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Decision-making support for selection of scenarios using AHP and simulation: a case study in an automotive industry

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Abstract: Decision making is present daily in organizations between different areas and functions. These decisions often involve tangible and intangible data that must be evaluated jointly for a correct analysis of the problem. In complex environments, is increasing the use of tools that help managers in the decision-making process. The present study aims to assess the integration of two tools, computer simulation and Analytic Hierarchy Process observing how the two methods when worked together can aid the decision making process. In this way, the study presents a case study in an automotive industry, where it is used an integrated analytic hierarchy process and computer simulation for prioritizing of futures scenarios. As a result, AHP is able to assist in choosing scenarios before or after simulation. Computer Simulation provides solid data that serve as more consistent input data to apply the AHP methodology. Thus, the research highlights the benefit of the integrating the two tools as support for decision-making.

Keywords: Decision Making, Computer Simulation, Analytic Hierarchy Process.

1 Introduction

With the ever-changing market, widely dispersed knowledge, and stiff competition, companies need to make assertive decisions in a short time. In industries, these decisions aim to improve performance factors such as quality, flexibility, cost, reliability. Therefore, the selection of the best scenario for a productive system that enables meet market requirements, it is a decision-making process with multiple criteria, where the choice of the better alternative becomes a difficult time-consuming process, even for professionals with experience (Taha et al, 2012; Marins et al, 2009; Dreher et al 2012; Garza-Reyes 2010; Cheng et al 2018; Acharya et al, 2018).

For this reason, more and more managers demand by formal methods to support decision-making (Shang, 1995). In this context, the simulation stands out as an important tool to support the manager, since it makes it possible to study different scenarios taking into account multiple variables (Freitas, 2001). Furthermore, the tool makes it possible to test and modify scenarios within the built model, ensuring the reliability of the adopted solution without disturbing the real system (Mani et al ,2013; Iron et al, 2017). Despite the promising use of the tool and the growth of its use in industries, computer simulation still presents difficulties to reach its full performance potential. The tool alone, for example, still can not take into account important opinions and requirements from different areas. In very complex environments, simulation studies can be lengthy and consuming high levels of resources, since important construction

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steps such as data collection, variable definition, data insertion in the computational model and interpretation of the output data can increase the complexity and also increase the costs and time of construction of the model. Thus, it becomes interesting to use auxiliary tools capable of directing the modeling of a system, making simulation results more reliable and faster to be achieved. (Mani et al, 2013; Iron et al, 2017; Martin et al, 2004; Gavira, 2016).

Faced with these realities and in to assist the decision-making process under multiple criteria, the present paper aims to use the AHP (Analytic Hierarchy Process) as a facilitator in the choice of simulation scenarios within a production system. The method developed by Saaty (1983), was chosen because it is a known tool, which enables the division of a complex problem in a structure of inter-related criteria, enabling a comparison between different alternatives, addressing both quantitative and qualitative aspects (Gomes, 2007; Ramanathan, 2001). This paper presents a case study carried out in an automotive multinational to verify how the integration of the AHP Method and Computer Simulation can help in the decision-making process of future scenarios.

2 Proposed Approach

The methodology presented in this paper aims to integrate the Computational Simulation and the AHP Method, to verify the benefits generated by the combination of the two tools in the prioritization of scenarios in complex manufacturing environments, to facilitate the decision-making process. This approach has a practical application carried out in an automotive multinational. Fig. 1 shows the process steps used to work with the two tools in an integrated manner.

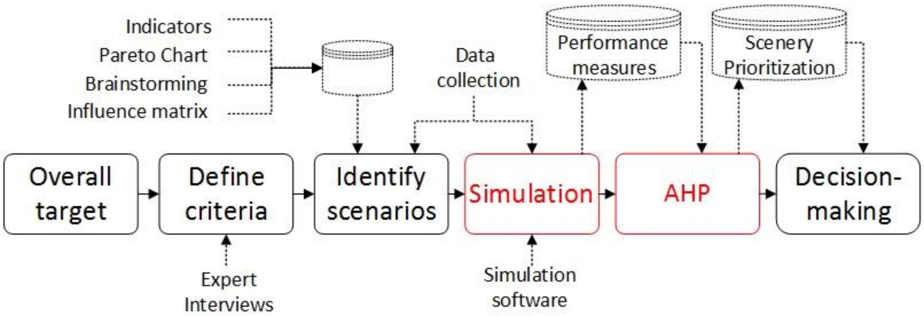

Fig. 1 Proposed methodology

For the integration of the two tools, Simulation and AHP, firstly, it is necessary to define the central problem / overall target. After that, it is necessary to identify criteria, and the possible scenarios that may solve the central problem. In both steps it is interesting the participation of people from all areas involved in the problem, so the main aspects and possible impacts of the future scenarios can be taken into account. To identify the scenarios, the methodology foresees the combination of different decision- making tools, such as: identification of relevant indicators, construction of an influence matrix followed by a Pareto graph and brainstorm for the selection of indicators that would most impact the system under study.

The next step is to simulate the scenarios, this step aims to represent as accurately as possible the scenarios, to verify what possible impacts can be found with the implementation of them. Moreover, in this study, the simulation was used to quantify one of the AHP criteria, performance. This criterion refers to the cycle time of the workstation. Other criteria are also evaluated through simulation, the maintenance criterion, for example, takes into account the Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) of the machines. Even though the simulation could indicate the best scenario regarding performance, other criteria are needed to achieve the overall target. Thus, after simulation of the scenarios, the AHP methodology was applied to incorporate other assessment criteria and prioritize the alternatives. Through the AHP, quantitative and qualitative data can be taken into account, as well as the opinions of different people. Therefore, the results presented by the integration of the two tools, enable the decision maker support the decision-making based on a systematic approach, instead of taking the decisions empirically.

3 Results

The company analyzed in this study is an automotive multinational. Located in the State of Paraná - Brazil, where it has a complex with 4 factories. The factory chosen for the application of the method is the vehicle assembly plant. To supply the assembly line that works with the diversity of products, the company adopted a process called kitting. This process allows around the production line to have only the required parts at the exact time. The kitting process consists of grouping together components and parts of a particular product model and sending them as a kit to the assembly line.

The object of analysis of this study is a workstation, whose function is to pre-assemble ABS brake blocks and add them inside the kit, which will be guided through an AGV (vehicle guided automatically) to the point of the vehicle assembly line. This station was chosen because it is not able to reach the cycle time line of the 1.84 min, causing a delay in the delivery of the kits in the vehicle assembly line.

3.1 Overall target

For the application of the two tools, Simulation and AHP, firstly, it is necessary to define the overall target. This study tries to find the best scenario that able to reach the cycle time of the ABS brake pre-assembly station, taking into account the conflicting opinions of the managers. The workstation under study has two operators perform the same function. The following are the steps that the operators perform:

1. Walk to the printer and pick up the label;
2. Walk up to the ABS block stock and pick up the block;
3. Stick the label on the block;
4. Take along the labeled block to the table;
5. Fix the block on the table;
6. Take brake pipe and perform the threading (6 tubes);
7. Screw the tubes to the block using the pneumatic screwdriver;
8. Take the finished piece to the AGV.

Each AGV needs to leave the station with 3 kits filled, when the operator supplies the last kit, presses a button, and releases the AGV to the next station.

Fig. 2 shows the displacement performed by the operators during the assembly of the kits.

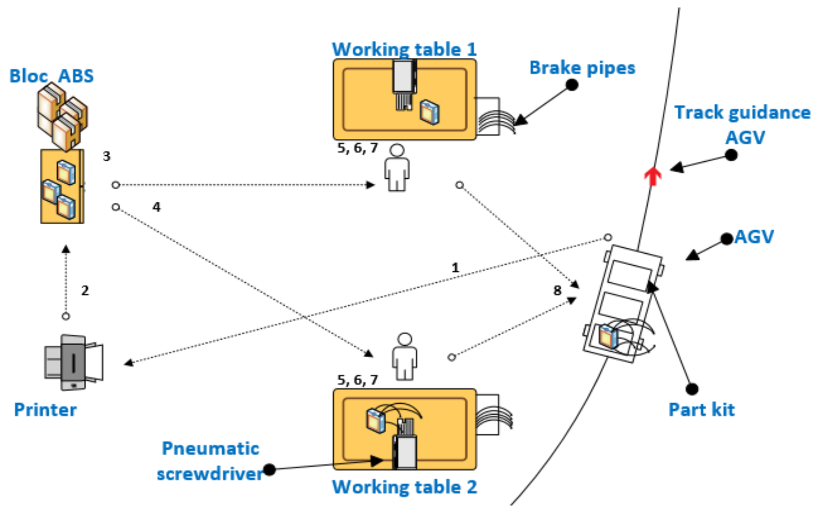

Fig. 2 Displacement performed by operators

3.2 Define criteria

Based on the company's objectives and with the help of a project manager, who has been working in the company for more than 15 years, the criteria were identified.

1. Safety: this criterion takes into account the safety of the operator, and facilities;
2. Ergonomics: ergonomic aspects such as constant operator movements, inadequate postures and, loading of weights.
3. Quality: quality assurance of parts.
4. Performance: cycle time.
5. Automation: agility, smooth operation.
6. Maintenance: easy and rapid maintenance.
7. Costs: total investment required to implement the adopted solution.

3.3 Identify scenarios

This step builds on performance indicators to determine which metrics are most important to incorporate into scenarios. Initially, the analysis and selection of indicators that are most impacted by the system were performed. For this, the influence matrix was used, where was made a pair-wise comparison. A Pareto chart was constructed with the results of the influence matrix, showing the indicators that most impact the system. After the discovery of the most influential, they served as a basis for the creation of future scenarios.

In the Pareto chart the indicators are organized in descending order, showing the cumulative percentage in the chart. Using the Pareto Principle, which states that 80% of the results are produced by 20% of the causes, it was possible to prioritize the most influential and thus use them as the basis for the construction of simulation scenarios. The influence matrix (Fig. 3) works as follows: each of the interviewed employees received some of the 25 selected indicators and analyzed if the indicator described in the column causes, influenced the others. When the employee felt that the indicator displayed in the row influenced the in the column, he would mark an "X" in the intersection cell in the table. After the evaluation of all indicators, the weight of the causes was added. The sum is shown in the last column (∑ weights). The next step was to build a Pareto chart with the ∑ of the weights found. The applied methodology considers for each "X" marked, weight one, however, the degree of intensity could also have been analyzed by substituting the "X" of the marking for values stipulated according to a table of values that relate the intensity of the influence.

Using Vilfredo Pareto's 80/20 rule, the first 5 indicators that most impact the others were selected. As can be seen in Fig. 4, the indicators IFA, OEE, Cadence, Engagement Rate, and Operating Income were selected.

To transform the selected indicators into scenarios, the present study held weekly meetings with managers involved in the problem, where they discussed what could be changed in the system so that it can reach standards of excellence in the selected indicators and consecutively solve the problem presented.

Alternative 1: In scenario 1, there remains two operators, but a conveyor is installed between the two operators, this reduces the time spent with displacement. In this scenario, the path that is currently made by the two operators will be carried out by the line supervisor, who will be called when the conveyor needs to be filled. Another benefit of using the conveyor is the organization that it provides, the operator easily locates and handles the part, decreasing the cycle time and improving the ergonomics of the workplace since the operator does not have to bend down at all times to seek and pick up the desired part.

Alternative 2: In scenario 2, it was included a collaborative robot, the workstation still remains with 2 operators, but the final torque step, which currently causes problems, will be performed by the robot, thus generating a decrease in the cycle time of the workstation. Ergonomics also improves, as operators will not have to perform the repetitive movements required by the pneumatic screwdriver in this scenario, but the threading activity still done manually by the operator.

Alternative 3: In scenario 3, it was included of two collaborative robots, requiring only one operator. The difference of this scenario to the previous one is that the robots realized the steps of threading and final torque of the piece.

Indicators (couse)	Cadence	Ociosidade	IFA quote	% engagement	SSAR	Nº absences at work	overtime cost	Lead time	Takt Time	STR	Hours of training	GMF 3 MIS	Scrap rate	Accidentability	VTU	Depreciation machines	Maintenance cost machines	Scrap and rework costs	ROI	Level of complexity	Effort Level Required	Noise level	Lighting level	5S level	OEE	∑ (weights)
	Indicators (Effect)																									
Cadence			X				X					X			X	X	X	X	X						X	9
Operating income	X		X				X					X			X			X	X						X	8
IFA quote	X	X		X	X			X	X	X		X	X	X	X			X	X	X	X			X		16
% engagement	X	X	X				X	X	X						X				X							8
SSAR	X		X					X	X			X			X				X							7
Nº absences at work	X							X							X				X							4
overtime cost															X		X		X							3
Lead time	X		X							X		X							X						X	6
Takt Time	X		X	X						X		X													X	6
STR								X	X										X						X	4
Hours of training	X												X	X	X				X							5
GMF 3 MIS			X										X						X							3
Scrap Rate			X		X													X	X						X	5
Accidentability	X		X			X	X		X						X				X							7
VTU			X											X					X							3

Fig. 3 Influence Matrix

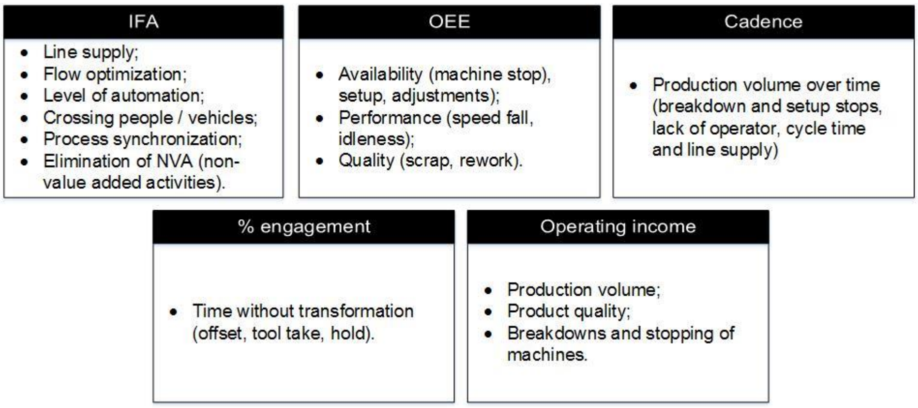

Fig. 4 Selected indicators and their assessment factors

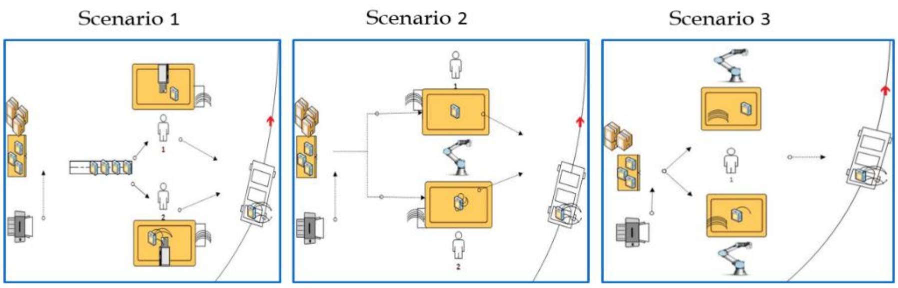

Fig. 5 Representation of future scenarios

3.4 Simulation

The present study aims to represent as accurately as possible the scenarios suggested for the workstation under study. To build the computational model, it was used the simulation software Witness® v.12. It is hoped, therefore, to identify how the pre-assembly station of ABS blocks will behave with the new changes, analyzing the variables that can interfere in the performance of the station. The criterion defined to evaluate the performance of the system will be the analysis of the cycle time, verifying if with the suggested changes the workstation will reach the ideal cycle time of 1.84 min. This cycle time is the time stipulated and tested by those in charge of the workstation so that the main vehicle assembly line is supplied at the correct time.

Table 1 Simulation results

Scenario	Operators	Idleness	Cycle Time(min)	Cadence's station
Current	2	0%	1.87	32
Future 1	2.2	1%	1.82	33
Future 2	2	25%	1.84	33
Future 3	1	7%	1.73	35

3.5 Analytic Hierarchy Process

The AHP method starts with the steps to define criteria and identify scenarios previously described. The next step is the classification of the criteria that had the employee's participation. Firstly, it was presented the operating mode of the table of comparisons developed by Saaty (1983). It has been explained that the scale uses values from 1 to 9 where 1 means the same degree of importance between two elements and 9 when one element is extremely more important than the other. Once the comparison table was understood, each employee individually filled out a questionnaire about the importance of the criteria, comparing the seven criteria. After this stage, the construction of the comparison matrix (Table 2) started, by analyzing the questionnaires. After that, it is necessary to verify the consistency of this matrix, for this, firstly it was created a normalized matrix (Table 3). For the creation of this matrix, it is necessary to divide the elements of each column of the comparison matrix by the sum of each matrix column, at the end is calculated the average of the lines, resulting in the average weight of the criteria.

Table 2 Comparison Matrix

Criteria	S	E	Q	P	A	M	C
Safety (S)	1	3	5	5	7	5	5
Ergonomics (E)	1/3	1	3	3	4	4	3
Quality (Q)	1/5	1/3	1	1	5	3	3
Performance (P)	1/5	1/3	1	1	3	2	3
Automation (A)	1/7	1/4	1/5	1/3	1	1/2	1/5
Maintenance (M)	1/5	1/4	1/3	1/2	2	1	1/3
Costs (C)	1/5	1/3	1/3	1/3	5	3	1
Total	2.28	5.50	10.9	11.2	27.0	18.5	15.5

Table 3. Normalized matrix

Criteria	S	E	Q	P	A	M	C	Average criteria's weight
Safety	0.44	0.545	0.46	0.45	0.26	0.27	0.32	0.39
Ergonomics	0.15	0.182	0.28	0.27	0.15	0.22	0.19	0.20
Quality	0.09	0.061	0.09	0.09	0.18	0.16	0.19	0.12
Performance	0.09	0.061	0.09	0.09	0.11	0.11	0.19	0.11
Automation	0.06	0.045	0.02	0.03	0.04	0.03	0.01	0.03
Maintenance	0.09	0.045	0.03	0.04	0.07	0.05	0.02	0.05
Costs	0.09	0.061	0.03	0.03	0.18	0.16	0.06	0.09

The next step is to find the maximum eigenvalue (λmáx.), for this it is necessary to multiply the weight of the criterion by the total value of each criterion (Table 2), the sum of multiplications will be the maximum eigenvalue.

$$\lambda máx = (0,39*2,28) + (0,20*5,50) + (0,12*10,87) + (0,11*11,17) + (0,03*27) + (0,05*18,50) + (0,09*15,53) = 7,65 \quad (1)$$

With λmáx., it is possible to calculate the Consistency Index (CI), subtracting λmáx. by the criteria's number of the matrix, and dividing this result by the number of criteria minus 1. The Consistency Index value will be used to calculate the Consistency Ratio (CR), divided by a Random Index (RI) Saaty (1983), related to the number of criteria.

$$CI = (7,65-7) / (7-1) = 0,11 \quad (2)$$

$$CR = 0,11 / 1,32 = 0,083 \quad (3)$$

According to Saaty (1983), the matrix will be considered consistent if it presents a CR less than 10%. The CR found was 8.3%, so the matrix can be considered consistent. Once it has been proven the consistent of the matrix, it starts the comparison and evaluation phase of the alternatives. For this, it is necessary to construct a comparison matrix for each of the alternatives. After that, it is necessary to build a decision matrix (Table 4), through the weights found in the analysis of the alternatives respect to each criterion, this matrix will be multiplied by the average weights of each criterion, resulting in the prioritization of the scenarios.

Table 4 Decision matrix

Alternative	**S**	**E**	**Q**	**P**	**A**	**M**	**C**		**Criteria's Average weight**		**Prioritization**
A	0,12	0,07	0,07	0,19	0,08	0,07	0,72	X	0,39	=	0,16
B	0,32	0,28	0,47	0,08	0,19	0,47	0,22		0,20		0,30
C	0,56	0,64	0,47	0,72	0,72	0,47	0,06		0,12		0,54
									0,11		
									0,03		
									0,05		
									0,09		

As can be seen in Table 5, the alternative that best meets the defined criteria is the alternative C. Confronting the result with the opinions of interviewed employees and the interests of the company, it can be said that the AHP was able to identify the best alternative, showing the importance of this methodology to support decision making.

4 Conclusions

In this paper, it was undertaken an integration of AHP and computer simulation to support the decision making in complex environments. The approach points out that the two tools can be used together making the analysis of the problems more consistent.

The integration of the two tools proved useful in assisting managers in the decision-making process, since the problems faced by these professionals usually involve several variables and uncertainties, thus increasingly requiring tools that support decision making, ensuring better results quickly.

In the case study presented, the alternative prioritized through the methodology was the alternative C. This alternative was also presented highest score in Safety and Ergonomics criteria, these criteria received the highest weights among all the criteria analyzed by the employees who answered the questionnaire of importance, justifying the prioritization of the alternative. From the results found, it can be said that the tools can be used together in two different approaches: AHP can be applied as a facilitator to choose the best scenario for the simulation. This situation is of great value, since the simulation process requires a lot of time, especially in complex environments, and the AHP method can direct of choice of scenario, making the decision making process faster. It is also possible to use the AHP methodology after the simulation of the scenarios, complementing the analysis with qualitative data, in this way the AHP can help in choosing the best scenario after the simulation of all the alternatives.

The second approach use simulation as a tool that provides consistent input data, so the AHP would not only consider qualitative but also quantitative data in its analysis, ensuring greater adherence to reality. The simulation is also able to exhibit unexpected behaviors of the system, as it was the case of the first scenario studied, where it could be realized that without the help of the supervisor of the line, alternative A could not reach the cycle time proposed, in other words, the simulation was able to show how the system would actually behave, presenting a different result than had been imagined.

In relation to the decision-making process, the use of the integration methodologies might represent a competitive edge for the companies, since it requires the interaction of several areas involved, besides allowing to work with consistent qualitative and quantitative data.

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