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Uma Reflexão da Literatura Sobre Técnicas Computacionais Aplicadas À Gestão Da Manutenção de Trens

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RESUMO

Este texto tem como objetivo fornecer orientações sobre o estado atual da literatura sobre aspectos relacionados à aplicação de recursos computacionais para melhorar a gestão da manutenção de material rodante e, com base nisso, propor diretrizes para pesquisadores sobre o assunto. Este estudo apresenta uma revisão de literatura com artigos de pesquisa aplicada. Em conclusão, verificamos que programação linear, algoritmos genéticos e redes neurais trazem bons resultados no auxílio aos gestores de manutenção ferroviária. Importa referir que ainda existe uma preferência pela automatização do trabalho manual de forma a conseguir a redução de custos ou maximizar a utilização dos recursos de manutenção. Devido ao grande aumento de pesquisas sobre aplicações de recursos computacionais, este artigo traz generalizações de aplicações para o mesmo tema, que é a manutenção do material rodante e a dificuldade de gerenciamento desses ativos.

Palavras-chave: planejamento e controle de manutenção; estrada de ferro; modelos computacionais.

Abstract

This text aims to provide guidance on the current state of the literature on aspects related to the application of computational resources to improve the management of rolling stock maintenance and, based on that, propose guidelines for researchers on the subject. This study presents a literature review with applied research articles. In conclusion, we found that linear programming, genetic algorithms and neural networks bring good results in helping railway maintenance managers. It should be noted that there is still a preference for automating manual work in order to achieve cost reduction or maximize the use of maintenance resources. Due to the large increase in research on applications of computing resources, this article brings generalizations of applications for the same topic, which is the maintenance of rolling stock and the difficulty of managing these assets.

Keywords: maintenance planning and control; railway; computational models.

1. INTRODUCTION

The use of maintenance as a support tool in asset management is not a new practice. With the present and easy access to technological resources, increasing the reliability of the components can be considered a survival strategy for any company. Railway companies do not treat maintenance differently, as they create ways to control the factors to manage the resources of this activity and drive continuous improvement.

The understanding of scientific approaches to the solution of maintenance problems allows us to show that it can increase the profit margin, create analyzes using computational algorithms and thus assist in directing the management of people or materials (Tonissen, 2018 & Arts 2018). With the development of computational methods, less dependence on learning from human experience has been created, in addition to the better use of its historical dataset, so that the knowledge curve in an environment and the employee turnover minimally affect the flow of information production.

Using the resources of railway maintenance is a topic of interest not only academic, but also corporate, as it requires a considerable capital investment (Lai et al.,2015). For the train to reach its goal of transporting people or cargo within the stipulated time, it must achieve productive improvements in costs and the maintenance production line. At the same time, continuous improvements in planning have become a requirement for a company's survival.

The train, in the context described here, is the union between the locomotive(s) and the wagons(s). This set of assets, which can also be called rolling stock, can be constantly optimized for maintenance by computational algorithms. The main objective is to increase availability and operability, in addition to improving the reliability of delivery times and adapting to unstable, current and future customer demands (Mira et al., 2020).

Planning and control in the context of railway research areas is generally applied to the planning of train movement and operation times, for a heuristic reordering that prepares drivers at the right time. This research evaluates the search for data mining so that the maintenance focused on the rolling stock is efficient and does not cause delays in the operation of the train (Turner et al., 2016). In the same way as the assessment and planning of the operation of the trains, the maintenance of the railway components must also be taken with the same seriousness, as poorly predicted failures can cause delays in the delivery of the transported product and even serious accidents.

The railway gains more prestige when using computational resources, to improve its main organizational performance indicators. Over time, this means of transport has been recognized as an aid to sustainability, economy and safety in cities (Erguido et al., 2020). The increase in the movement of trains is not proportional to the volume of the undercarriage wear. This analogy creates uncertainties in the maintenance plans, which influences the growth of the interrupted service tariff, causes a profit reduction and increases the need for technologies to perform better evaluations. (Gençer et al., 2020a).

The objective of this research is to carry out a literature review of case studies, which are used in the planning and control of the maintenance of railway rolling stock. In this way, we were able to describe how the computational algorithms used by companies optimize the restoration of their rolling stock. More specifically, this research evaluated the use of computational algorithms to create cost savings, or increase train maintenance production. The result of this research is a mapping of articles published in magazines that answers the following question: "What are the algorithms used in the literature, to create improvements in train maintenance planning and control?". The contributions of the proposed approach were:

- A general understanding of the main focus activities of maintenance planning and control;
- Understand the complexity of the railway to keep the rolling stock in good condition;
- Exemplifications of the use of linear programming to bring simpler guidelines in maintenance planning and control, with historical and complex databases;
- Case studies that can guide applications of genetic algorithms, together with people with experience of the process, to achieve improvements in maintenance planning;
- Applications of neural networks in improving the maintenance of trains, highlighting in a case study the researcher reported that he did not need to use a deep knowledge about the object of study.

This article achieved these findings by conducting a literature review related to the planning and control of railroad maintenance in order to improve the process of recovering the rolling stock. Subsequently, the contextualization and exemplification of the computational techniques used to model the process and improve planning efficiency begins. Then, case studies that apply computational algorithms to maximize production or minimize costs are reviewed.

2. METHODS AND TECHNIQUES OF RESEARCH

Submissions must be accompanied by a Cover letter, which must highlight its adherence to the Editorial scope of the journal, theoretical and practical relevance, aims, methods, main results and its original theoretical, empirical and/or methodological contribution. This proposal can be categorized with theoretical-applied work. Among the works of this type are the literature reviews used to identify, know and monitor the development of the research, in addition to raising the main concepts, applications and allowing direct coverage of primary and secondary sources. When this evaluation is well performed, it becomes possible to create possibilities for new proposals, in addition to better targeting the contributions of a specific situation (Almeida & Miguel & Silva, 2011). The reviews are classified according to the purpose of execution, scope, function and type of analysis. Evaluating the conceptual work of Noronha & Ferreira(2000), this work can be explained as follows:

●As for the purpose of the review: it is analytical, as it aims to evaluate a specific theme and to group case studies that occurred in the planning and maintenance control, in this case, in the literature on the theme "railroad".

●Regarding the scope of the Review: it is thematic, since it addresses the specific focus on existing applications, related to studies that work with computational algorithms for the purposes of the review.

●As for the review function: it is updated, as it considers the possible applications of computational and management concepts, in a compact way, allowing to bring insights to those interested in the topic.

●Regarding the treatment and approach of the review articles analyzed: it is bibliographic, without pointing out or heavily criticise the research used. This work aims to build a subsidy that exemplifies and gives the possible applications of computational algorithms that facilitate the work of the planner and executor of the maintenance tasks of a train, with the selection of research focused on case studies.

The work was divided into two stages, the first being a bibliographic review on train maintenance planning and control and the second showing computational algorithms applied to bring excellence to the topic in question. The literature review included the search, retrieval, selection and organization of scientific production sources, based on case studies citing characteristics and later the advantages and disadvantages of each proposed model. The search initially occurred through the selection of articles available on Google Scholar, which contained the term "railway maintenance planning". Then, it was mapped in its bibliographic references, which of the citations of these articles were case studies that used computational algorithms to assist the maintenance of trains, in addition to other cross-reference sources obtained.

The individual experimental knowledge of each worker cannot be simply discarded from an organization, but it cannot be unique, as in many railways in the world (Hipólito et al. 2019). For the mentioned reason, this research sought to demonstrate how the maintenance planning of a rolling stock can be done not only with the aid of simple spreadsheets, but also with studies developing mathematical models capable of evaluating the high number of variables and restrictions. This bibliographic review sought todefine what would be "Maintenance Planning and Control" and essential concepts that bring the importance of research on the railway, with a rolling stock focus. Then, a selection of computational algorithms was made within the academic articles, whose research demonstrated the ability to promote continuous improvement in the maintenance process. Once the works were evaluated, it was possible to describe important particularities of the case studies. The observations made in each research, allowed to bring an application view of the ways of modeling a problem, using a computational algorithm and proposals that direct any researcher of interest to go deeper into the desired theme.

3. ROLLING STOCK MAINTENANCE PLANNING AND CONTROL

This topic aims to demonstrate the importance of maintenance planning and control in the industrial context, justifying its need to track, ensuring the integrity of the functions of the railway assets and the delivery quality of the final product, with the assistance of the Maintenance Team (Costa, 2013).

3.1 Maintenance Planning and Control

Maintenance is the initiative that organizations formalize as an activity, to avoid resource failures and encompass business techniques and strategies (Slack et al., 2009). Maintenance managers must be aligned with deficiencies and points for improvement, in order to manage the available resources and deliver the product with the desired quality assurance. Studies of improvement and development of technological innovation in this context, normally must be initiated by the leaders of the strategic area and later aligned with the managers and collaborators, to guarantee the efficiency(Josemar and Barbosa, 2021). By working with computational algorithms, you can increase the efficiency of traditional maintenance environments and create the opportunity to require continuous adaptation of your value strategy and operational workforce, without sacrificing the quality of the desired resource (Souza et al., 2008).

The problem consists in defining the minimum of human and / or material resources, in order to reach the maximum volume of maintenance production and / or to maximize the maintenance production given a variable set of resources. To this end, it is necessary to respect the available resources in the cash flow of the public or private initiative (in question), in addition to the physical, legal and financial needs and limitations of the labor that adds value to the raw material.In theory, maintenance planning and control should involve technical mastery over assets, in order to be able to create assertive predictions about their reliability, but statistical analysis can bring greater strength to decision making. The subject in question also assesses the transformation process, which must be properly mapped, so that the raw materials and knowledge are sufficient to guarantee the efficiency of the maintenance investment.To create improvements in the maintenance process, coworkers can not be a manager's concern cause, as they are the ones who know how to create improvements and make decisions that computers are not capable of. Figure(1) shows the main pillars of maintenance planning and control in addition to exemplifying some difficulties.

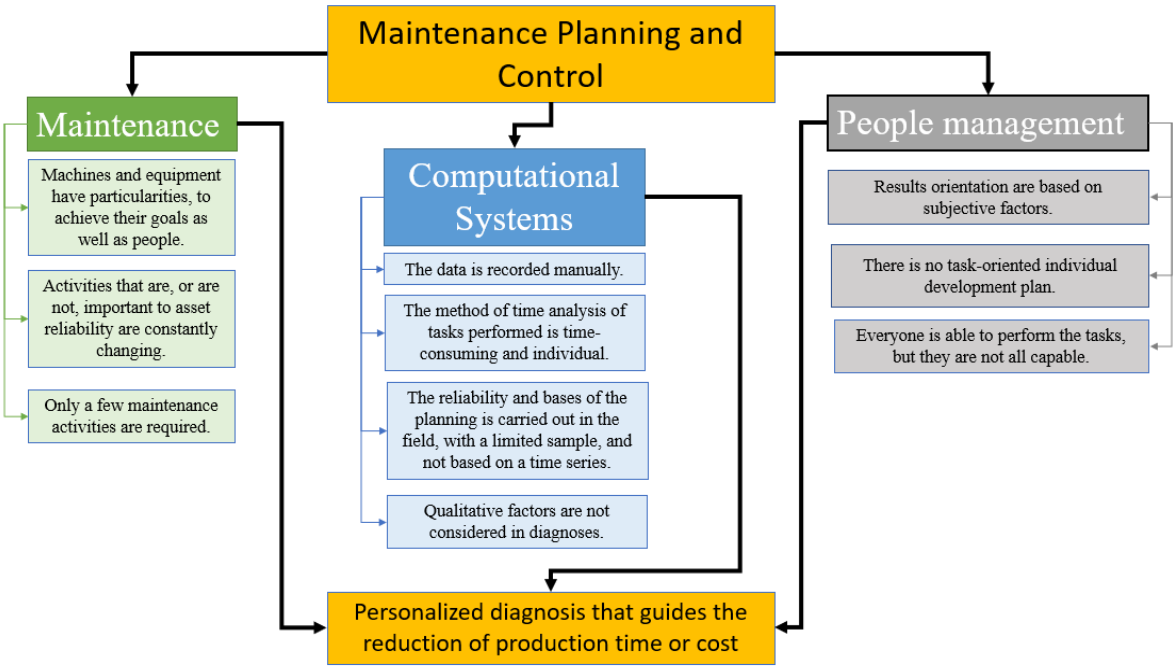

Figure 1- Groundwork of Maintenance Planning and Control and some difficulties

Computers must be used as powerful tools to perceive reality, assess which procedures are best and build a vision of the future in routine, organizational tasks or to obtain competitive advantages over its competitors. As competent maintenance performance was considered an advantage in relation to the market, it is common to find databases created in a hurry and without due study. With the growing approach and disorderly growth of some companies, tacit knowledge has gained greater value than explicit and new technologies and innovations encounter some barriers in the modernization of maintenance resources (Ramos & Schrattner, 2020).

A real case study of the Shanghai Railway, showed that it is possible to combine knowledge about computational resources to reduce costs in maintenance plans at railway companies. Train maintenance planning is a problem that can be controlled through discrete mathematics and various algorithms and computational methods in the Middle East and the West, such as Artificial Neural Networks and Genetic Algorithms. The calculations made must be accurate, so that you do not have excessive expenses and do not have unforeseen breaks.

With a well-structured database, it becomes possible to create a regression model with different computational resources and reduce errors in production planning (Wu et al., 2018b).

Since the 1990, it has been found that, to control and monitor maintenance planning, it is necessary to seek computational resources and domains, which underlie the administrative, economic and social processes present in the organization. When the manager is properly trained and invests in the development of new resources, it is possible to reduce the risks of implementing cost reduction programs, inventory sizing and outsourcing balance, for the development of any business (Belhot & Campos, 1995). The problems of a maintenance planning and control environment usually consider as a database to create a management resource the quantity of products and their unit prices, in addition to the need for working hours and their cost of labor.

3.2 The Railway and Undercarriage

The railways were fundamental to solve the problems of communication and movement of people and cargo in the 19th century. The iron train replaced carriages in the modern era in 1814, with the first locomotive and was a milestone in the relationship between man and technology. The industrial revolution boosted the search for the technological development of means of transport and the reduction of circulation costs. In order to serve its customers, technology has transformed and further adapted the use of the train to reach new markets through research and innovation (Borges, 2011).

In common sense, locomotives, wagons and lines that make up the permanent track are what make up a railroad, but there are "secondary" assets as important as these, which are not very visible. Like the operation planning sector, which in structured companies has important computational resources to guide drivers. Maintenance planning also uses this technology to work with the financial and operational control efficiency in the asset recovery practice. The most striking component of a train is the locomotive, this machine has several different models with different characteristics of cost and power, which gives a company flexibility and complexity in planning and controlling the maintenance and operation of the train. Machines that bring beauty to logistics, can pull or tow any pair of wagons and have high maintenance costs and specific tools to ensure their smooth operation (Santos, 2014).

Wagons are the second item that makes up the rolling stock (train), this asset is responsible for transporting the cargo and can have cylindrical, rectangular, closed or open shapes, in addition to being able to contain people or cargo. The aesthetics of this asset depends on its target objective and its complexity requires evaluations of both the components and the 5 major subsystems that constitute it (Structure, Trick, Shock-Traction, Wheels and Brake System). Depending on demand, maintenance plans for this type of railway asset change, as trains can be made up of different numbers and types of wagons, depending on the customer's volume and needs (Freitas, 2015); (Felix et. al., 2021).

To optimize the maintenance cycle and increase the availability of rail vehicles, large investments may not be necessary. Working with computer software brings greater assertiveness in planning controls, because with this method it is possible to associate the level of reliability, mileage and abstract decision making, so that the system as a whole reaches its objective (Xu et al., 2019).

4. MODELS FORMED BY COMPUTATIONAL ALGORITHMS

This topic describes the resources available in the literature for using algorithms capable of modeling and providing guidance for optimizing a maintenance planning process. This topic shows important aspects about the case studies and particularities that can assist in new applications of computational algorithms, to provide a more assertive search in the search for problems in the control of the management planning of train recovery.

4.1. Linear Programming

The case studies have shown that the works can be modeled using linear programming techniques. Papers built with research by the authors Gábor Maróti in partnership with Leo Kroon have similar approaches and seek to solve maintenance routing problems, in addition to being common in this area as a source of information and knowledge. These researchers reported that the application was only possible after a thorough work of understanding computational algorithms, routing, linear programming and people management in maintenance. There was a need to modernize the management system and search for less dependence on learning knowledge, based on the trial and error of its employees (Maróti & Kroon, 2005). In one of these works, the same authors gave more details about the same applications with complex results, with suggestions for better solution methods and computational results based on practical instances (Maróti & Kroon, 2007).

These studies have been realised with the support of the method called linear programming, which can be considered a computational technique capable of being applicable in branches of productive activities or services, and can be found in any computer application (Wagenaar & Kroon, 2015). Linear planning approaches made it possible to work with poorly structured databases and with a lot of unimportant information. The evaluation of these parameters was only possible because railway specialists created improvements in the resources management with computational use, since only data specialists would not be able to evaluate and bring valuable results to the organization.

There are authors who claim that this technique is a topic of informatics and its ramifications can be used by simple and sophisticated planning teams. Among the advantages, it is possible to highlight the possibility of identifying bottlenecks in productive environments and the ability to expand the study factors, to evaluate the application potential (Prado, 2016). There are disadvantages in using linear programming, the most important is that it can only be applied in cases where the objective function (FO) and the constraints are linear polynomials (Pilar et al., 1998).

Be X, in a maximization problem, a vector of decision variables, consisting of the available hours of work and the raw material volume to carry out the process, C is a transposed vector of unit costs associated with the variables X. So, with the construction of A, a matrix of coefficients for the variables X in the restrictions of the problem (Budget) and b is a vector of upper limit of restrictions (spending limit), makes it possible to form the Equation 1, to achieve the optimal number of resources for maximum maintenance production.

$$Max\ C^t X \quad (1)$$

S.a:

$$AX \leq b$$
$$X \geq 0$$
$$X \in R+$$

When it is necessary to seek cost reduction, it is possible to construct a problem of minimizing human or material resources, in which the production volume that previously constituted vector C in Equation 1, becomes a component of vector X together with one of resources of interest mentioned above, which constitutes the vector C process. With this information, the mathematical formulation can be changed to identify what is the minimum of physical or material resources to achieve a given production, or to identify what is the maximum of production possible with a minimum number of resources. The constraints constituting matrix A of coefficients of the variables x restrictions, are now constituted by fixed parameters of the desired production plus some material or human resources, which are not found in the required solution, always considering the budget as limiting the evaluation.

Even in studies that require stochastic analysis, a preliminary analysis using linear programming is interesting, as it can facilitate the choice of maintenance script parameters, to later use more advanced techniques (Tonissen & Arts, 2020). Due to the strategic nature of the facilities, factory design and customer service, the railway can generate a high annual cost of installation to maintain its services and possibly more than a computational resource to be able to monitor its complex assets (Giacco et al., 2014). The evaluation of the routes of the transport operation considering the type of composition, is a way to serve a multiple volume of customers, but it adds complexity to the maintenance evaluations. Linear programming is able to simplify the variables that interfere in this material investment decision, to minimize the costs of maintaining the process (Andrés et al., 2015).

Efficient rolling stock programming is a concern for railway companies worldwide. At China High Speed Railway, planners are responsible for manually scheduling the maintenance of trains. Decision making depends on the knowledge and experience of the sector in question, but research with linear programming has helped to choose the best constraints that impact the system and facilitate decision making. The company's investments in research in China have led to a reduction of approximately 10.5% in operating costs and a reduction in the complexity of planning and evaluating maintenance (Zhong et al., 2019).

Dutch Railways, the main railway company in the Netherlands, sought to give more support to managerial perceptions, as the location of the rolling stock for maintenance brought uncertainties in the planning and handling of the fleet. This problem was dealt with in detail, as the costs of making interference are high in creating improvements and it took a long computational development work to point out and simplify the variables that most impact rail maintenance (Tonissen et al., 2019).

Linear programming can help to solve parts of a problem and thus later, use another algorithm to achieve the desired improvement and the best path for the relationship between time and cost in planning and controlling maintenance (Luan et al., 2017). In this context, it becomes possible to optimize the working time of maintenance tasks considering the routes, movement and reliable behavior of the trains (Wagenaar & Kroon, 2015). Mixed models of entire programming, in the mentioned context, are able to facilitate the ways of tracking each railway unit that needs maintenance, evaluating and, if necessary, reprogramming the maintenance plan. These applications showed that linear programming can avoid unforeseen events in the circulation of undercarriage (Wagenaar et al., 2017).

To improve the maintenance volume of the rolling stock, the linear schedule has already been applied to meet the time and safety requirements, aligning strategic goals with the scheduling of maintenance tasks (Mira et al., 2020). The mathematical models creation, using computational resources, helps in the uncertainty of quantitative techniques and facilitates the maintenance schedule. Initiatives to use logical computational resources can be a trigger to improve the production of railway management, when access to data validation can be made between the researcher and the company that consents to the information.

In the technical railway context, linear programming is able not only to evaluate objectives, but also to assist in the behavior of machines essential to the rolling stock. An example is the possibility of evaluating the reliability of a wheel lathe. When you have the dimensions of the train wheels, it becomes possible with computational algorithms, controlling the item restoration process, assessing the wear and tear in the use of physical and human resources in addition to keeping the equipment in good condition on the railroad maintenance planning (Andrade & Stow, 2017).

In some problems treated by means of heuristics and the use of hybrid algorithms, they make it possible to obtain solutions at a reasonable computational cost. Linear programming in case studies may not be the only resource to solve the problem in question, but it is a resource to prepare databases and achieve, with other techniques, the maximum capacity of a manufacturing environment. Linear programming is capable of working generically with problems in areas considered by common sense to be totally different, such as material failure and physical variations of a worker. This technique is able to evaluate the indirect factors that affect maintenance planning and control over time, in addition to assisting in the analysis of redundant and disorganized databases, which makes it useful in case studies that address the topic in question.

4.1. Evolutionary Algorithms

There are articles that prove that the mastery of genetic algorithm techniques, associated with the possession of well-structured data makes it possible to find solutions to improve maintenance planning. The literature seeks solutions in algorithms based on "simple" elitism, to always preserve the best individual and guarantee the best next generation, thus providing case studies with the best condition for the variable in question (Bento & Kagan, 2008).

Genetic algorithms (GAs) are ways of optimizing heuristics that use randomization and artificial intelligence to achieve the best parameters for a given result. To apply any algorithm and obtain good results, it is necessary to study, understand and visualize in a clear and objective way, the problem of the environment that can be automated (Sriskandarajah et al., 1998).

We can mention the advantages of using genetic algorithms, the ease of dealing with the discontinuities of the variables, as there is a small effect on the response surface. The technique in question is capable of considering the complexity of the system and only the particularities, in addition to executing large-scale optimization problems very well and being simple to apply to the most diverse optimization problems. Among the disadvantages of GAs, we can mention the low efficiency for problems solved with other algorithms that reach an approximate solution, in addition to being difficult to evaluate and modify GAs developed by other researchers. There are studies that point out that to use this technique, it is necessary to know the meta-heuristic tools and their limitations, to achieve better results (Tsuruta & Narciso, 2000).

The genetic algorithm addresses the possible solutions to the problem of optimization of maintenance planning and control and takes as parameter the best transformation resources (individuals), constituent of a database with a determined volume of tests (population), which will be selected as ideal according to the budget evaluation (evolution and selection). For that, it is necessary to build an evolution model, in which individuals are the ideal volume of resources to find the desired production. The basic components for the construction of the previous reasoning, were based on the scientific disclosures of Pozo et al. (2005) and enabled the construction of Figure 4, explained in Table 5.

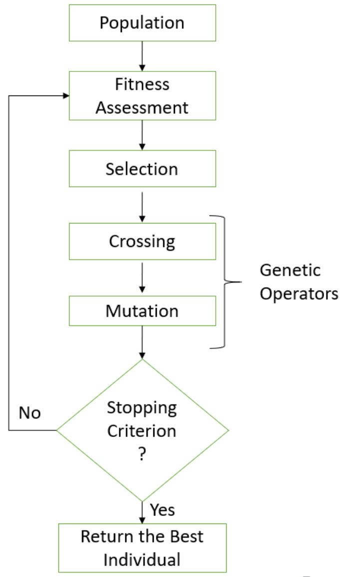

Figure 1 - Basic structure of an algorithm.

Source: adapted from Pozo et al. (2005).

Table 1 - A genetic algorithm basic operation execution.

Phases	Description
1	Initially, an initial population is chosen, usually formed by individuals (production resources) created at random.
2	The entire population of individuals is evaluated, according to criteria determined by budget limits and determines whether the available individuals are suitable ("fitness" function).
3	Then, through the "selection" operator, they choose the best resources previously selected and become the basis for creating a new set of solutions, called the new "generation".
4	This new generation is achieved through the application of operations in selected individuals that mix different types of human and material resources (characteristics called "genes"), through "crossing" operators, in which new individuals are developed combining characteristics of two individuals, and "mutation", an operation that randomly modifies some characteristic of the individual.
5	These steps are repeated until an acceptable solution is found, until the predetermined number of steps is reached, or until the algorithm is no longer able to improve the solution already found.

Source: adapted from Vianna & Vianna (2014).

As found in applications of other techniques, genetic algorithms also have examples capable of designing maintenance strategies that are able to guarantee the reliability and availability of assets without jeopardizing the productivity of the maintenance team. In this way, it is possible to create an objective function that will be able to select the best estimator, to reach a certain orientation. Thus, it increases the probability of allocating trains according to the productive capacity of the maintenance center, facilitating management and investment guidelines (Gu et al.,2019).

The Hong Kong Mass Transit Railway Corporation (MTRC) workshop used this algorithm to create a method that reconfigures trains and balances the workload to optimize maintenance planning and control. This result arose from the need to transform a manual work by an experienced planner, into an automated resource, which uses statistical calculations and brings more objectivity and less subjectivity to the decisions of maintenance managers (Sriskandarajah et al., 1998).

Some case studies point out the relevance of using genetic algorithms (GA) to solve problems that aim to maximize the production of rolling stock maintenance, as in Spain, in which research has pointed out the efficiency in the application and development of maintenance strategies. The researchers have used data from a railway company to evaluate the simulations and classify them based on their assertiveness and to obtain more precise guidance on asset management and reliability plans. With this classification and evolutionary operations, it was possible to achieve better orientations and considerably increase the quality of the results of the railway equipment (Erguido et al., 2020).

4.3. Artificial Neural Networks

There are articles that prove that the mastery of genetic algorithm techniques, associated with the possession of well-structured data makes it possible to find solutions to improve maintenance planning. The literature seeks solutions in algorithms based on "simple" elitism, to always preserve the best individual and guarantee the best next generation, thus providing case studies with the best condition for the variable in question (Bento & Kagan, 2008).

The case studies raised on the planning and control of maintenance have shown that the problems of budget forecasting and resource management can be solved with the help of artificial neural network algorithms, to recognize hidden patterns and correlations between the data. This computational technique uses concepts based on biological neurons and is composed of several processing units that have simple operations. These units work with an intelligent behavior coming from the interactions between the processing units, which operate through their connections and channels (Carvalho et al., 2019).

There was an emphasis on the ease of handling of this technique by people with little specific knowledge about the data, the way its logic is based on historical data makes it more accurate in the ability to deal with data inconsistency. However, networks can achieve contradictory results, the test can be time-consuming and it is impossible to check the predicted output, in addition to the need for a large volume of data (Carvalho et al., 2019).

In works that use ANN, the input signals are aligned with the budget proposal for the management of maintenance resources. The mapping of resources to guarantee the reliability of the assets, generates a vector p productive indicators, which through the use of the algorithm is found an ideal volume of resources that meet the maintenance plan and do not harm the financial limit of the organization. The RNA is trained according to the characteristics of the company's operating hours and the amount of material to perform maintenance. The hidden layers are trained with the unit cost of each human hour and of each material necessary to carry out the maintenance. The activation function f, is the transformation function that creates the financial impact weights w, which act on the input signals that are the volumes of each resource X and determine whether or not V will generate an output vector a. Thus, to form a neuron, each layer of the network is represented in Figure 2 and described in the construction of Equation (2).

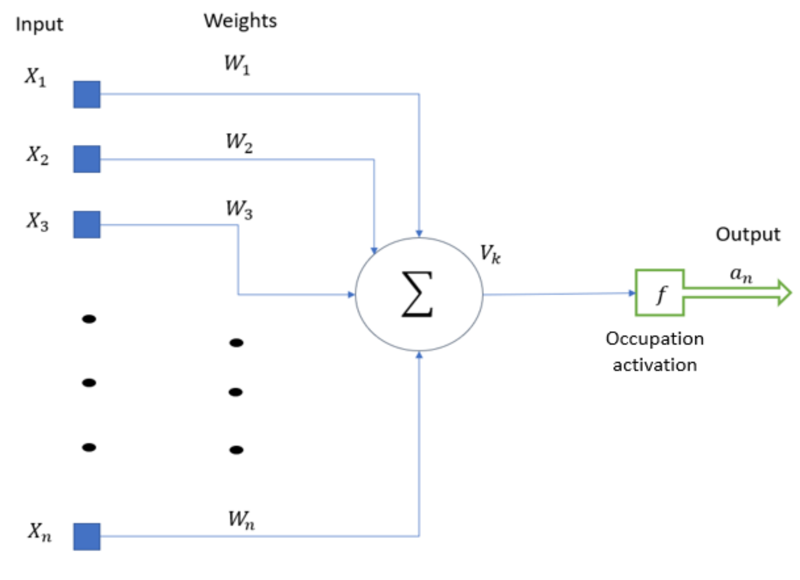

Figure 2 - Structures of artificial neurons.

Source: (adapted from Haykin, 2001)

$$V_k = \sum_{j=1}^{n} X_j W_{kj} \quad (2)$$

There was an emphasis on the ease of handling of this technique by people with little specific knowledge about the data, the way its logic is based on historical data makes it more accurate in the ability to deal with data inconsistency. However, networks can achieve contradictory results, the test can be time-consuming and it is impossible to check the predicted output, in addition to the need for a large volume of data (Carvalho et al., 2019).

The components of the input vector are X_j and the corresponding weight for W_kj, connects input j to the neuron V_k. The activity of the neuron V_k is formed by the sum of the inputs, which became the output a_n_k only if the activation function f, declares that meets the necessary limit for the production of maintenance. To analyze and model a resource minimization problem, you can follow these steps:

• Initialize the neural network with the inputs considering the volume of material and need for operational labor, configure the weights considering the corresponding costs for each human and material resource of the problem;

• Apply the activation / transformation function, built by the relationship between the need for production and the budgetary capacity for the working day and the volume of raw material. In this way it is possible to dictate the topic that determines the validity of the response variable desired by the researcher;

Change the weights in the hidden layers, manually or automatically, to be able to evaluate the usage history of the variables that impact the output and later check the answer.

In China, Artificial Neural Networks were used in order to select a maintenance strategy for the rolling stock, propose a perspective of possible quantities of parts and thus carry out revitalization of the train components. The empirical result was to facilitate maintenance planning and control, in addition to intensifying that preventive maintenance should be valued more than corrective maintenance (Cheng & Tsao, 2010).

There are not many studies that implement maintenance planning as a possible resolution problem using neural networks and that analyze all the train's equipment together with several operational failure factors, but it is possible to obtain results considered relevant in improving maintenance management (Gençaer et al., 2020b). High-speed railways around the world have fault diagnosis systems called VOBEs (vehicle on-board equipment). These systems evaluate signals from electric railway vehicle designs and are considered uncertain and complex, as there has not been an adequate investment in research. Thus, diagnoses need to be judged manually, which makes decision making unreliable, due to the large volume of data generated in rail traffic. The evaluations were carried out with neural network techniques and with the creation of a mathematical model. The automated diagnosis became more precise and accurate, which reduced the subjectivity of the previously used means (Yin & Zhan, 2016).

The Ankara metro, a city in Turkey, assessed the factors affecting train failures and aligned the tacit knowledge of experts with computational models. Neural networks were used to assess the factors that affect undercarriage failures, as there was uncertainty in activities and maintenance plans. These studies have shown that there was more efficient use of resources to limit planning errors. This railroad has demonstrated that it is possible to build a model using the artificial neural networks, so that failure forecasting in train maintenance planning is effective (Gençer et al., 2020b).

The wear between the wheels and the undercarriage rails is a subject of study on the railroad. The neural network was able to assist in the prediction of this wear and, consequently, in the derailment prevention. This analysis was only possible because there was interconnection and support from a multiprofessional team of researchers to evaluate and interpret the data, as it requires an evaluation of conditions and external variables, which were not mappable yet. Knowledge of several areas is necessary to assist the data researcher and ensure guidance for the reliability of the results and reduce simplistic and equivocal findings (Shebani & Iwnicki, 2018).

Among the search for neural network applications, there were studies that demonstrated that an electronic component of the rolling stock, can be monitored using neural networks and facilitate the accuracy of breaks in railway components. This application makes it possible to point out advantages and disadvantages of the component and directly influence the safety of the train's operation. Interventions in this item, require strict direct care because it is a complex technology that cannot be simply evaluated by the experience of a data researcher. So there were case studies that showed that traditional neural networks like FANN (Firefly Artificial Neural Network), PSONN (Particle Swarm Optimization Neural Network) e GANN (Genetic Artificial Neural Network), considerably increase the accuracy of diagnostics in the strategy that creates maintenance planning (Zhao et al., 2017).

7. FINAL CONSIDERATIONS

Research that explores themes related to the railway and its planning and maintenance control are multidisciplinary. Often organizational managers need the support of specialists in the field to build research together with data scientists. The literature search made it possible to find works that prove that computational resources are important to improve maintenance planning and control, because they are able to assist in reducing costs or maximizing maintenance production.

To increase the availability of rolling stock in train operations, the use of Linear Planning, Genetic Algorithms or Neural Networks, has the ability to improve asset management. In the course of this study, it was possible to visualize that these computational algorithms can facilitate management decision making, evaluating the company's demand and its limited and complex resources.

The linear planning algorithm is most useful in environments where the database was not built in order to improve production. Among the most notable features of using this technique is the possible resolution of complex problems with simple and popular computer applications. Sophisticated teams cannot, with this resource, evaluate productive environments without the experience and knowledge of plural teams. At the same time, there is a disadvantage that any researcher of this technique must know: its use is only possible if it is feasible to create linear restrictions, for frequent and not very complex activities in the productive environment that is normally considered unstable.

The literature points out that the limits of creating bonus or penalty limits in the techniques of genetic algorithms is the great challenge for continuous improvement professionals. These parameters, which depend on a lot of specific knowledge on the topic analyzed here and on their needs can make it difficult to evaluate simplistic groups. It should also be noted that it is difficult to assess the development changes in genetic algorithms developed by other researchers. At the same time, those who properly master this computational resource can make modifications and solve local problems and perform global analysis of complex environments.

In the use of Neural Networks, the advantage that most stands out over the other algorithms, according to the case studies described here, was the ability to carry out improvement research with little or no specific knowledge. In the maintenance production environment, it is possible to find unusual activities in corrective maintenance and the ANNs are capable of evaluating historical data and providing a safety margin on unforeseen events. It is worth mentioning that these same surveys state that it is difficult to verify the veracity of the answers when a forecast is aimed at.

These scientific works of this literature review treat the locomotive and its wagons as a single item in the evaluation of planning and control of the maintenance of undercarriage. The development of more specific research, separating the train components individually, can bring a perspective of developing better approaches to reduce costs, maximize production and improve the assets availability

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