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The Application of the EDAS Method in the Parametric Selection Scheme for Maintenance Plans in the Nigerian Food Industry

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Abstract

Nowadays, maintenance performance in organizations has become compelling due to competitiveness in the global market and the inclusion of more legislation issues (such as safety and health regulations) in assessments. In this article, the purpose is to formulate in maintenance problem for a food processing unit as a multicriteria problem and solve it using the evaluation based on distance from the average solution (EDAS) method. To attain this purpose, the authors defined a set of weighted criteria and a set of alternatives, and the solution is the alternative that scores the best in those criteria. Consequently, analysis was done based on the EDAS method and the calculated results from the literature data. Consequently, the parameters considered include the frequency of failure, MTBF, MTTF and MTTR while availability is the response. The EDAS method was used to select the best alternative (MTTR, 0.8802) and this score of 0.8802 is for an alternative. The chief novelty of this article is the unique introduction of an innovative EDAS method, which requires only two measures of the desirability of alternative (positive and negative distances from the average solution) but excluded the evaluation of the idea and nadir solutions for the key performance indicators of maintenance. Consequently, this study initiates a maintenance plan for the food industry referring to the key performance indicators as a cause for poor availability of equipment in the Nigerian food industry.

Keywords: *maintenance analysis, availability, EDAS, food industry, maintenance planning*

Introduction

Today, many maintenance key performance indicators are available in the literature, accounting for diverse process concerns such as the technical process attributes, cost, safety, environment, efficiency, effectiveness and quality (Gonzalez et al., 2017; Gerbec and Kontić, 2017; Amrina et al., 2020; Sarkheil, 2021). Their computations are aided by the sophisticated computer powers and specialized packages developed to ease maintenance planning; this puts the maintenance engineer and manager into a dilemma to rank and select alternative solutions using parameters as criteria regarding key performance indicators to adopt because computer package manufacturers are providing such key performance indicators at the cut-throat price have a broad scope of characteristics (O'Donoghue and Prendergast, 2004; Fumagalli et al., 2009; Lopes et al., 2016; Oliveira et al., 2016; Munyensanga et al., 2018; Meira et al., 2020). Furthermore, the central practice in the maintenance of food manufacturing facilities is to focus on cost-effectiveness, have restricted production interruptions, positively affect cleanliness, and drive all the quality aspects of the foods being produced (Adebiyi et al., 2004; Aarnisalo et al., 2006; Asioli et al., 2017; Branská et al., 2016; Fernando et al., 2019).

To achieve these goals, decision-makers in food manufacturing are quick to adopt the HACCP (hazard analysis and critical control points) scheme that imposes strict standards in the maintenance of food manufacturing facilities, for success, many efficient facility decision-makers prefer a joint implementation of predictive, preventive, proactive and reactive methods (Chemat and Hoarau, 2004; Wang et

al., 2013; Dzwolak, 2019; Liu et al., 2021). Unfortunately, the predictive approach, which should give the essential details regarding how to rank and select alternative solutions using parameters as criteria among the key performance indicators, fails to account for the necessary understanding for maintenance decision-makers (Fernandes et al., 2019; Aremu et al., 2020; Karuppiah et al., 2021). They require a clear understanding and appraisal of the key performance indicators before creating several optimal plans (Coria et al., 2015; Dutoit et al., 2018; Fan et al., 2019). But this stimulates cost-effective optimisation and accordingly lower maintenance expenditure and reduce the food product cost (Zhang et al., 2012; Halvorsen-Weare et al., 2017). However, in maintenance improvement, ranking and selecting alternative solutions using parameters as criteria has the following advantage. It permits the encouragement of the food facility characteristics which are more advantageous to the maintenance decision-makers.

At present, maintenance decision-makers build maintenance plans without awareness of the accurate present state of how to rank and select alternative solutions using parameters as criteria. Although some target results may be specified, attaining these targets will be influenced by the importance given to a key performance index over the other. Consequently, an exact maintenance analysis is essential as a prerequisite for any significant improvement in the availability of their food equipment. Thus, research is necessary for the prioritization of performance indices that strongly influenced the availability of food equipment's in a Nigerian plant. Today, prioritization is an extra inducement than before to implement in maintenance planning since an extraordinary goal-achieving attitude is expected from commencing parametric selection in maintenance plan developments regarding food facilities.

In this article, the purpose is to formulate in maintenance problem for a food processing unit as a multicriteria problem and solve it using the EDAS method. To attain this purpose, the authors defined a set of weighted criteria and a set of alternatives, and the solution is the alternative that scores the best in those criteria. Consequently, analysis was done based on the EDAS method and the calculated results from the literature data. The paper examines five key performance indicators, namely the frequency of failure, downtime, MTTR, MTBF and MTTF while the response is the availability.

Accordingly, this study applied the premise of EDAS to examine and revise the present knowledge on maintenance plans through a parametric selection of key performance indicators. The theory of EDAS has a theoretical foundation that ranks parameters according to merits, based on the inputs of the experts. This work is substantial as it provides a structure to develop the essential deficiency of ranking among the key performance indicators in a maintenance plan exercise. Besides, it provides significant information to maintenance decision-makers regarding the main parts of an EDAS method in interactive and ranking perspectives and the essential procedures to its implementation. Furthermore, by utilizing and establishing this research problem which is yet attended to and the limitation in the context of selection of the best scenario plan and parameters, further investigations are stimulated. This study has shown that appropriate plan options could be developed since the motivating parameters were identified. This study contributes to the use of the EDAS method as a quantitative approached uniquely by the availability analysis of a food equipment company. Consequently, this study initiates a maintenance plan for the food industry referring to the key performance indicators as a cause for poor availability of equipment in the Nigerian Food Industry.

The present review entails the thought process on parametric selection in alignment with the maintenance plan: this may link up with the dynamics of the maintenance key performance indicators such as availability, downtime, MTBF, MTFR and MTTF. Consequently, examining the relationship among these parameters will precisely reveal new knowledge on maintenance KPIs and reveal the advantages of an effective maintenance plan in the food industry. Thus, the objective of this study is to examine the unique application of the EDAS method while considering the parametric selection scheme for maintenance plans in the Nigerian food industry. Besides, the study engaged in the development of a robust literature review and the article discusses the study's method, analysis of data and the study's results. It further

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made concluding remarks as well as implications of the study together with future studies.

Literature Review

This section of the paper presents a review of key performance indicators in maintenance engineering. First, an introduction to key performance indicators is presented. Maintenance key performance indicators are measures that establish how the maintenance system effectively accomplishes its principal objective. The maintenance department is compelled to ascertain the complete availability of the food equipment at the optimum cost while adhering to the strict conditions of cleanliness, the drive for quality food, safety conformity and environmentally conscious manufacturing. In the maintenance system, the key performance indicators indicate what is to be appraised and the evaluation method state when and how it will be appraised. The goal of maintenance is first identified to evaluate maintenance key performance indices, the crucial factors from the defined goal are determined and the key indicators from these crucial factors are determined. Besides, measures are collected and the metric is evaluated from the maintenance measures.

Key Performance Indicators in Maintenance

Tracking the suitable maintenance metric is critical to achieving minimum downtime of equipment, the proper mix of maintenance strategy and conformity with the present regulation on food manufacturing practices and health safety and environment standards. Moreover, Oliveira et al. (2016) established the maintenance performance indicators used in an industrial cluster in Brazil. It was reported that the adoption of indicators in the cluster of industries was low. It was noted to rely on whether total productive maintenance was implemented or not, the use of computerised maintenance management, staff strength and the number of equipment. Further, Re Cecconi et al. (2019) surveyed the use of the facility condition index as a measure in asset management. It was affirmed as an enabling parameter to establish a competent strategy. The literature associated the facility condition index with a replacement value of an asset and deferred maintenance value. In addition, Naji et al. (2019) offered an original measurement scheme for the maintenance system, which is useful to establish those forecast parameters that add to achieving superior standards of maintenance practice. The principal indicators were grouped using the analytical hierarchy process multicriteria tool. Moreover, Stefanovic et al. (2017) dealt with the subject of the ranking maintenance process, cost and equipment indicators with the methods of fuzzy sets and genetic procedure. The proposed procedure allowed the optimisation of the chosen principal performance indices.

The EDAS Approach and Its Applications

Maintenance KPI selection is a process to establish the best-eligible indicator from a list of probable choices of the most representative indicators for the maintenance activity assessment of the wheat processing plant. The purposes of KPI selection are to help the maintenance engineer manage the performance growth in the wheat plant, establish a good cash flow for a fair resource distribution among the maintenance activity centres and ensure satisfactory services to the production department. KPIs are essential to the objective of the wheat processing plant since they position maintenance objectives at the forefront of maintenance decision analysis and implementation. It promotes the culture of every worker is aware of and responsible for their KPI outcomes. In this context, workers assess themselves whether they are fit for the attainment of the company's goals even if they are capable of coping with the work requirements of the plant or not.

Having considered the importance of KPIs, the available models that serve as alternatives to the approach considered here needs to be taken into account. Some of these methods, which have been established to come late with the selection and ranking of KPIs, include the DEMATEL method (Maduekwe and Oke, 2021). DEMATEL as a multicriteria method is founded on the causal relationship principle. This has been applied in the food environment. A second approach (Bader and Rahimifard, 2020) is referred to as the FIRM steps and is a unique approach that selects food using the robots technology based on four pillars; definition of food features, food grouping, the establishment of the kind of food operation and the definition of the IR parameters. The third approach is the

EDAS method. However, in the present article, the impact of the EDAS method in the selection and ranking process of maintenance criteria in a wheat processing plant is studied. It is thought that no substantial study has been undertaken on the unique development and application of the EDAS method to the wheat processing plant. Thus, the following review attempts to support the argument.

One of the key studies that supported our argument was credited to Kundakci (2019) that offered an excellent description of the differences between the EDAS approach and VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) as well as TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and concluded that the key benefit of EDAS, when interpreted for maintenance systems is that the maintenance manager or engineer in the food manufacturing plant does not require establishing the ideal and nadir outcomes. Proposed by Keshavarz-Ghorabaee et al. (2015), the EDAS technique was described as a multicriteria decision-making approach that is extremely important to solve problems that reveal features of conflict (Kundakci, 2019). For instance, applied to the present maintenance development plan problem, which consists of five criteria, it was noticed that while the data for frequency of failure grew, it suddenly declined at the third point. This is also true for the downtime and MTTR criteria which afterwards grew again in trend. At the same time, the MTBF grew but declined at the second point before growing again. These are the characteristics of a conflicting problem: one that grows and declines at various data points for the different criteria under consideration.

Besides the ordering of the KPIs that the EDAS method produces, it provides the maintenance manager with the opportunity of knowing in what combinations efforts should be diverted to each of the parameters since the final results score with high and lower values that dictate the ordering. Thus, the EDAS method proposes a procedure that corrects the crucial weakness of the alternative methods of ABC classification that was considered in the original work by Keshavarz-Ghorabaee et al. (2015). As mentioned by the innovator of the EDAS, considering only one criterion in the ABC method expenses the company substantial financial losses. However, many criteria are considered by the EDAS method and this provides a huge opportunity for performance and financial gains in maintenance service.

Moreover, Kundakci (2019) declared that regarding the EDAS approach, the superior option is determined through guidance on the distance from the average solution. Here, the author declared that it is essential to evaluate two measures concerning the desirability of the options: the positive distance from the average with the negative distance from the average. However, VIKOR and TOPSIS are concerned with the distance from the ideal and nadir solutions to establish a superior option. With the stated benefit of EDAS, it has gained recognition in several fields in the literature: traffic problems (Kikomba et al., 2016), steam boiler choices (Kundakci, 2019), autonomous maintenance (Srivastava et al., 2020), smartphone evaluation (Aggraval et al., 2018), maintenance performance assessment (Stefanovic et al., 2017), logistics (Stevic et al., 2016), sewing machine choice (Ulutas, 2017), waste disposal site choice (Kahraman et al., 2017) and third-party logistics (Ecer, 2017).

Furthermore, Aggarwal et al. (2018) employed the evaluation based on distance from average solution (EDAS) method to appraise smartphones regarding a restricted budget, to select an adequate phone for customers. It was concluded that it provided reliable outcomes. Apart from this, Keshavarz-Ghorabaee et al. (2015) diverted from the traditional perspective of inventory classification that uses the lens of a single criterion to a multi-criteria perspective, using the positive and negative distances from the average solution to appraise options. The work confirmed that the approach is steady in various weights and reliable compared with other methods. Besides, Srivastava et al. (2020) are one of the latest articles to apply EDAS to maintenance. While focusing on autonomous maintenance, the authors removed the concerns regarding vague decisions and inexactness by apply fuzzy EDAS to the problem. The prioritisation in the information technology–facilitated tool situation positioned the database management and sensor know-how as relevant features.

It is exciting to note that the outcome of these articles supported the importance of the EDAS method in aiding decision making with applications in logistics, steam boiler choices and smartphone assessment. Yet the

importance of the method has not been demonstrated in the maintenance system with emphasis on the wheat processing plant. Although the studies on autonomous maintenance by Srivastava et al. (2020) and the maintenance performance assessment study of Stefamovic et al. (2017) are in the maintenance domain, surprisingly, leads on how to specifically tailor the research outcomes in these two studies to the special needs of the wheat processing plant is absent. Besides, the prominent KPIs established in our study are the frequency of failure, downtime, MTTR, MTBF and MTTF wheat availability is the response. To our surprise, none of the criteria was discussed in the article and the response was completely ignored in the analysis.

Besides, the methodology promoted by Srivastava et al. (2020) implemented the expert's assessment matrix in a pairwise format while analysing the fuzzy EDAS method and the fuzzy TOPSIS method for comparison. But the factors considered are technology-oriented, including sensor know-how, data management, data analysis and data storage. None of these criteria coincides with our study's criteria. Hence, there is a gap in the literature to address the selection problem with the use of the EDAS method in the wheat processing plant and considering the important criteria mentioned in our study.

Furthermore, there is a growing group of studies that have supported our study on EDAS application and their bias are towards the choice of energy sources, policy development and the selection of optimal energy resources. In this respect, Karatop et al. (2021) tackled the renewable energy investment problem whereby several optional energy sources are considered for the choice of the best option. The considered options are geothermal, hydropower, wind energy, biomass energy and solar energy and analysed using multi-criteria models of EDAS, fuzzy AHP and fuzzy FMEA. The first position was assigned to hydropower based on the data and it was also shown to exhibit a low value of risk. The conclusion was that Turkey needs to focus resources on hydropower as well as wind energy as viable investments in renewable energy. Moreover, Asante et al (2020) worked on renewable energy with particular emphasis on policy development. The approach adopted by the authors involves the joint analysis of MULTIMOORA and EDAS methods to examine renewable energy frontiers. With a case application in Ghana, the outcome of the analysis revealed that particular standards of renewable energy, simplify the certification steps and grid connection quotes are essential. Furthermore, the authors suggested a bottom-up method for policy development. Besides, Yazdani et al. (2020) worked on renewable energy and fused the EDAS approach and Shannon entropy to achieve optimal energy resources. With a case study drawn from Sandi Arabia, it was asserted that wind energy was marked as the most appropriate source of energy that decision analysis should consider for policy and objective formulations in renewable energy.

Indeed, the results of these studies supported the use of the EDAS method in renewable problems. This clean energy that is obtained from natural processes shares the same characteristics of a system as the maintenance system. Thus, by extension, these studies supported the implementation of the EDAS method in the maintenance system of the wheat processing plant. However, besides incorporating the EDAS method in other methods such as fuzzy AHP, fuzzy FMEA, MULTIMOORA and their comparison with the EDAS approach, the parameters considered in the various articles are diverse and do not coincide with any of the important parameters of assessing the maintenance performance of a wheat processing plant indicated in the present article.

A group of other studies have supported our proposal to analyse the KPIs in maintenance with the EDAS method. At the frontline of the studies is the work by Schitea et al. (2019). Here, the concern for hydrogen mobility roll-up site assessment and the choice was discussed and analysed. The authors deployed EDAS, intuitionistic fuzzy set-oriented WASPAS and COPRAS method to a hydrogen site in Romania. Based on 14 criteria segmented along the following lines of reasoning the assessment of the locations was done: economy, fleet, road infrastructure, demography and refuelling infrastructure. Bucharest was the best choice according to the model. Apart from this, Zhan et al (2020) advanced a method called a reflexive fuzzy-neighbourhood operation. The authors deployed the operator to develop a covering-oriented variable exact fuzzy rough set that

tackled the problem of misclassifications and perturbations regarding decision analysis. These methods were joined with the EDAS approach and the PROMETHEE method. The effectiveness of the method was confirmed with examples.

Moreover, Darko and Liang (2020) theoretically analysed the decision maker's action using the EDAS approach. The principal concern was on the deployment of the q-rung orthopair fuzzy Hamacher aggregation operator while relating it to the enhanced EDAS method. It was concluded that an effective approach to establishing weight information was proposed. In addition, Keshavarz-Ghorabaee et al. (2017) modified the EDAS method in supplier assessment and order assignment with the use of an interval type-z fuzzy set. The author affirmed the usefulness of the method with an example.

Interestingly, this set of papers have focused exclusively on the imprecision and uncertainly in values when assessing parameters for selection in a diverse instance such as hydrogen site selection, supplier assessment and theorizing concerning fuzzy methods. While the present article has not considered fuzziness it is appreciated that such a concept may be present in the wheat processing plant. However, as a research strategy, we have omitted this in the current article and hope to analyse it in our next article. Nevertheless, the papers support the idea of the need to implement the EDAS method in the maintenance system. The shortcoming of the papers is that none of our parameters has been extensively deliberated upon.

Another class of studies that supported our work include Mishra et al. (2020) that applied a new type of EDAS method with an intuitionistic fuzzy set. The approach involves the development of measures, evaluation of decision experts and calculation of criteria weights and preference order illustration. With four waste disposal options of landfill disposal, incineration, microwave and steam sterilization considered, the highest score of 0.0725 was allocated to steam sterilisation and preferred as the best option. Further, Behzad et al. (2020) assessed how to solid waste management practices perform in the Nordic countries by viewing from the lens of recycling waste, waste generation, waste-to-energy rate, composting waste, greenhouse gas emissions, recycling rate and landfilling waste. The EDAS method was combined with the best-worst method to judge a practical instance from the Nordic region. It was concluded that Sweden exhibits a superior waste management profile, which was assigned a value of 0.9748. However, with a value of 0.2425, the least performance was obtained for Iceland.

These papers are hygiene/health-related as they discussed healthcare and solid waste management issues. They support the use of the EDAS method in these two areas and by extension, our study on maintenance. Nonetheless, very invited information is profited in them regarding how the EDAS method could be implemented in a wheat processing plant. Besides, the important parameters of the maintenance system have not been expanded in the studies and this gap promotes the need to examine the problem in a wheat processing plant.

All the outcomes of the various studies reviewed confirmed the importance of the EDAS method and its application in the process. They supported the application of the novel method of EDAS in the maintenance system and particularly the wheat processing plant. However, a limitation to all these papers is that the important key performance indicators considered in this article are not treated in detail by such authors. None provided a lead on the application approach to the specific needs of the wheat process plant.

Moreover, in the Nigerian food industry, maintenance planning has a substantial role in offering accurate and adequate services through a parametric selection scheme. However, in Nigeria, Adebiyi et al (2004) in an article on the evaluation of maintenance practices within the food industries established the feasibility of deploying quantitative measures among its various parameters. But this evidence alone on maintenance practices is inadequate to reveal the parametric selection scheme in a manner that sufficiently represents the Nigerian food industry. The current authors of this article were unable to locate previous research that selects parameters in maintenance planning. Consequently, to cover this aspect in the Nigerian food industry, this article had deployed a robust EDAS method to establish the idea in a wheat processing plant. Besides, additional new significant information in the article is the establishment of a regression

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relationship between all the parameters of the maintenance function (KPIs) and availability in a comparative mode with the EDAS method.

Research Gap Analysis

The wheat plant studied is an organisation that does not compromise the availability of the plant. The plant will deploy all the necessary resources to ensure that the plant is available at the utmost and that operations are not significantly influenced by downtime to meet production targets. Although the zero-downtime philosophy is believed to be feasible in the company, a programme such that no breakdown is recorded at all during production, is hardly achieved in the plant. One reason for the non-attainment of this goal is the poor understanding of the relative importance of each key performance indicators deployed in the plant. By understanding the most important KPI the requirements to meet up with the KPI is different from the other. Take the MTTR as a KPI of interest, if it had been chosen as the best, efforts would be to minimise it.

When a piece of equipment breaks down, substantial time is used for troubleshooting, setup time and actual repair time. However, the engagement of a contractor in specialized repairs will reduce the repair time but this may add significant costs to maintenance expenses. For frequency of failure, a high failure rate may suggest that a piece of equipment is old, prompting replacement with a new one. This is expensive. So, the cost incurred for replacing equipment is substantially different from that required to invite an expert for repairs as in the case of reducing the MTTR. But commitment may not be made by the management to either issue unless it is known that one is of higher priority than the other. Unfortunately, at present, there is no measure to enrich our understanding of which of the KPI is important according to the maintenance historical data available in each plant. With the order of importance of KPI known, then adequate budget planning for maintenance could be done and maintenance decisions could be optimally made.

Method

In the present study, the EDAS method was employed since it is an appropriate method for parametric selection in maintenance planning, which plays a significant function in the effective maintenance practices for the food industry. This method requires only two measures of the desirability of alternative (positive and negative distances from the average solution) but excluded the evaluation of the idea and nadir solutions for the key performance indicators of maintenance. It is a reliable and valid method. Besides, several articles, including those of Kikomba et al (2016), Ulutas et al (2017), Kahraman et al (2017), Kundakci (2019), Behzad et al (2020) and Darko and Liang (2020) have used this method.

The Basis to Select Maintenance Key Performance Indicators

In this section, the essential basis that guided the selection of the key performance indicators for the wheat product plant studied is discussed. The wheat plant, among other equipment, manages the packing machine, weigher, pneumatic values, chillers, alarm systems and boilers. The failures of these pieces of equipment and parts cause downtime. Although downtime may be planned to exploit opportunities for holiday programmes or during the introduction of new equipment, unplanned downtime is however common. In this situation, the maintenance manager counts from the time the equipment ceases to function to when the expertise of the repair team has brought about equipment repairs to make the pieces of equipment functional again. Thus, in the wheat plant, the downtime of equipment, for example, the packaging machine could be a leading obstruction to the wheat plant. As the downtime occurs, restoring the machine depends on the competence of the maintenance personnel, the available resources and the time these resources are released for job completion. The deployment of appropriate key performance metrics, including the mean time to repair, frequency of failure, mean time between failure and mean time to failure and adequately controlling them in the context of deploying effective strategy aids the attainment of reduced downtime for the wheat plant. Figure 1 is given about the process in the wheat product plant to permit a better understanding of the article.

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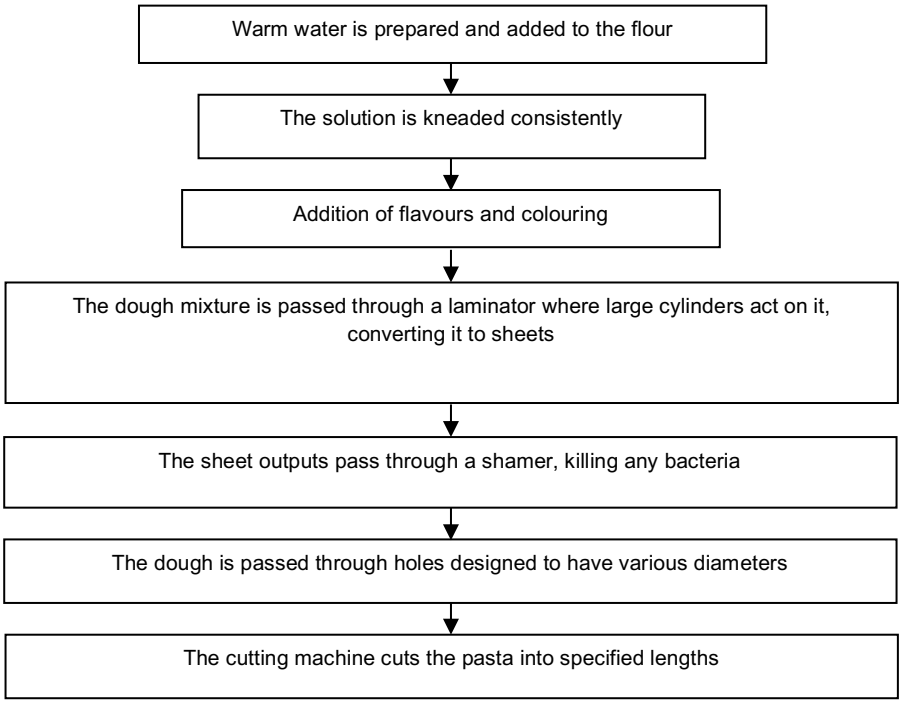

Figure 1. Step-by-step showing how flour is produced

To present a better picture of the wheat product plant the process is hereby discussed. Wheat kernels (harvested grains) are sold through the supply chain to the flour millers for domestic consumption and ground into different kinds of flour. Before grinding, the cleaning and conditioning of the wheat kernels are done, which entail removing the impurities from the kernels and breaking them into further phases to release their parts. Lastly, the process of reduction where the flour is refined and separated into diverse groups is actualized. In the wheat product plant, warm water is prepared and added to the flour. The protein in this process is hydrated, indicating that it absorbs water. The process creates a protein referred to as gluten when gliadin and glutenin combine. This gluten smells and a constant arrangement of fine strands is created. Attempts are made to reduce water surface tension through the generation of high-frequency vibration. The aim is to improve the efficiency of water dispersion on the grains mass as well as water diffusion into the kernel. The solution from the mixing of warm water and flour is then kneaded consistently. The dough is kneaded by working and pressing it into a mass to spread the gas produced by the yeast equally, to make the dough more elastic and smooth and permit a proper blend of the ingredients. Besides, the kneaded dough is passed through holes designed to have various design diameters. Finally, the cutting machine cuts the pasta into specified lengths.

Maintenance Downtime

First and foremost, to measure the downtime of the percussion grinder as an example, it is in actual time. Here, the amount of time that the percussion grinder breaks down during each month is evaluated in hours. The downtime for the percussion grinder may be compared against the average obtained for all equipment. This shows the equipment that is doing well and those that need enhancement. With the equipment availability, which is the response in the process parameters being optimized in a wheat processing plant is considered, establishing the downtime, which may be planned or unplanned, is an essential action. Regarding this, the use of productivity loss computation, taking into account the number of idle production workers multiplied by the fraction of the influence of the stoppage on productivity and the product of the average salary payable per hour by the company and

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the product of the period of downtime which measures the downtime influence, is of substantial value. The downtime is necessary since it exerts a substantial impact on the efficiency of the wheat plant. It also dictates the maintenance policy to adopt: preventive, breakdown, corrective, predictive or a mixture of these actions in an informed and pre-determined proportion. The downtime is significantly responsible for choosing what quantities of products the plant is expected to produce as the marketing department makes deals with the customers. Furthermore, Equation (1) summarises the downtime formula:

Downtime = 1- Uptime = 1 – [(Available Time – Breakdown Time)/(Available Time)] Eq. 1

Mean Time to Repair

The mean time to repair (MTTR) is obtained by dividing the total unplanned maintenance time expended on the wheat processing equipment such as the percussion grinder by the total number of failures experienced by the percussion grinder over a particular measurement space of time. The unit of measurement of MTTR is hours. Furthermore, the mean time to repair metric evaluates the maintainability of the wheat equipment. It showcases the average period necessary to reactivate failed equipment. The mean time to repair is a crucial parameter as the maintenance engineer and manager choose the parameters that will influence the availability of the plant, towards achieving the maintenance target of zero downtime maintenance frameworks. The choice of MTTF becomes it exhibits a direct impact on the attainment of superior availability levels. The MTTF should be a minimum if availability would be enhanced. However, Equation (2) summarises the MTTR formula:

MTTR = (Total downtime from failures) ÷(Total number of failures) Eq. 2

Frequency of Failure

Sometimes described as high, medium, low and in some cases remote, the frequency of failure represents the frequency that the wheat processing equipment such as the percussion grinder fails, measured as failures per unit of time. To appreciate its measurement, the failure rate (frequency of failure) of the percussion grinder during its fourth year of usage could be several many times more than the frequency of failure in its second year of analysis. To calculate the frequency of failure, obtain the ratio of the number of failures to the total number of hours. For instance, a final answer for the percussion grinder may be obtained as 0.016 failures per hour. Furthermore, the frequency of failure metric is commonly called the failure rate and defines the number of times the wheat equipment fails. Commonly described as failures per time, it is also linked to the reliability of the wheat equipment. However, there is a close association between the reliability and availability of the wheat plants. The frequency of failure is a substantial factor that ought to be incorporated in the choice of parameters that impact availability. The reason is that more frequently failing equipment distort production plan, sending signals of moral decline to production workers that have planned to work the day long. Significant progress in product output may be achieved if the failure rate is properly tracked and controlled by the maintenance department. Furthermore, Equation (3) summarises the Failure Rate formula:

Failure Rate = [Number of Failures]/[Number of unit-hours of operating time] Eq. 3

Mean Time Between Failures

The MTBF measures the predicted average time that elapses between a preceding failure of the wheat processing equipment and the subsequent failure in regular function. Furthermore, this metric of maintenance is a forecast of the elapsed period between stoppages of equipment while it is engaged for production. The MTBF connects with the reliability of the wheat processing equipment and is often measured in hours. As an example, the percussion grinder as auxiliary grinding equipment in a wheat processing plant could have been in use for 980 hours in a year. However, during the 2019 accounting year, it may have broken down five times. In the scheme of choosing the parameters influencing availability in the maintenance system, there is substantial

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scope to introduce the mean time between failures. Nonetheless, to promote the least value of MTBF, effective preventive maintenance is recommended as it will greatly prolong the MTBF. This means introducing practice actions to halt equipment concerns before their emergence. However, to make preventative maintenance effective the resources needed by the team should be provided timely. However, Equation (4) summarises the Mean Time Between Failure formula:

Mean Time Between Failure = (Total uptime) ÷ (number of breakdowns) Eq. 4

Mean Time to Failure

The units used to analyse the mean time to failure (MTTF) are hours or lifecycles. The MTTF expenses the association of the wheat equipment's MTBF and its failure rate. Furthermore, the mean time to failure metric evaluates the average period it takes the wheat equipment to fail. The MTTF should be regarded as important when the maintenance engineer and manager are considering the parameters to choose when designing programmes for the availability response in a wheat plant. Besides, Equation (5) summarises the Mean time to failure formula:

Mean time to failure = 1/Failure Rate (λ) Eq. 5

Availability

The availability of the wheat processing equipment is measure by comparing the percentage of time the percussion grinder, for example, is available. Measures of availability allow an understanding of the past and projection of the future service of the percussion grinder. An example of units to quantity availability is 99.955. However, Equation (6) summarises the Availability formula:

Availability = uptime ÷ (uptime + downtime) Eq. 6

The EDAS Method

In EDAS, two measure are central to it functionality, namely, the positive distance from the courage, PDA, and the negative distance from the average, NDA. The distances in these two directions are needed to align with the objective of EDAS, which tracks the average distance from the solution to evaluate the parameters of interest in the study. The PDA and NDA are evaluated from the perspectives of any analysed parameter being beneficial or non-beneficial in the context of the system's objective to achieve the optimum availability for the food industry, each parameter is considered regarding whether its growth will be beneficial to the system or not considered the frequency of failure, its increase will not be beneficial to the system but efforts to reduce it will be counted as beneficial to the system. The MTTF is a measure that is desired to retain a high value. For instance, a longer period for equipment failure means that the equipment will be available most of the time as this is beneficial. However, a low MTTF is not desired because the time a failure occurs is too soon and hence not beneficial to the system.

Consider the MTBF. It means the time between when a failure exists and the other is desired to be high, indicating that equipment gets used up for a long time before it fails. This is declared beneficial. However, if the MFBF is low, it is considered a non-beneficial activity. The metric MTTR is such that its low value is desired and this low value is considered beneficial to the system. But if a high value of MTTR is recorded, it is declared as non-beneficial to the system. The downtime metric is such that being low; the system considers it beneficial. However, if it is high, it is considered non-beneficial to the system.

In the EDAS method, a criterion is a standard by which the maintenance planning subsystem is judged, called the decision criterion. In maintenance, cost-saving may be a criterion while planning for maintenance. However, attached to the different criteria such as cost-saving and ease of implementation of maintenance plans, for instance, are different alternatives. So considering the cost-saving, for instance, the analysis could be made where every parameter considered in this article is mapped to the cost-saving criterion: MTTF, MTTR, MTBF, frequency of failure and equipment downtime. Consequently, diverse options may

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represent the parameters while diverse criteria may involve such terms as cost-saving and ease of implementation of maintenance plan, for instance.

This work uses the steps presented in Aggarwal et al. (2018) to utilize EDAS in this maintenance application. At the outset, the universal set of the diverse options and criteria are defined as follows:

Let P = {1, 2, 3, …, m} define a set of diverse options and Q = {1, 2, 3, …, m} be the set of diverse criteria. Then proceed to step 1.

Step 1: Establish the options and the appraisal criteria regarding the maintenance selection problem statement

Step 2: Establish the decision defining matrix B, introducing the options and the criteria

$$B = \left[B_{PQ}\right]_{j\times k} = \begin{bmatrix} B_{11} & B_{12} & \ldots & B_{1j} \\ B_{21} & B_{22} & \ldots & B_{2j} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ B_{j1} & B_{j2} & \ldots & B_{jk} \end{bmatrix} \quad \text{Eq. 7}$$

Equation (7) is a matrix **B**, which is an array of numbers often arranged in a rectangular form. The entries in matrix **B** are known as B_{ij} which are present in both rows and columns represented by their dimension as a p x q matrix where the matrix has p rows and q columns. Furthermore, thus matrix **B** containing items called entries are written in a bracket. For Equation (7), B_{PQ} represents the appraisal of the p^{th} option on the q^{th} criterion.

Step 3: Establishment of the average solution values for the options regarding the criteria. The average is represented as *AVR* in Equation (8)

$$\text{AVERAGE} = [AVR_{PQ}]_{1PK} \quad \text{Eq. 8}$$

where k = {1, 2, 3} and AVR is the new matrix of size 1pk

But the AVR may be further expressed as Equation (9)

$$AVR = \frac{\sum_{p=1}^{T} B_{PQ}}{t} \quad \text{Eq. 9}$$

Step 4: Computation of the positive distance, PD, together with the negative distance, ND, from the average solution matrices. This is a function of the kind of criteria, which may be beneficial or non-beneficial.

The positive distance from the average matrix, shortened as *PD* in Equation (10)

$$PD = [PD_{PQ}]_{1PK} \quad \text{Eq. 10}$$

The negative distance from the average matrix, shortened as *ND* in Equation (11)

$$ND = [ND_{PQ}]_{1PK} \quad \text{Eq. 11}$$

If the chosen criteria is beneficial, then PD_{PQ} may be expressed as Equation (12):

$$PD_{PQ} = \frac{\max(0,(B_{PQ} - AVR_k))}{AVR_K} \quad \text{Eq. 12}$$

and ND_{PQ} may be expressed as Equation (13):

$$ND_{PQ} = \frac{\max(0,(AVR_k - B_{PQ}))}{AVR_K} \quad \text{Eq. 13}$$

Equations (14) and (15) show the computation of the non-beneficial and beneficial criteria, respectively, as

$$PD_{PQ} = \frac{\max(0,(AVR_k - B_{PQ}))}{AVR_K} \quad \text{Eq. 14}$$

and

$$ND_{PQ} = \frac{\max(0,(B_{PQ} - AVR_k))}{AVR_K} \quad \text{Eq. 15}$$

Step 5: Equations (16) and (17) show the respective computation of the weighted sum of positive distance (SSoP) as well as the sum of negative distance (SSoN), individually for every chosen option. Here, w_k is the weight of the chosen k^{th} criterion.

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$$SOP_P = \sum_{j=1}^{k} w_k PD_{PQ} \quad \text{Eq. 16}$$

$$SON_P = \sum_{j=1}^{k} w_k ND_{PQ} \quad \text{Eq. 17}$$

Step 6: By standardizing the values of SoP (SSoP) and SoN (SSoN) for every chosen option, Equations (18) and (19) are obtained as

$$SSoP_P = \frac{SoP_p}{\max_p SoP_p} \quad \text{Eq. 18}$$

and

$$SSoN_P = 1 - \frac{SoN_p}{\max_p SoN_p} \quad \text{Eq. 19}$$

Step 7: Compute the appraisement score (APS) for every chosen option, Equation (20)

$$APS_p = \frac{1}{2}(SSoP_p + SSoN_p) \quad \text{Eq. 20}$$

where the values of APS_p is bounded as $0 \le APS_p \le 1$

Step 8: Consider the appraisement scores, organize them in a rising array and assign ranks to them. The option showing the maximum value in the appraisement score arrangement is the best while in search of the superior option.

The Case Study

The studied company has a wheat milling operation that serves a broad variety of customers with milled wheat products. The maintenance engineer in the wheat plant has the responsibility to maintain and repair wheat processing equipment and heavy machinery. The scope of these activities entails intermittent maintenance tests, diagnosis, examining malfunctioning of equipment and observing the general performance of equipment. Furthermore, the maintenance engineer is to propose equipment upgrades and ascertain that the plant companies with the legislation on safety and health practices to achieve the above set goals, one of the activities engaged upon by the maintenance engineer are to predict failures before they occur, this is achieved with the idea of predictive maintenance with an integrated condition monitoring system that keeps track of equipment's status for safety and machine efficiency. In this perception, sensors are deployed to take constant measurements to offer important values, including data on vibration and temperature on pumps, for instance.

Consequently, by using these data, the maintenance engineer establishes deviations in machines or equipment functions with the potential to cause machine breakdowns. Furthermore, in the wheat plant studied, the maintenance engineer is expected to take proactive care of the wheat processing equipment, reducing the risk of downtime and foresee failures before occurrence. If any breakdown occurs, the engineer is expected to deploy junior engineers and technicians to resolve the machine problem quickly and prevent the problem's reoccurrence.

Furthermore, the maintenance manager recognizes the changing landscape of maintenance strategy requirements and the need to develop a plan, enhance product quality and achieve excellent service performance of machines delivered to the production department. So, the mix of the maintenance strategy in an efficient manner is considered the engine of success in the wheat plant. But it is often noted that the success of the maintenance effort needs to be measured by key performance indices to decide what strategy among options should be deployed in what percentage to obtain optimal mix. Unfortunately, it is required to also know how to rank and select alternative solutions using parameters as criteria to decide on resource deployment to the maintenance function.

Moreover, several KPIs abound in the maintenance literature and a few are deployed in the wheat processing plant. Unfortunately, there is no prescription on the ranking and selection of alternative solutions using parameters as criteria regarding KPIs to adopt in particular instances. But adopting a KPI which was judged as the alternative solution using parameters as criteria in the wheat processing plant without prior testing of the scenario considered may be misleading and

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counterproductive. As choosing the wrong KPI could offer negative impacts on decisions in the wheat processing plant, the investigator considers this selection and ranking problem to be of significant influence on the future of the wheat processing plant and the development of the industry as a whole, an innovative solution is desired. The development of a novel EDAS approach to select important key performance indicators of maintenance in the wheat processing plant may be the most promising solution to this problem. The principal KPIs that influence the performance of the plant are as follows: frequency of failure, downtime, mean time to repair, mean time between failures and the mean time to repair.

Results and Discussion

The wheat plant studied focuses on two main programme types, namely the company-wide and departmental-specific programmes to make its maintenance service more effective and efficient. The introduction of the philosophy permeates through the whole organization, from inventory management to supply chain management, quality management, production and maintenance. However, the overall equipment effectiveness programme installed in the company is maintenance service-specific. The outputs of these programmes have immensely enhanced maintenance efficiency and effectiveness in the wheat plant. However, to date, no challenging concept has questioned the importance allocated to each of the performance metrics.

The key performance indicators (KPIs), used in the plant, or available for use, are through the knowledge of best practices in the industry. Consequently, the use of EDAS to prioritize the KPIs and study the interactions among them is not known to the maintenance engineer and manager in the wheat plant. In this section, the frequency of failure, MTTF, MTBF, MTTR and downtime were considered as the parameters (criteria) while the response is availability. Data were collected on the downtime for wheat plant equipment. Downtime refers to the period of idleness triggered by the failure of the machine in which the whole system fails to function due to a technical problem on the production line.

In deploying the EDAS approach as a solution method to establish the order of importance and interaction among the KPIs to obtain the utmost availability, the criteria and alternatives must be specified. The criteria are the KPIs, namely the frequency of failure, MTTR, MTBF, MTTR and downtime. These are elements that are considered to be independent variables on which the response, availability, depends. It is to be found out if each of these elements may be taken as equally important or otherwise. As such, historical data on downtime is analysed in this respect. The alternatives are the experiments with numbers considered and for each of the criteria, five experiments have been conducted. In experimenting, it was noted that the MTTF yielded the same value. But it is a criterion, which should be evaluated. So to overcome this problem, the idea of quartiles was used for the experimental value generation in which the first, second, and third quartiles were taken as 25%, 50% and 75% of the initial values and a uniform quartile method was then used to produce the experimental results. Now, the distances of these alternatives from the averages solution are considered. The average been the sum of all entries divided by the number of entries. In this work, availability, which is the response, is the only beneficial item in the work as it is desired. However, all the criteria MTBF, MTTF, frequency of failure, downtime and MTTR are considered as non-beneficial criteria. By following the procedures in section 3.2, Tables 1 to 6 were generated.

Table 1 was developed from the field data from which information regarding the available time, breakdown time and frequency of breakdown among other data were collected. Upon collection, the formula in Equations (7) to (20) were applied and summarized in Tables 1 to 6. To obtain the weights used in Table 1, the well-known analytical hierarchy process (AHP) method was used and this relied on the historical data gathered in the process. The AHP method is based on the consensus of expert's opinions in which the best and worst KPIs for the maintenance plan in the Nigerian food industry were determined on the data collected weekly but summed up and analyzed on monthly basis. However, a limitation of this work is that the expert's opinion was limited to an expert but an

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aggregation of experts' opinions (more than one) is often more reliable than using an expert. Consequently, the weight obtained using the AHP method was 0.05 for frequency of failure, and downtime while 0.15, 0.10, 0.2 and 0.45 were obtained for MTTR, MTBF, MTTF and availability, respectively. To guarantee robust data, the experimental design principle was deployed on the data wherein the orthogonal array of L.25 (5**5) with five factors (excluding availability which is the response) and the number of runs was 25. Based on this array, experimental trials 1 to 5 were repeated from the frequency of failure and the value 109.7 was chosen. Subsequently, the values 1445, 121.7, 147 and 158.2 were chosen as alternatives 2, 3, 4 and 5, respectively. For other inputs, the patterns of the numbers were similarly observed and used to fill table 1. The formula in Equation (9) was then deployed to obtain values on the last row in Table 1. Table 2 was obtained by using Equation (10) on the outcome in Table 2 while Table 3 was obtained by using Equation (11) on Table 2. By using Equation (14) and (15) in Table 3, Table 4 is obtained as the computation based on beneficial and non-beneficial criteria, respectively. Equations (16) and (17) are deployed to obtain in Tables 5 and 6. The remaining Equations (18) to (20) are also used to obtain Table 6.

The term negative distance from the average is based on the response obtained from the various decision-making criteria of frequency of failure, downtime, MTTR, MTBF, MTTF, including the response item availability. Consider a defined origin and a specified direction such as the height of a ship above sea level. However, it is possible to evaluate the distance of a point on the ship from that plane, and this is referred to as the elevation of the landscape. Besides, if the elevation dips below zero, then that point is described to have a negative height or negative distance. It should be noted that the height above this elevation is described as a positive distance.

Beneficial criteria are those that are advantageous to the measurement system. If a criterion is not advantageous to the system, it may be referred to as non-beneficial

Table 1. Design data

Criteria		Frequency of failure	Downtime	MTTR	MTBF	MTTF	Availability
Weightage		0.05	0.05	0.15	0.10	0.20	0.45
Alternative	1	109.67	169.10	1.52	9.87	126.00	0.9910
	2	144.50	265.31	1.89	6.98	134.40	0.9889
	3	121.67	196.06	1.39	7.25	142.80	0.9918
	4	147.00	361.29	2.49	6.56	151.20	0.9854
	5	158.17	350.08	2.27	6.47	159.60	0.9867
AVR_k		136.20	268.37	1.912	7.426	142.8	0.9888

Key: Frequency of failures (failures per hour); downtime (hours); MTTR (hours), MTBF (hours), MTTF (hours)

Table 2. Positive distance from average

Criteria		Frequency of failure	Downtime	MTTR	MTBF	MTTF	Availability
Weightage		0.05	0.05	0.15	0.1	0.20	0.45
Alternative	1	0.1948	0.3699	0.2050	0	0.1176	0.0023
	2	0	0.0114	0.0115	0.0601	0.0588	0.0001
	3	0.1067	0.2694	0.2730	0.0237	0	0.0031
	4	0	0	0	0.1166	0	0
	5	0	0	0	0.1287	0	0

Table 3. Negative distance from average

Criteria		Frequency of failure	Downtime	MTTR	MTBF	MTTF	Availability	SoN_p
Weightage		0.05	0.05	0.15	0.1	0.2	0.45	
Alternative	1	0.0098	0.0185	0.0308	0	0.0235	0.0010	0.0835
	2	0	0.0006	0.0017	0.006	0.0118	0.0001	0.0201
	3	0.0053	0.0135	0.041	0.0024	0	0.0014	0.0635
	4	0	0	0	0.0117	0	0	0.0117
	5	0	0	0	0.0129	0	0	0.0129

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Table 4. The computation of the non-beneficial and beneficial criteria

Criteria		Frequency of Failure	Downtime	MTTR	MTBF	MTTF	Availability
Weightage		0.05	0.05	0.15	0.1	0.2	0.45
Alternative	1	0	0	0	0.329	0	0
	2	0.0609	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0.0793	0.346	0.302	0	0.0588	0.0034
	5	0.1620	0.304	0.187	0	0.118	0.0021

Table 5. The weighted sum of NDA

Criteria		Frequency of failure	Downtime	MTTR	MTBF	MTTF	Availability	SoN_p
Weightage		0.05	0.05	0.15	0.1	0.2	0.45	
Alternative	1	0	0	0	0.0329	0	0	0.0329
	2	0.0031	0	0	0	0	0	0.0030
	3	0	0	0	0	0	0	0
	4	0.0040	0.0173	0.0453	0	0.0118	0.0015	0.0799
	5	0.0081	0.0152	0.0281	0	0.0235	0.0009	0.0758

Table 6. Normalized values of $SSoP_p$ and $SSoN_p$

Criteria		SoP_p	SoN_p	$SSoP_p$	$SSoN_p$	APS_p	Rank
Alternative	1	0.0835	0.0329	1	0.5882	0.7941	2
	2	0.0201	0.00305	0.2407	0.9618	0.6013	3
	3	0.0635	0	0.7605	1	0.8802	1
	4	0.0117	0.0799	0.1401	0	0.0701	5
	5	0.0129	0.0758	0.1545	0.0513	0.1029	4
Max		0.0835	0.0799				

Comparison of Results from Using the EDAS Method and Predicted Values from Regression Analysis

The experimental data has been used (Table 1) and the final results using the EDAS method is shown in Table 6. But how well could these results be predicted by the regression model is not known. Consequently, an inquiry is launched along this direction using the final results attached to the various parameters through the computation of APS_p, which consists of the normalised values of the $SSoP_p$ and $SSoN_p$. These values range from 0.0701 being the least to the highest value of 0.8802. Thus, in applying the regression method, the data obtained from the field (Table 1) is used where the matrix is fixed to the Microsoft Excel data analysis tool such that the parameters of frequency of failure, downtime, MTTR, MTBF and MTTF are taken as the independent variables and availability is the dependent variable. The analysis was done at a 95% confidence level and the results obtained revealed equation 21 as the regression relationship between all the parameters of the maintenance functions (KPIs) and availability.

AV= 0.9897 + 3.1795E – 05FF – 4.6193E – 05DT + 5.0838E – 05MTTF Eqn. 21

(

where AV, FF, DT and MTTF are availability, frequency of failures, downtime and mean time to failure, respectively.

It was noticed that MTTR and MTBF have a negligible effect on the model and hence are not captured by the regression equation. Based on Equation (15), which shows the predictive equation, substitutes of experimental figures from Table 7 is made to obtain the predicted availability, which can be compound with the experimental figure in Table 1. Here, the values of 0.7941, 0.6013 and 0.0701 were substituted for FF, DT and MTTF, respectively in Equation (15) and the AV value yields 0.989732008. But the experimental data obtained from Table 1 is 0.988. This shows an error of 0.0942%, which reveals that the regression model almost accurately predicts the availability values based on the EDAS results and that our model is reliable.

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Table 7. Comparison of results from the current paper (EDAS method) and literature data

	Current paper (EDAS method)		DEMATEL (Maduekwe and Oke, 2021)		Taguchi scheme-motivated DEMATEL (Maduekwe and Oke, 2021)		Taguchi-Pareto scheme-motivated DEMATEL (Maduekwe and Oke, 2021)	
KPIs	APS_p	Rank	(D – R)	(D + R)	(D – R)	(D + R)	(D – R)	(D + R)
Frequency of failures	0.7941	2	3.2896*	22.7758	0.0013	0.0059**	0.1380	0.1520
Downtime	0.6013	3	–6.7546**	28.7764*	0.0031*	0.0107	0.1323	0.1519
MTTR	0.8802*	1	–0.075	24.0580	0.0009	0.0061	0.1407	0.1475
MTBF	0.0701**	5	–1.8608	28.5886	0.0027	0.0065	0.1422*	0.1556*
MTTF	0.1029	4	2.9520	21.3136**	0.0026	0.0062	0.1395	0.1455
Availability			2.4488	21.7756	-0.0053**	0.0113*	-0.0028**	0.0028**

*highest values, **lowest values

Comparison of the Current Paper with Data from the Literature

The data collected from the wheat industry has been analysed using the EDAS method in the present work. However, the same case study investigation had been previously examined using three methods: DEMATEL, Taguchi scheme – motivate DEMATEL (T-DEMATEL) and Taguchi – Pareto scheme – motivated DEMATEL (TP-DEMATEL) (Table 7).

Since the source of data is the same, it is interestingly to note the performance of the various method compared with the EDAS method, which had been used to analyse the data in the present study. Consequently, based on the results obtained from the application of the various methods, the following conclusions are drawn:

1. There is a disagreement of results of the highest value for the EDAS method (MTTR at 0.8802) with all other methods of DEMATEL, T-DEMATEL and TP-DEMATEL. This may be due to the introduction of an optimisation mechanism in the T-DEMATEL and TP-DEMATEL methods, which enhanced the performance of their models. However, optimisation was not done in the current wish and may be the subject of future studies.
2. Regarding the lowest values, the EDAS methods chose MTBF (0.0701) as the least contributor to the improvement of performance in the maintenance system. However, the results of the TP-DEMATEL method concurs with the EDAS methods result in our method both in the (D - R) relationship as 0.1422 and the (D + R) association as 0.1556. Thus, our model is sensitive to the choice of the worst-performing parameters (KPIs) for the maintenance system. Further work is expected in the future to see the magnitude of the differences of other methods since the DEMATEL chose Downtime in the (D - R) relationship, as -6.7546 and MTTF in the (D + R) association as 21.3136. Furthermore, the T-DEMATEL chose the frequency of failures as the worst case (with a D + R value of 0.0059) and availability to represent the (D - R) relationship, as -6.7546 and MTTF in the (D + R) association as 21.3136. Furthermore, the T-DEMATEL choose the frequency of failures as the most case (with a D + R value of 0.0059) and availability to represent the (D-R) association at a value of -0.0053

Nonetheless, this work has limitations that should stimulate further research. In this article, the EDAS method has been to analyse a wheat processing plant. To achieve the aim of the article, the traditional perceptive that use the same averaging method has been deployed to the wheat processing plant's analysis of the parametric selection scheme. However, in reality, the averaging method used should be according to the structure of the problem tackled. Thus a different averaging method may be required such as geometric, harmonic and quadratic. Future studies may find this aspect very interesting. Furthermore, as a result of the restriction imposed by the company management during data collection, the experts used for the study are not representative. The same could be improved in future research. An interesting study may be to extend the study to the packaging industry. A choice among various types may be necessary, including polybags, corrugated boxes and chipboard packaging, among others.

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Implications of the Study for Practice and Society

The maintenance of wheat processing plant equipment is extremely expensive and this makes it impossible to establish preventive maintenance only in the plant. On the other hand, installing, condition-based maintenance may not be the sole focus of the maintenance department as monitoring equipment are very expensive to deploy in the wheat plant. Also, breakdown maintenance is not possible to implement as huge losses of production may be the case. In this dilemma of the maintenance manager, a blend of preventive, condition-based and other categories of maintenance is implemented but with close attention to the maintenance key performance indicators. Unfortunately, there are scarce mechanisms to establish the relative positioning of the KPIs and their ranks in the maintenance function and in the context of blending the maintenance strategies.

But the successful development of new selection and ranking ideas for the maintenance KPIs is critical for the wheat plant to enhance the maintenance process through the adoption of correct blends of maintenance strategies. The EDAS method in its applied form to the selection and ranking of KPIs in a wheat plant aims to enhance maintenance efficiency through timely suggestions of the best and worst maintenance factors for proactive resource deployment and distribution within the maintenance system. More importantly, the EDAS method's deployment will enhance maintenance profitability. The EDAS method's innovative practices in maintenance entail commercial use and successful development in the wheat plant. It is argued that beyond the theoretical merits of the approach as an effective selection and ranking method, the EDAS approach has a commercial application in maintenance engineering and needs to be successfully exploited for the wheat plant.

The introduction of the EDAS method to maintenance selection and ranking in a wheat processing plant adds value to the maintenance practice of strategy selection. This differentiates the plant that we are studying from others as the right blend of maintenance strategy adoption promotes the environment at the friendliness of the maintenance plant. This enhances the perceived value of the wheat plant to the government, customers and the target market. In the long run, the innovative EDAS approach idea will assist to reduce or eliminate environmental pollution penalties (cost), build value for the organization's brand and make it more competitive. However, failure to implement the EDAS method in the wheat plant makes the organization run at risk of decline in efficiency and losing money and key staff that values innovation.

Another practical implication of the EDAS method, as innovatively proposed to enhancing maintenance, is to help the maintenance manager consolidate and leverage knowledge from the implementation of the EDAS method and external collaborations and external networks such as the society of engineering professionals or the association of maintenance engineers. In the manufacturing industry in developing countries, there is a growing interest in cooperative activities whereby maintenance managers share perspectives from different angles of innovative concepts, expertise and maintenance capabilities. This consolidation and the leverage of knowledge is often done within the group of companies managed by the same owners. In this arrangement, opportunities are created for sister companies to exploit that scale of innovation and expertise and this could be extended to the EDAS method proposed innovatively in the present article.

With this, the company where the method proposed is installed could serve as a lead. Nonetheless, working collaboratively in the group of sister companies offers challenges, including the high cooperative cost due to the diverse locations of the sister companies. The lead's (our implementation company) resources are often stretched, but cooperative agreements may be made with the sister companies for financial and logistics support.

Furthermore, this research supports knowledge improvement in maintenance planning by attempting to discover the parametric selection scheme within the Nigerian food industry. The study's findings guide researchers that strive to understand the idea of parametric selection in maintenance planning, employers that attempt to regulate maintenance planning in time and financial control, policymakers such as governments that attempt to protect the environment and the community at large, arguing the necessity to change the parametric selection procedures and policies on maintenance strategy regarding maintenance

plans. This research could bridge a gap in worldwide consultation through analysis of the key performance indicators of maintenance in the Nigerian food industry. An additional enhancement is achievable by the generalization of the ideas. Consequently, this research may offer a basis for novel ideas, to add to the maintenance literature particularly from the perspective of maintenance planning restricted to the food industry.

Conclusions

In this article, a maintenance multicriteria problem is solved. In the problem, there is a set of weighted criteria and a set of alternatives, and the solution is the alternative that scores best in those criteria. Thus, the conclusions from this article are as follows:

1. The EDAS method is used as a multicriteria decision-making tool for the maintenance system. It is used to rank and select key performance indices as alternative solutions using the KPIs as the criteria.
2. The EDAs method was used for selecting the best alternative (MTTR, 0.8802). Thus a score of 0.8802 is for an alternative.

However, this work has limitations that should stimulate further research. Future studies may apply the key performance indicators proposed by this work to other industries such as the packaging industries. Furthermore, this work applied only an expert to create alternative plans. Future studies may replace this approach by applying many experts to enhance the validity of the study. Besides, this study only analyzed five parameters to enhance the availability of food equipment in the Nigerian Industrial sector. Further studies may not be limited to these parameters but may form the initial development of a causal relationship diagram of the key performance indicators as they influence maintenance and availability in general.

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