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REUSE RESIDUAL SAND CASTING FOR PRODUCTION OF CONCRETE BLOCKS

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ABSTRACT

Sand casting is a viable waste as an alternative raw material, regarding a good solution in the production of concrete blocks. The use of sand casting to produce concrete blocks is performed by about 80% of the productive capacity of the company considered in this study. Thus, this work aims to make an improvement by applying fuzzy logic. The methodology was applied from the formulation of ranking criteria, which improved the production process. Therefore, after the implementation of the established criteria, was achieved an improvement of about 10%. Thus, the results achieved can help companies, generating alternatives with more excellent reliability and assertiveness. Moreover, Fuzzy is a methodology that provides strong support for decision making, supporting subjective and intuitive criteria.

Keywords: Fuzzy Logic, Production Management, Concrete Blocks, Casting Sand.

1. INTRODUCTION:

The economic empowerment of the whole world is based on a balanced economic, political, social, cultural, and environmental model (Cataluña *et al.,* 2018; Zirham and Palomba, 2016). All generations can follow on radio, television, and newspapers, seeking the commitment of all so that they meet the needs of current generations without compromising the ability of future generations (Best, 2017; Cataluña *et al.,* 2017).

With the accelerated development process and the dynamization of the market, organizations are obliged to look for ways to improve their operations, thus optimizing the final results obtained. Besides, another relevant factor is companies considering the consequences of their actions, thus denoting concern for the environment, adopting policies and measures that lead to a sustainable workforce (Venturini *et al.,* 2018; Caetano *et al.,* 2018).

However, this research seeks to show the large amount of "foundry sand" waste produced and its reuse as an alternative raw material to replace normal sand in the production of concrete blocks (Sua-iam *et al.,* 2019). For example, it is shown in the results of a study that concrete workability decreases as the amount of foundry sand increases, which was attributed to the larger surface area of this sand compared to the aggregate used (Prasad *et al.,* 2018). In this case, in addition to the utilization, there is greater resistance in the product due to the components added to the sand in the matrices (Torres *et al.,* 2017).

In this case, in a constant transformation market that is continuously emerging new goals and objectives to be achieved, managers require a lot of attention to find better tools and solutions to manage the production (Gerônimo *et al.,* 2017; Caetano *et al.,* 2017). Moreover, production management models have traditionally been composed of two dimensions: the technical dimension and the social dimension (Pérez-Barea *et al.,* 2018). The technological dimension refers to production, such as processes, activities, the physical arrangement of equipment, and the flow of material that results in goods and services (Zou *et al.,* 2019).

The other dimension relates to social and refers to the organization of work. In such a case, there are essential elements for a company to become competitive, such as strategy, product development, logistics, production management, and manufacturing technology, where all these elements must be integrated to optimize processes based on the market demand of the organization (Zhu *et al.,* 2019; Sutherland *et al.,* 2016). An example is a study of Pablos *et al.* (2012) who devised a methodology that establishes a waste encapsulation process using the solidification/stabilization technique in Portland cement matrices. This process makes the residues act as small and large aggregates in the concrete composition (Okoronkwo *et al.,* 2018).

Thus present the possibility of using this concrete in the manufacture of concrete pieces (blocks). In this context, industrial waste, where it is disposed of makes organizations pay a high price for it (He *et al.,* 2019; Caetano *et al.,* 2015). However, foundry sand is a viable reuse residue as an alternative raw material to replace normal sand, so it is an economically advantageous solution. (Matos *et al.,* 2019). The authors also suggested a methodology to reuse these solid wastes by testing the use of shingles incorporating foundry sand in different concentrations, in increasing order of 5%, where natural sand was replaced by foundry sand, where the result of the methodology was satisfactory for consumption. Current studies highlight the concern with the environmental sector, preserving natural resources and waste mainly in civil construction (Wahi *et al.,* 2016; Sieffert *et al.,* 2014).

Therefore, it is observed in research the approach of the use of foundry sand as a base component of mortars, concrete blocks, concrete pavements, and self-compacting concrete. (Kruger *et al.,* 2013). Consequently, this research seeks to apply fuzzy logic to perform optimization simulations of producing concrete blocks from foundry sand, aiming to enable managers alternatives that generate improvements to their products. In this scenario, the criteria to be evaluated are equipment, time, cost, and human resources involved in producing the blocks (Iqbal *et al.,* 2019). According to Prabakaran *et al.* (2018), investigating the process of reducing fertilizer consumption and improving crop productivity using fuzzy logic systems is relevant. Data were analyzed in MATLAB to establish feasibility rules for crop decision support systems.

This justifies the importance of using the fuzzy logic theory to achieve relevant results in the use of foundry sand to produce concrete blocks (Beheshti Aval *et al.,* 2017). Considering that there are several examples in the literature that were considered successful in research, the fuzzy logic was used. Thus, through this theory, it is possible to understand the criteria so that they may contribute to the performance of the organization under study (Carbajal-Hernández *et al.,* 2012).

In an organization, the production process is inherent in the extraction, manufacture, distribution, consumption, recycling, and reuse of resources, as these relationships become paramount to optimize its performance (Klunk *et al.,* 2019a; Ruoso *et al.,* 2019). Also, production management can be defined as a function of planning management, organization, direction, coordination, and control of inputs and process elements and has the objective of manufacturing high value-added goods and services (Klunk *et al.,* 2019b). The operations of a production process are controlled in time and space and are assisted by suppliers and customers (Tezel *et al.,* 2016).

In the modern context of production management, organizations have large amounts of data sourced from past industrial processes due to current technology and the benchmark. However, large data volume makes it difficult to quickly convert data into action for the benefit of an organization, but this is extremely important so that process cycles become shorter (Fraga *et al.,* 2014; Klunk *et al.,* 2012). In this way, an organization's data analysis capabilities make it a competitive advantage, optimizing production management in decision making (Bumblauskas *et al.,* 2017). Thus, production management has traditionally been defined as the set of activities required to plan and control the manufacturing process. Regarding the theme, given the current market competitiveness, the challenges of companies is to innovate so that products are relevant items in the face of consumer market influence. Besides, innovation needs to be valued at long, medium, and short-term strategic planning levels, as it is a tool that impacts cost savings and increases quality (Gerônimo *et al.,* 2018).

Given this, the appropriate use of sustainable resources aims to bring economic benefits to production processes to reduce the impact on environmental interactions of resources beyond the limits (Bentes *et al.,* 2012). Thus, with the growing interest in preserving the environment, it is necessary to explore ways to transform, recycle, and reuse the industrial waste in building materials.

It is noted that the metallurgy industry generates waste that is no longer used throughout the production process, where the inefficient waste management can characterize an environmental problem (Iluţiu-Varvara *et al.,* 2017). Thus, one of the wastes generated by these organizations is foundry sand, which is of uniform size and high quality and is fine sand useful for reuse (Sithole *et al.,* 2019). Moreover, over the years, this material has been disposed of in landfills. Still, the large volume currently generated costs have become a problem in the United States, which has about 3000 foundries, using 100 million tons of sand annually, and generating about 6 to 10 million tons of foundry waste (foundry sand) that is disposed of in landfills (Dolage *et al.,* 2013).

In Brazil, foundry sand is the industrial waste with the highest volume since each ton of molten metal generates another ton of sand to be disposed of. Foundry sand can be defined as a raw material based on other chemicals to make molds in the metalworking industries. In this context, it requires cultural and awareness changes, so research is found that refers to the successful use of industrial waste foundry in concrete blocks (Fernandes, 2004).

Thus, the challenge is to find sustainable solutions that lower the high costs of landfill disposal and generate a return for the metallurgy industry, as waste sand is a safe material for engineering applications. Thus, to assist in managing industrial waste production, fuzzy logic with triangular numbers was used to elucidate improvements in the production of concrete blocks using foundry sand (Matos *et al.,* 2019).

Fuzzy logic is widely used to solve decision-making problems (Iqbal *et al.,* 2019). Fuzzy Logic (also called multivalued logic) was introduced in 1930 by the Polish philosopher and logician Jan Lukasiewicz (Godo and Gottwald, 2015). Using terms like tall, old and hot, he proposed using a range of values [0,1], which would indicate the possibility for a statement to be true or false (Lim *et al.,* 2016). In 1937 the philosopher Max Black suggested the concept that continuity described degrees (Black, 1942).

Given this, this logic uses the modeling of systems with poorly defined boundaries; when working with complex processes, it is observed that several classes of objects do not have a well-filled belonging criterion, with inaccurate or approximate information. Thus, it comes from convergence to fill the lack of theories that use a usual mathematical treatment for linguistic variables. The concept is that the values are attributed by words or sentences in the natural or artificial language (Zadeh, 1996; Lima Junior and Carpinetti, 2015).

Thus, the Fuzzy approach is pertinent when using qualitative linguistic variables such as low, medium, high, and probable, unlikely, interpreted by Fuzzy numbers and articulated by valid arithmetic. Consequently, it makes it possible to consider a more significant number of variables, allowing simulations of the human judgment process, thus facilitating the search for problem-solving and making the foundation of a knowledge base more straightforward. However, data processing speed is one of the reasons that hinder the application of logic in multiagent modeling outside the academic context. (Braga *et al.,* 2017).

It is noteworthy that within fuzzy sets, a particular variable can belong to more than one linguistic set, a fuzzy set where values from 0 to 1 are provided in each element, where it represents the degree to which it belongs to the inaccurate concept to the set. Fuzzy Consequently, the numbers are part of a Fuzzy inference group; the first step is to convert qualitative variables to fuzzy numbers having the name of fuzzyfication, followed by data processing, ie inference based on fuzzy rules, Finally, defuzzyfication consists of the information analysis stage of the fuzzy set (Moraes, 2014). Thus, the next topic characterizes the methodology outlined for this research, aiming to elucidate all the means employed to achieve the defined research objective.

2. MATERIALS AND METHODS:

A scientific study contributes to the obtaining of knowledge. Where the results found help decision-makers find the best alternatives to improve their organizations. The research on the approach can be pointed as qualitative and quantitative due to the methods employed. Regarding the central themes, the research is still classified as a case study because it sought to systematically describe the characteristics of the company and the application of fuzzy decision support logic to hierarchy for decision making (Vergara, 2002).

Based on this assumption, to define the scope of fuzzy methodology, sets, and logic aiming at the modeling and development of control systems, it will be evidenced only what is necessary to understand the basic fuzzy control theory (Qureshi *et al.,* 2018). Interpretations through fuzzy logic of a data structure is a natural and intuitively plausible way to formulate and solve various problems. In this sense, the methodology of the methodology, as the nature of the research, can be considered applied due to the practical answers obtained and implemented (Abaei *et al.,* 2018). Regarding the objectives is exploratory and descriptive, having the need to study in more depth the concepts and characteristics of the problem. The approach is qualitative and quantitative, and it is a case study. This research was carried out in a concrete block industry, being an exploratory study, because it was sought to have more familiarity with the subject, where through observations, it was verified how was the productive process of the manufacture of concrete blocks from of foundry sand (Makul *et al.,* 2018).

The data were obtained through the interview and observation. This one can define each of the criteria, working with Cr1 in units, Cr2 in day, Cr3 in reais, and Cr4 in the number of employees. Thus, the company under study can be considered as a universe of all employees of the organization. We used the fuzzy logic for analysis purposes, with fuzzy triangular numbers, developed by Lofti Zadeh in 1965, with these fuzzy sets (Zadeh, 1996). Since then, other researchers began to use it; within this theory, it is understood that within each set, there are gaps or vague phenomena, serving such methodology to describe and verify them. Consequently, this research seeks to apply the logic fuzzy logic to perform simulations of optimization of the process of production of concrete blocks from foundry sand, thus enabling to define of better alternatives that generate improvements in products (Gent *et al.,* 2015).

3. RESULTS AND DISCUSSION:

3.1. Initial Diagnosis

Understudy, the organization has a corporate characteristic framed by the IRS as a Small Company - EPP, being a family structure industry. The company was opened in 2007, and is managed by two partners, and has four employees, and the organization operates directly in the field of block manufacturing.

Thus, the company manufactures pre-lage, cement, concrete, Roman tile, bricks of all types and sells building materials in general. However, the main product sold by the industry under study is concrete blocks made for masonry and paving, which has a production capacity of 90,000 pieces/month. However, the organization currently manufactures about 72,000 pieces/month of concrete blocks.

Also, the company makes available from a remote area of the city due to the sound emitted by the machinery for the manufacture of concrete products and parts. The site has a space for locating machines, equipment, warehouses, among others. Its facilities are housed in a pavilion with about 800 m^2 with a total area of approximately 20,000 m^2, with a production cost of R$ 59,200.00.

3.2. Analysis of the concrete blocks production process

In the initial stage, the foundry sand is received and then conveyed to the hoods by conveyor belts to be weighed separately. After this, the residue is mixed in a mixer where additives and cement are added together with the foundry sand, thus generating base material for the manufacture of the blocks. Subsequently, the base material is conveyed by conveyor belts to the vibratory press so that the necessary shaping and final production of the blocks occur.

Finally, the brushing and elimination of the chips are performed, analyzing if they are following the norms. The structural part of the block (compressive strength and water absorption) meets the specifications of ABNT NBR 6136: 2010, NBR 12118: 2012, and NBR 9781: 2013. Given this, the criteria can be defined to achieve maximum productivity in the manufacture of concrete blocks from the foundry sand, helping managers decide.

3.3. Definition and Criteria

Given the analysis and observation, together with the managers of the production process, four criteria were defined that will be used to improve the efficiency and productive capacity of the organization. As shown in Figure 1, the behavior of the inlets in relation to the outlet was observed, that is, the influence of each one to optimize the productivity in the production of concrete blocks from the foundry sand.

3.4. Fuzzy Simulations

With the help of managers, simulations were performed, from which the limitations for analyzing the criteria in relation to quality in the production process were elaborated. Thus, the rule base for a collection of fuzzy propositions. Therefore, all possible combinations were used to give more accuracy to the application of the method.

The temporality dimension is of paramount importance as it relates between the time of entry of the record in the databases and the time of occurrence of the event where a service is completed. Moreover, the time between the occurrence of production events and the availability of relative information to users can also be considered.

Therefore, once the constraints were determined, simulations were obtained, as shown in Figure 2, to observe the production behavior, considering the cost and time variables. Detailed cost analysis, production cost calculation, loss quantification efficiency estimation provides a solid basis for financial control. Managers must also be concerned about future costs, their level of supply and production decisions, and pricing policies.

It is noticeable that the behavior of the variables is not constant, showing that there are changes when the time in days is increased about the cost, thus helping the manager to note the best time with the lowest cost. Figure 4 shows the cost and equipment variables concerning production. It can be seen that the manager can understand the correct number of machines to use to reduce their costs.

Figure 4 shows the constant development of companies and their production processes seeking to reduce costs through the amount of human resources needed to produce effectively and efficiently. Figure 4 shows the behavior of production to the variables cost and human resources. Controlling variables such as human resources and equipment efficiently and effectively leads to better results at lower costs. Figure 5 shows the relationship of production to human resources and equipment.

Regarding the variable human resources related to equipment, the manager analyzing the figure may decide how staff to use not to have staff stopped generating less productivity. Figure 6 shows the behavior of production with human resources and time. Thus, the figure above shows the time to human resources, thus denoting the best values to improve production, helping the manager verify the time to be spent and the number of employees needed to improve productivity. In Figure 7, one can see the behavior obtained in production when compared to time and equipment.

Thus, improvements and automation in the data collection process can also contribute to a good performance of these measures; therefore, these results help managers in decision making to improve the production of concrete blocks from the ADF. According to the simulations performed, it was evidenced that, to reach an optimization in production, one must work with a cost of R$ 67.700.00, optimizing its production time to approximately 18 days, where previously it was 30 days, still using about 65% of its equipment and about 2 of its employees. Doing a new survey in the company found that the first work has been implemented and aims to reach the maximum capacity. The managers showed that from 2017 until June 2018 began to use 90% of production capacity, and previous data showed 80% of it.

4. CONCLUSIONS:

The objective of the present work is to optimize the productive capacity of concrete blocks from foundry sand using fuzzy logic. Thus, finding managers a possible alternative in decision making for the future of the enterprise. The same has been achieved given that the organization has great market potential, as it is a pioneer in its region to use foundry sand in the manufacture of blocks. It emphasizes a vision of sustainability established by the company by reusing harmful materials and presenting a possibility for the disposal of industrial waste generated by the mechanical manufacturing industry.

However, it is worth noting that the study is a simulated proposal for multiple reasons, both internal and external, which may lead to changes in the results. Moreover, it is noteworthy that the fuzzy sets methodology strongly supports decision-making, which comes against the solution of subjective and intuitive criteria widely used by experts (Hisrich and Jankowicz, 1990; Mitchell *et al.,* 2005).

Thus, the company understudy has a lot to gain, because the evidence helps in the decision making increasingly safe, therefore using the resources effectively, thus avoiding waste and idle time, which is one of the biggest problems diagnosed in the company. However, the company is open to suggestions denoting; therefore, future plans intend to reach the maximum plant load that is 100%, target for the next six months. The company seeks to develop reaching the goals of improvement and efficiency and thereby gain an effective production process.

As a limitation found in the research, it is controversial that managers spontaneously corroborate the adopted strategies regarding the reliability of data collection. An imperfect way to overcome such an obstacle would be the empirical separation of the intensity of adoption of the relevant variables, based on publicly available related information. Another limitation worth mentioning is the time to conduct the interviews. The managers often did not have the time because they were busy doing their work in the company's administration and could not receive the researchers.

Based on the above, as a suggestion for future work, it is indicated a study on the effects of casting sand compared to river sand on the mechanical properties and on the microstructure of these concretes. It is also indicated, a study comparing the fuzzy topsis methods and the ANP, to analyze the sectors of the company regarding the productive system, defining a hierarchy of action, thus solving the possible existing bottlenecks.

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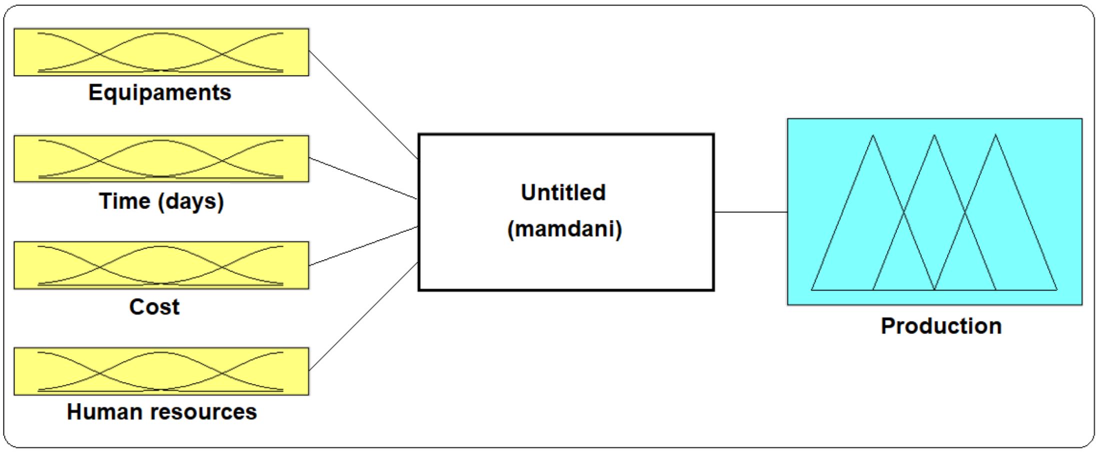

Figure 1. *Simulation inputs and outputs for production quality improvement*

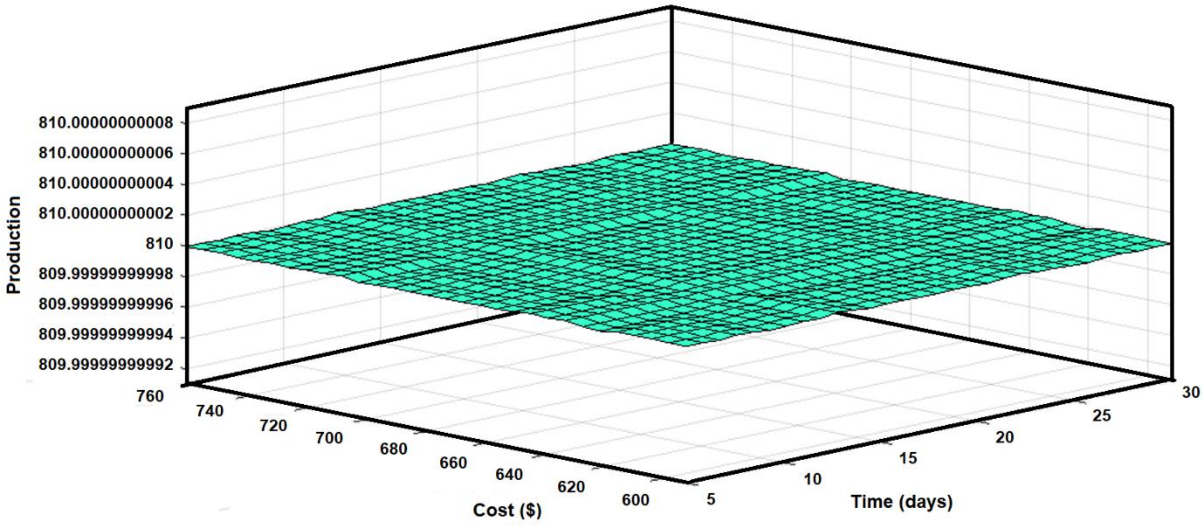

Figure 2. *Cost vs. Time*

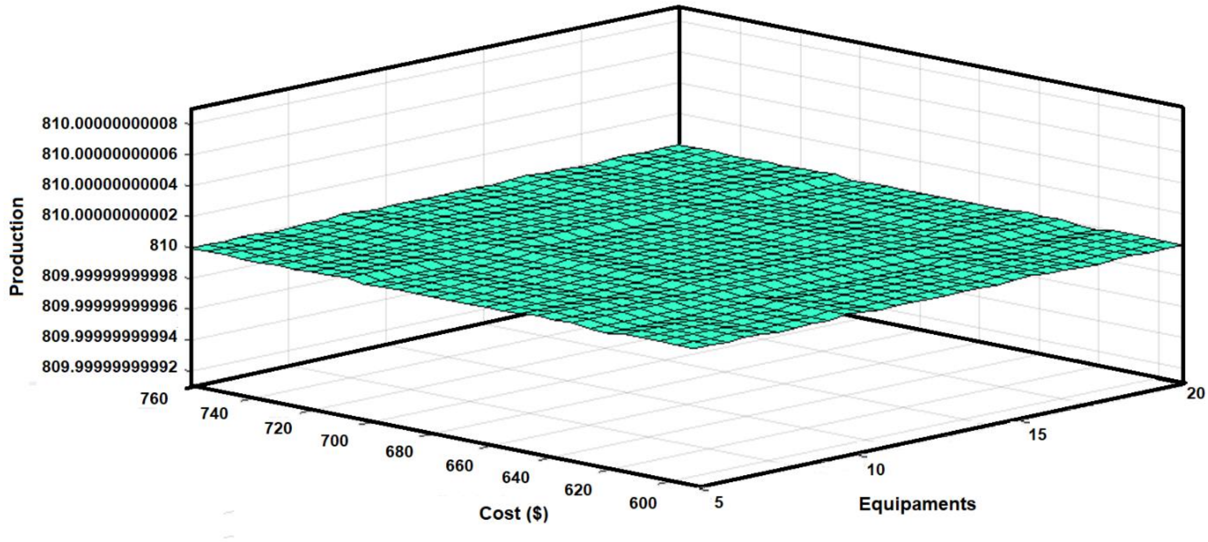

Figure 3. *Cost vs. Equipment*

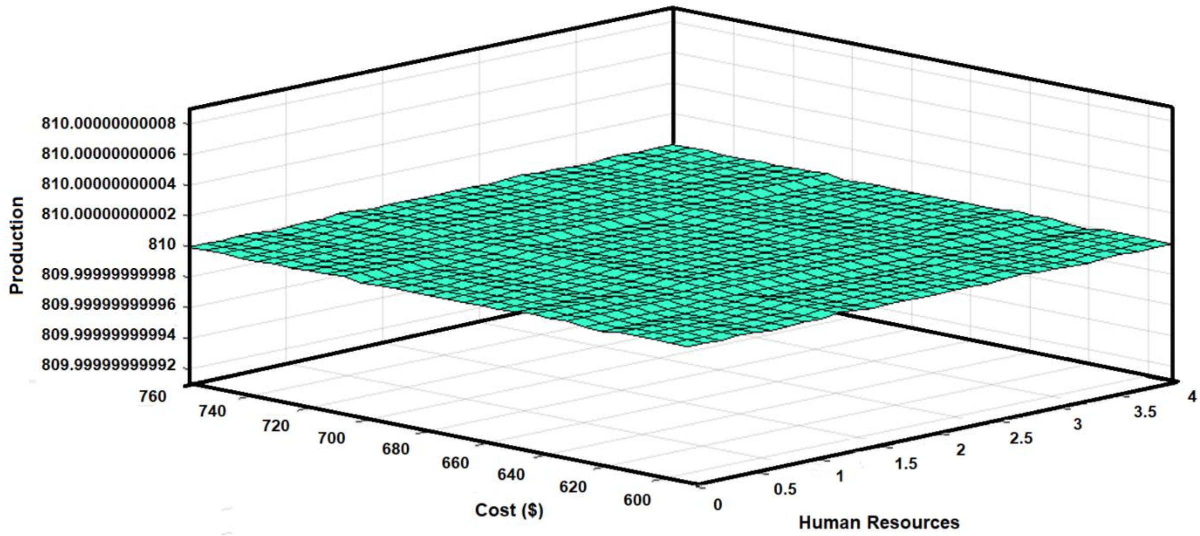

Figure 4. *Cost vs Human Resources*

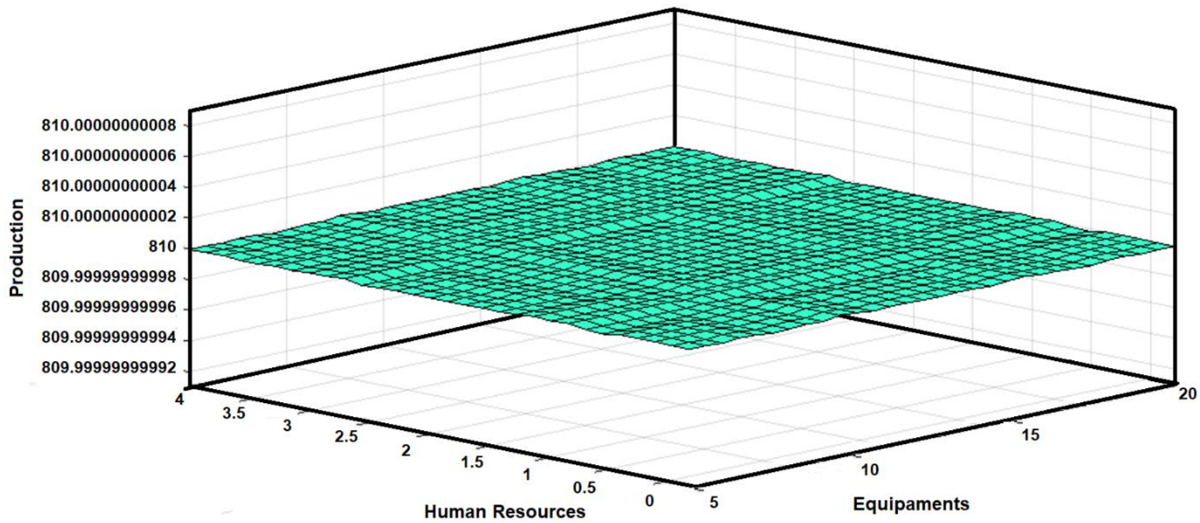

Figure 5. *Human Resources vs. Equipment*

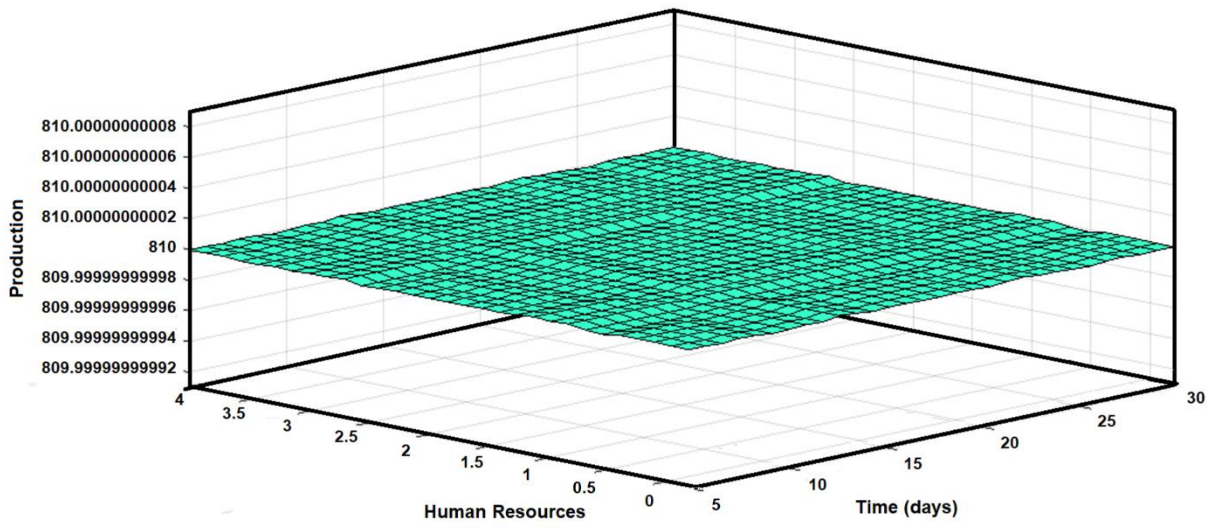

Figure 6. *Human Resources vs. Time*

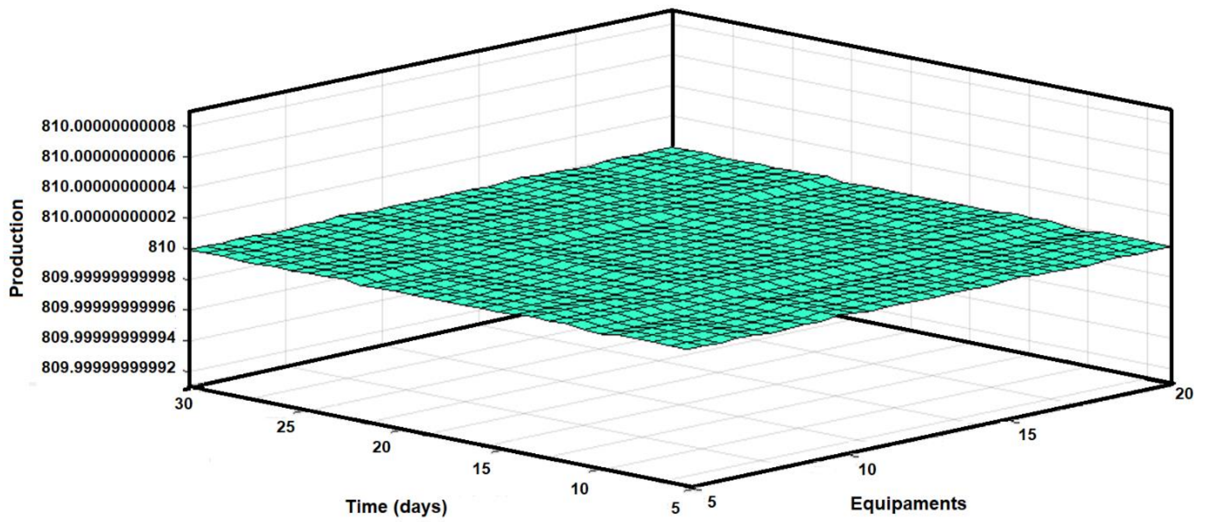

Figure 7. *Time vs Equipment*