the Normalized Data For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method.

**TABLE 3.** Deviation Sequence

| | Preventive Maintenance | Reliability Centred Maintenance | Condition Based Maintenance | Predictive Maintenance | Opportunistic Maintenance |
|---|---|---|---|---|---|
| **Database Management** | 0.365169 | 0.627881 | 0.49945 | 0.744352 | 0.190091 |
| **Data Storage** | 0.602729 | 0.55236 | 0 | 1 | 0.333492 |
| **Data Analysis** | 0.199037 | 1 | 0.380638 | 0.500595 | 1 |
| **Sensor Technology** | 1 | 0.874863 | 1 | 0.149822 | 0 |
| **Weight (Wj)** | 0 | 0 | 0.630363 | 0 | 0.443068 |

Table 3 Shows the Deviation sequence For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method.

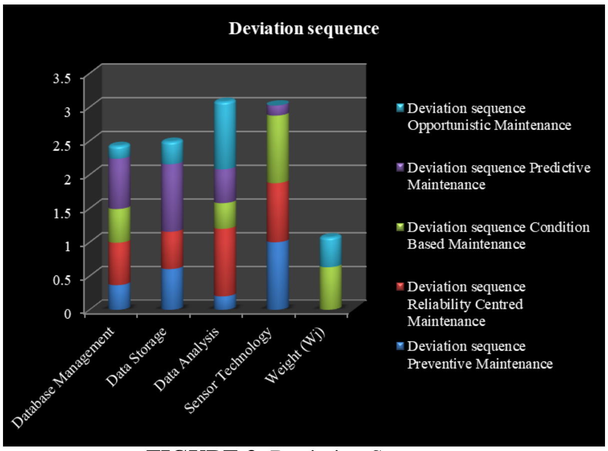


**FIGURE 3.** Deviation Sequence

Figure 3 Shows the graphical representation of Deviation Sequence For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method

**TABLE 4.** Grey relation coefficient

| | Preventive Maintenance | Reliability Centred Maintenance | Condition Based Maintenance | Predictive Maintenance | Opportunistic Maintenance |
|---|---|---|---|---|---|
| **Database Management** | 0.577922 | 0.443309 | 0.500275 | 0.401816 | 0.724543 |
| **Data Storage** | 0.453421 | 0.475123 | 1 | 0.333333 | 0.599886 |
| **Data Analysis** | 0.71527 | 0.333333 | 0.56777 | 0.499703 | 0.333333 |
| **Sensor Technology** | 0.333333 | 0.363673 | 0.333333 | 0.769442 | 1 |
| **Weight (Wj)** | 1 | 1 | 0.442336 | 1 | 0.530184 |

Table 4 Shows the Grey Relation Coefficient For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method

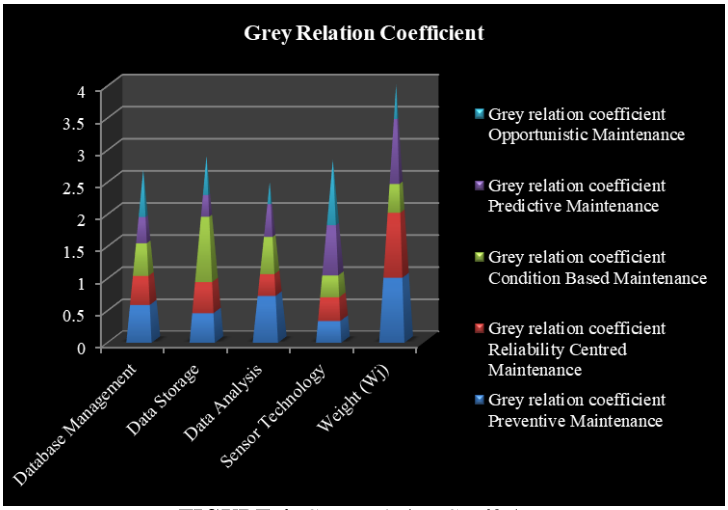


**FIGURE 4.** Grey Relation Coefficient

Figure 4 Shows the graphical representation of Grey Relation Coefficient For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method

**TABLE 5.** GRG and Rank

| | GRG | RANK |
|---|---|---|
| Database Management | 0.529573 | 4 |
| Data Storage | 0.572352 | 2 |
| Data Analysis | 0.489882 | 5 |
| Sensor Technology | 0.559956 | 3 |
| Weight (Wj) | 0.794504 | 1 |

Table 5 Shows the value of GRG and Rank For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method. In which weight took the first place and Data Analysis took the last place.

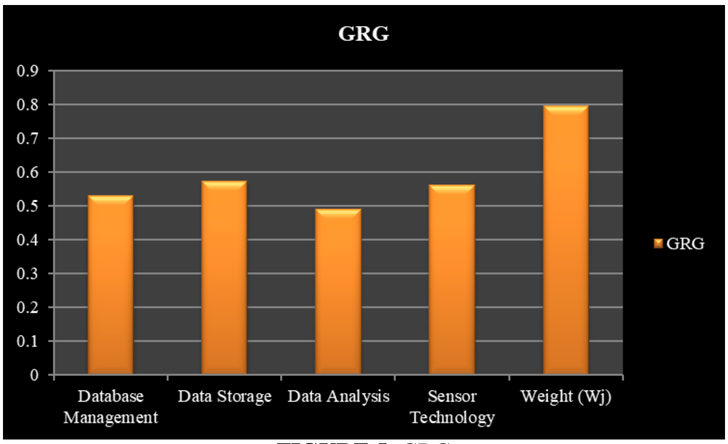


**FIGURE 5.** GRG

Figure 5 shows the graphical representation of GRG For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method.

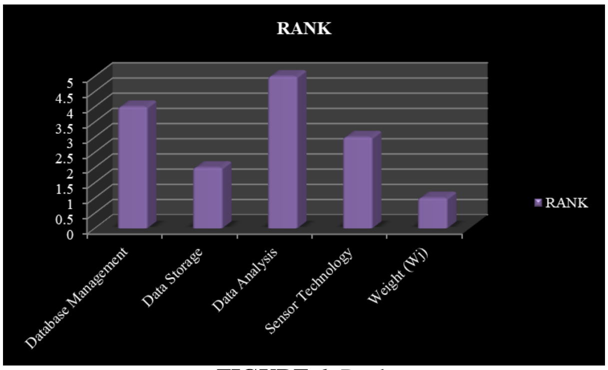


**FIGURE 6.** Rank

Figure 6 shows the graphical representation of Rank For the Autonomous maintenance which incorporates all the Alternate and Evaluation Parameter by the GRA method in which weight took the first place and Data Analysis took the last place.

## 5. CONCLUSION

The initial phases of total production maintenance (TPM) research have largely been ignored by the maintenance and reliability literature. However, more contemporary writing has started to touch on these issues. In order to decrease the mean and variation of production cycle time, McCone and Weiss carried out an examination of the business decision to make investments in scheduled autonomous maintenance. By including regular upkeep as a result variable which helps in lowering the incidence of equipment issues, their model improves on earlier models. In order to properly manage cycle time, this module enables managers to decide on both the order amount and the time commitment for maintenance. The automotive sector is renowned for being demanding, calling for constant gains in efficiency from both vehicle makers and the suppliers who supply their parts. In the current economic climate, cost cutting, productivity growth, and cost cutting are all given a lot of attention. Machine tool or FMS operators are responsible for continuing maintenance under operator-centered autonomous maintenance. But doing so calls for efficient management techniques, including training machine tool operators appropriately to assure their collaboration. To enable the transfer of some duties and activities form maintenance workers to operators, some modifications to maintenance engineering practises may be necessary. High levels of staff motivation must be effectively managed in order to be sustained. Through the provision of maintenance-related information in a manner that operators can simply comprehend and apply, this study endeavour seeks to assist machine tool operators. Recognising the value of storing all pertinent data concerning the state and efficiency of the mechanical system is essential for creating completely autonomous maintenance systems. GRA is a multi-attribute decision-making (MADM) issues, including identifying defects in silicon wafer slicing, power distribution system recovery planning, integrated-circuit indicating evaluation, and quality operate deployment modelling. GRA consists of a number of processes, the first of which is grey relative formation, which transforms the performance of every alternative into a comparable array. An ideal sequence for target is created from these sequences, and the grey correlation coefficient—the measurement of how closely each comparable sequence resembles the ideal target sequence—is computed. The grey correlation strength among the ideal sequence of interest and each similar sequence is then calculated using these coefficients. The ideal alternative is the one that most closely resembles the ideal goal sequence in terms of grey correlation. When patterns in the data are interchangeable, Grey Relational Analysis (GRA) serves as a highly helpful tool for handling complex relationships. GRA has many benefits, including the ability to provide computations that are straightforward and applicable and to base outcomes on actual facts. When tackling issues with manufacturing technology, GRA can be used to make the best choices. This method scales and normalises the experimental data (MRR and TWR) to a range between 0 and 1. The grey correlation coefficient is computed using the normalised data to reveal the link among the desired and actual data. TWR is regarded as the “lowest ideal” response type, whereas MRR is the “highest ideal” response. The authors used grey correlation analysis to undertake multiple-response optimisation in order to allay reviewers’ concerns regarding the practical use of fuzzy logic in this work.

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