ANALYSIS OF IMPLEMENTATION OF AN AGV IN AGRIBUSINESS COMPANY

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ABSTRACT

Objective: This paper presents a case study, in a large agricultural machinery assembler, where a method is proposed to ensure an analysis, implementation and validation of the implementation of AGVs in the agribusiness industry.

Theoretical framework: The use of AGVs in the agribusiness industry provides several operational benefits, which are reflected in the optimization of its processes. Thus, becoming more competitive, reconciling new trends and market demands, providing margins of error and increasingly narrow quality standards.

Improvement of product quality: When it comes to car dealerships and their after-sales services, customer satisfaction and/or complaints, there is a scarcity in the literature that reinforce the use of the process mining technique. Thus, to cover this gap, there is a clear need for this research.

Methodology/approach: Using practices from the Lean Manufacturing philosophy, strategies were defined on how to reduce these losses, replacing idle labor with autonomous vehicles.

Results: Results demonstrate significant gains in a low payback time of 45 days and a 22\% reduction in operating costs.

Research, practical and social implications: Based on the studies presented in this document, it is possible to verify a considerable loss of labor, due to operator idleness and its resources, such as the transporter cart, as well as layout restrictions and supply models.

Originality: Industry 4.0, also called the Fourth Industrial Revolution, brings technologies to the manufacturing environment. One of them is the use of self-guided vehicles - AGV - to ensure greater agility, dynamism and organization in the operation in an industrial environment.

Keywords: Industry 4.0, AGV, Lean Manufacturing.
melhoria da qualidade dos produtos. Quando se trata de concessionárias de automóveis e seus serviços pós-venda,
satisfação do cliente e/ou reclamações, há uma escassez na literatura que reforça o uso da técnica de mineração de
processo. Portanto, para cobrir esta lacuna, há uma clara necessidade desta pesquisa.

Metodologia/abordagem: Utilizando práticas da filosofia Lean Manufacturing, foram definidas estratégias sobre
como reduzir estas perdas, substituindo a mão-de-obra ociosa por veículos autônomos.

Resultados: Os resultados demonstram ganhos significativos em um tempo de retorno baixo de 45 dias e uma
redução de 22% nos custos operacionais.

Pesquisa, implicações práticas e sociais: Com base nos estudos apresentados neste documento, é possível
verificar uma considerável perda de mão-de-obra, devido à ociosidade do operador e seus recursos, tais como o
carrinho de transporte, bem como restrições de layout e modelos de fornecimento.

Originalidade: A indústria 4.0, também chamada de Quarta Revolução Industrial, traz tecnologias para o
ambiente de fabricação. Uma delas é o uso de veículos autoguiados - AGV - para garantir maior agilidade,
dinamismo e organização na operação em um ambiente industrial.

Palavras-chave: Indústria 4.0, AGV, Manufatura Enxuta.

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1 INTRODUCTION

The manufacturing industry is seeking to optimize its processes to become more
competitive, reconciling new trends and market demands with increasingly narrow error
margins and quality standards (DEUS, 2009).

Within the logistical stages, there is significant waste with activities that do not add
value. The movement of materials carried out by the warehouse operators to the production line
can be seen as a classic task of lack of added value to the product. Santos Junior, Maciel and
Catapan (2019), reinforce that order picking optimization is of great importance, as its low
performance can lead to reduced overall efficiency and increased operating costs.

Therefore, it is interesting that these activities adapt to the automation processes, to
reduce their costs and without losing the focus on quality in the development of their activities.

It is understood that the application of an Industry 4.0 tool proves to be an efficient
solution that would enable the use of labor in necessary processes (SOUZA & ROYER, 2013).

The introduction of autonomous-guided mobile vehicles (AGV), an Industry 4.0 tool,
provides extremely important flexibility with obvious benefits for the production chain. Lee et
al. (2018) define the AGV as a driverless, steerable, and wheeled company, driven by electric
motors that consume energy from batteries. It follows predefined paths along a corridor to
deliver materials from one point to another and can load and unload loads automatically.

Hruščeká, Lopes, Juřičkova (2019) add that the AGV is the most recent type of vehicle
introduced in the company. They have the potential to play a critical role in supporting a variety
of services such as: order picking, consolidation, reverse logistics, just-in-time manufacturing,
customer support.

In this way, the problem in question converges on knowing: what is the procedure for
identifying, implementing, and analyzing the financial impact of a self-driving vehicle in an
agribusiness equipment industry?

The main goal of the research is to present a method to guide a pilot application of AGV
in a multinational assembly of large agricultural machines in Curitiba - Paraná. To succeed, it
must identify industrial wastes operating with traditional processes, implement a robot in the form of a self-guided vehicle as a pilot in the production line of an agribusiness company to eliminate logistical waste; validate the impact of implementing the technology in the manufacturing environment.

The method consists in three major steps: problem assessment, improvement implementation of the AGV and implementation feasibility.

1.1 Selection of The Bibliographic Portfolio

The selection process started by searching publications that were found relevant for the study related to the area and with the same approach of the study perspective. It started from a method called Systematic Bibliographic Reviews (SBR). They helped to identify research gaps and served as a theoretical foundation for the topics covered in each.

For the present research, a systematic literature review was developed, of an applied and exploratory nature. The purpose of using this method is to use the literature review as a tool to map published works on the specific research topic as indicated by Conforto, Amaral, Silva (2011).

After processing the search, three steps of filtering were applied to the publications that were found, based on the relevance of the publication searched. For the first filter, 304 articles were selected, due to a logic based totally in keywords to the process. At the next phase, the filters were applied to define the best results for the analysis. On the other side, the Filter 2 also focused on publiciations in books, journals and articles in the Engineering environment. The end of filter two, the result was 46 articles selected for the final reading. Finally, it was applied the filter 3, and articles were obtained for full reading. After this filter, the criteria applied were not elimination, but classification in terms of impact for the research by the color.

2 METHOD

Figure 1 demonstrates the structure to guide the transformation pilot project. It is possible to check each of the steps considered, as well as their tasks, inputs, and outputs. The first step is to define the problem. Once the problem is defined, it is possible to proceed to the implementation of the improvement, where all the action factors must be analyzed. And then, validate the implementation results in a quantitative way.
Figure 1 - Proposal method for implementation of a self-driven vehicle.

Step 1: Problem raise

The initial step of raising the problem guarantees assertiveness in the implementation of the technology, always in line with the appropriate tasks. At the end of the section, the area and process to be transformed should be clear. As well as its characteristics regarding the logistical process.

This first step serves as a compass for prioritization to define the improvement initiative. The identification guarantees that efforts will be concentrated on the area that presents the greatest participation in the loss.

Task 1.1: Identify the biggest costs of the company’s operation

As mentioned at the bibliography, costs can be classified between:

- An operational cost (activities that add value) and should be considered in the transformation of the product.
- A loss (activities that do not add value).

Their identification distinguish which activities should be optimized and which ones should be suppressed.

Within the logistical sector, daily, all costs generated during operations are classified according to their macro category:

1. Inventory: costs involving the quality of stock – value of stored material.
2. Handling: costs that involve the internal transport of material. The value added to the hours of presence of employees and hours of work of the equipment (tugs and forklifts).

For the present work, the macro category of interest is handling. The macro category of
handling is composed by the subcategories of labor and equipment. Since it deals with working hours to do the internal transport. The lines of losses are based on the operations that comprise each process. Its core activity guides the division between excess, efficiency and need losses.

For labor, the excess loss is the movement linked to the excess of hours performed in relation to the planned hours of production. Activities such as patrolling parts, moving material to supply missing items are considered when performing the classification. For efficiency, the desaturation time between the end activity (planned hours) and the time dedicated to the operation. Finally, the necessary loss subcategory analyzes the operation itself: transshipment, full and empty position movement (Kanban) and line supply.

For equipment, the only difference is that the handling of full and empty positions is not considered a necessary loss. Such relation between labor and equipment is natural, as the activities described operates by tugs and forklifts.

To fully guarantee a good guideline for actions and obtain expressive results, one must go up one more level between the directions conducted and prioritize the greatest causal (WOMACK, 2004). Figure 2 shows the result of the analysis with the stratification of losses.

![Figure 2 - Pareto graphs of logistics costs of losses.](image)

Initially, the manufacturing area with the greatest loss is investigated. Among them: tractors (TRA), combines (COL), transmissions (TRN) and platforms (PLA). By selecting the area of greatest loss (tractors), the value is segregated between the mentioned subcategories. The labor is the most significant, around 70% of the total. Thus, following prioritization, the activities that generate the most impact within the labor subcategory are those linked to necessary loss. Within it, inadequate line supply stands out as the most expressive cause.

Task 1.2: Mapp the operation in loco

To create the ideal scenario for logistics 4.0, the activities must be analyzed to find the phenomenon. The tool used to start the studies was 5G. A step-by-step process was made to understand the phenomenon as indicated by Ohno (1997), following the proposed sequence.
In the first “G” (go to the site), the study area can be seen in Figure 3. Each balloon demonstrates the view of the factory within the point of view of the points monitored in the operation. The ones highlighted in yellow, and green are the supply points and those in blue and red are the collection points. At each observed point, it is possible to verify the activities that are repeated: positioning, engagement, and disengagement.

![Figure 3 - Place of operation of the analysis for improvement proposal.](image)

Now, for the next consideration (examine the object), inside the tractor factory, the supply process of the parts considered Bulky were investigated. These parts are bulky if they are over 12kg, and their value is between 20% of the most expensive parts in the inventory.

The parts identified for sequence in the study are frame, rear window, roof and right door glass are exemplified in Table 1.

![Table 1 - Characteristics of bulky parts from the tractor factory.](image)

The frame weighs 315 kilograms, the roof 47, the rear window 25 and the side window 22. Given their dimensions, they are taken as a single unit to the workstation to avoid restrictions on the area during the tugboat's movement. All are supplied according to the line's schedule, which, in the analyzed period, was in 24 machines per day.

For the analysis of the operating principles of the processes, the tug operator with high loss of handling and idle time is verified, as shown in Figure 4. The tug operator must leave the vehicle (action A) to then disengage the rack (action B) and finally push the rack to the marked position (action C). Each step of the process demonstrates the necessary and unnecessary movements to guarantee the supply of the line of a single par. Subsequently, to check the facts and data, dividing the activities of the operators and the time dedicated to each, it is necessary to classify them into activities with a logistical purpose and losses that do not add value to the process. To then segregate actual process time from what is expected based on cycle time (line time when operating under ideal conditions). Figure 5 shows this analysis graphically.

The values are more impacted by the inefficiency presented by the tug, which alone has around 25% of the total loss and desaturation activity. It should be noted that the total time for
the process alone is approximately $\frac{3}{4}$ of an hour. It is also worth mentioning that the time spent on it composes the costs and losses not only of labor but also of the equipment used in the process.

When performing the final “G” (comparison with the theory), the theory, according to Ohno (2015), indicates that losses must be mapped and eliminated efficiently, to make the operation as lean as possible and free of waste. Therefore, the process must be improved.

In conclusion, with the 5G tool, the operation in question presents a significant level of loss in relation to the efficiency of the process, being performed by five operators and one machine (tug). The measure of the operators involved in the logistical process of the area suggests that the entire scope of work must be revisited and that the impact of the project will affect the entire workload of the team involved and trigger subsequent actions.

Figure 4 - Tug operator with loss of productivity.

Figure 5 - Distribution of logistics operators' time in the process

Task 1.3: Identify the process

To facilitate the understanding of the actions involved in the supply process, based on the on-site research, it was possible to assemble a value map demonstrating the activities carried out by the logistics operators.

In Figure 6, the waste in the logistical stages is highlighted, the operator's core activity is not adding any value. Within the definitions already mentioned, it is possible to indicate what is loss (boxes in red) and what is logistical activity (boxes in green). It exposes the sequence of the entire supply chain available in the reported process. Thus, it is possible to have a macro view of the entire operation and step available in the studied process and allows the definition of the activities that the AGV must perform as mentioned.

In each activity, the tugboat is dedicated waiting for the execution. Therefore, the two
resources (labor and equipment) have an approximate operating time of operation of 16 minutes. Just to fill up takes around eight minutes, as well as to return.

Analyzing the value map, the only activities that add value are transport and supply. Of the ten mapped of the process, eight that are executed and that dedicate an operator and a tugboat are classified as losses. The already analyzed activities of sequencing, coupling/uncoupling, positioning the carts demonstrate that the activity is extremely manual and depends on operator input with simple initiatives. This fact supports what 5G stands regarding the level of idle time of the tug.

<table>
<thead>
<tr>
<th>Check the progressive</th>
<th>Locate the part</th>
<th>Engage full cart</th>
<th>Transport</th>
<th>Disengage full cart</th>
<th>Place the cart</th>
<th>Engage empty cart</th>
<th>Transport</th>
<th>Disengage the empty cart</th>
<th>Place the empty cart</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>0,05</td>
<td>0,15</td>
<td>0,32</td>
<td>7,3</td>
<td>0,23</td>
<td>0,38</td>
<td>0,32</td>
<td>7,3</td>
<td>0,23</td>
<td>0,38</td>
</tr>
</tbody>
</table>

**Figure 6** – Value stream map of the kits as is.

**Task 1.4: Identify the route**

In order to understand the route involved in the process, a layout analyzes is made. Figure 7 represents the area and the trace of the studied operation. It represents the trajectory of the identified pieces, from their initial to the final position. It is possible to identify the layout of the area involved in the process and the space restrictions for the routes. Especially when it comes to equipment that has a turning radius for conversion. In the case of the tug, four meters. Also, it becomes clear the need to maintain human-machine separation and the duty to comply with all safety requirements. Since the movements occur between productive areas and with a considerable flow of people.

**Figure 7** – Layout and flow of the logistics processes.

**Task 1.5: Identify the call of system**

To understand the systems integrated to the process, it is necessary to analyze the data management and persistent information flow to the operation. The standard process is made by...
screens displayed on the tablet, as the Figure 9 represents the production control system (MMS).

![Production sequencing screen in MMS](image1)

![Kit assembly screen according to MMS registration](image2)

**Figure 8** – Operations management system.

The operation is already sequenced, necessary for the leveling of the operation, as exposed. And the sequence of parts to be sent to the production line too, with kit assembly or unit shipment.

The standardization integrated in the MMS allows a programming interface that the automation will need, it demonstrates that the assembly order and the collection actuation respect the rhythm of the line and can be monitored according to input in the system. This will enable the implementation of the AGV with as little human intervention as possible.

**Task 1.6: Identify the training method of the operators**

As identified in the previous section, the process has a level of data automation that directs the operator in the assembly and line supply. It is reliable to say that the deviation is still possible as the input and the decision depend on the operator.

As shown in Figure 9, it is possible to identify the frequency of supply delays (collection and delivery outside the correct time, the machine goes from the assembly station without the part) for the analyzed parts and the deviations in the process of delivering the wrong kit to the operation (collection and delivery of the incorrect part).

![Occurrences of deviations in the process by machines (tractors) released for the parts under analysis](image3)

**Figure 9** – Analysis of deviation occurrences in the supply operation of parts.
Figure 10 – Process sheet of the assembly line supply operation.

From the analysis of Figure 10, from October 2020 to October 2021, 40 supply delays and 13 incorrect supplies were verified against 332 released cabins. The pattern of occurrences is shown to be random, which indicates that these are uncontrolled events, and their mediation must be done individually, without a plausible chronic root cause. What is possible to infer from the process is that the visual indication with the tablet is not enough. It is necessary to transpose the information automatically.

The standardization of activities is made from the process sheets as shown in Figure 10. They direct the activities to be carried out in a macro way and do not consider the particularities of the process, such as changes to carts, kits, couplings and routes. The sequence of activities must be guidelines for operators.

From the operation sheet it is clearer the manual level of the operation. Each movement step is described to guide the operator’s action.

**Step 2: Implementation of the innovative technology – AGV**

Based on the qualitative and quantitative analyzes discussed in the previous section, it becomes possible to map the process and identify opportunities for improvement. The project aims to implement a 4.0 Industry technology with subsequent analysis of its technological and financial feasibility for the area.

Having acquired a deeper view and knowing the current situation on the shop floor, through research conducted in loco, it is necessary to establish the main objectives. This will be able to propose changes and provide clear indications about the desired future state. In this case, according to what Hrušècká, Lopes, Juříèková (2019) comment, viable solutions must be developed and assessed.
Task 2.1: Analyze the AGV logic

Following what Balé (2013) says, there must be an established standard for the operation. The standard for the process is the supply through the tug after the kit is assembled, as already validated in the previous step.

Figure 11 shows the expected process of the AGV, from the order received to its return. As exposed, its action is triggered with the order received, exemplified in the first frame. Then, it moves the vehicle to the target to collect what must be supplied, and then it is transported to take the empty kit cart.

Thus, to adapt the AGV to the operation, some assumptions must be considered. All tasks guide the line of work that allows the AGV cycle to operate as regularly as possible.
Task 2.2: Design the new logistical route

To understand the new route, it necessary to evaluate the layout. Tre restrictions were already recognized at the previous step. The Figure 12 shows the route that the AGV must take. Starts in the way of collecting the items. Subsequently, it returns with the empty kits for new assembly. The area has a main line that has access to the edge of the line to stop at the stations indicated as A0, A1, A2 and A3 and two others with access to the collection point for full kits and their delivery when empty: glass market back and right side, door and roof (B2) and frame paint buffer (B1).

The return and reversal areas of the AGV’s direction are delimited and indicated as Area 1, Area 2, Area 3. In them, the distance from the turning radius of the AGV must be ensured, considering the maximum number of kits that will be coupled and their dimension.

With the implementation of the AGV, it becomes possible to connect three more kits. Thus, the route that was dedicated carries out the process of supplying four stations in the sequence. A linear supply flow is defined between each collection and delivery point. A new rhythm is created with the flow delimited in: full collection at B1, then B2 and supply at A3, A2 and A1 to go to A0 and proceed with the delivery cycle.

![Figure 13 – Frame supply mode with AGV for the production line.](image)

Task 2.3: Establish supply modes

The definition of the supply modes gave the activities an analysis in terms of space and the distribution of parts. The motivation of the task is to meet the requirements of the organization of the line workstation and the distribution in the warehouse and painting. Always ensuring the availability of the part at the right time.

For the frame, the supply modal remained in a unitary cart, its volume and its delivery position on the line directed it to a supply as shown in Figure 13. The customized cart for the part allows the sequential accommodation of the frame, in which it is already directed to the line in the assembly position. Such logic facilitates the entire cycle from operation to production.

Figure 14 shows the packaging intended for the roof. As well as the frame, the need for a unitary cart was identified. The mechanism also allows the roof to move in 360º to carry out the necessary assemblies in the line.

In the Figure 15, for the rear window, a kit is defined with all the parts that will be pre-assembled positioned together on the cart. Such a configuration facilitates the line process. The closer the parts are placed, the shorter the assembly time. In which the part is accommodated in a metal tube material kit and delivered to the assembly point of the production line.
Figure 14 – Kit trolley for ceiling assembly.

Figure 15 – Kit trolley for rear glass assembly.

Figure 16 – Kit trolley for assembling the left side glass.

Figure 16 also shows the kit pattern for the left side window. Where the choice of kit proves to be more advantageous due to the ease of pre-assembly in the line. For each modal, the required number of carts and kits in the flow was evaluated based on the cycle time and delivery time of the AGV. The point that was considered was the attach and detach mechanism, being one of the premises that should not need human intervention.

To ensure a complete transformation of the activity, the supply process should contain all automated steps. The engagement and disengagement mechanism could not need human intervention. The hitch mechanism was adapted for the AGV for two different triggers.

The first, shown in Figure 17, works with an induction system that activates the hook that couples and uncouples the pin fixed to the unit cart. This mechanism is used only for the frame trolley, as the attach system must be more robust to maintain the stability of the set. In addition to its positioning in the waiting area for collection, it favors the use of a bar.

The second, Figure 18, works with a pin system that triggers according to positioning and demarcation on the route. When it arrives at the supply or collection stop, it performs the
vertical movement of the pin and allows the cart to engage or disengage in position (also, according to the programming logic). In this case, the kit cart itself must contain the position of accommodation of the pin and check the locking to proceed with the route.

**Figure 17**- AGV automatic coupling mechanism for unit cart.

**Figure 18**- AGV automatic coupling mechanism for kit cart.

Task 2.4: Determine new delivery cycle

The definition of the collection cycles from the receipt of the order had as factors the speed of the AGV, the distance between routes and the cycle time of the process. The number of kits that must be filled per minute and the vehicle’s delivery capacity as shown in Figure 19.

The validation of the times allows to understand if the AGV will be able to carry out the deliveries within the necessary time. The routes and multiples that each cycle must have need to be considered, as all supplies are made individually (in the form of a cart or kit), their supply must follow the rhythm of the line.

Thus, every 12 minutes, the parts must be supplied at the point of consumption. According to the average of the distances between the points, as already exposed in the layout, of 270 meters and the speed of the AGV of 50 meters per minute. It fills up every 5.4 minutes. Thus, it has a free time of 6.6 minutes. With the information on the supply cycle times and the AGV, it is possible to configure the rhythm of the operation.

<table>
<thead>
<tr>
<th>Supply needs</th>
<th>Cycle time [min]</th>
<th>Consumption of parts/cycle</th>
<th>Supply/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGV Delivery capacity</td>
<td>12</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>AGV Speed [m/min]</td>
<td>Route distance [m]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>270</td>
<td>5.4</td>
</tr>
</tbody>
</table>

**Figure 19**- AGV Delivery.
Task 2.5: Create a new route

According to the bibliography, there is the possibility of applying four types of navigation technologies: guided system, track system, LASER triangulation, markers. Evaluating the applicability of each trajectory, it was divided into three categories of analysis: cost, flexibility and maintenance as shown in Figure 20.

As a validation of the method with the greatest potential, a weight from one to five is used in each criterion in order to demonstrate the best solution. The one that returns with the highest score is the most advantageous mechanism for the operation according to the selected points.

The magnetic lane, a track system, ensured greater efficiency and return in relation to available space, as well as a greater ability to follow the determined route and acceptable flexibility, plus a viable market value for the project. It is also verified a low cost of maintenance of the tapes, a good adaptability of the route and flexibility for changes and diverse configurations. Reinforcing that this fact does not exempt the need for an annual maintenance plan, since the system and tapes are subject to ambient interventions.

<table>
<thead>
<tr>
<th>NAVIGATION SYSTEM</th>
<th>COST</th>
<th>FLEXIBILITY</th>
<th>MAINTENANCE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUIDED SYSTEM</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>TRACK SYSTEM</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>LASER TRIANGULATION</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>MARKERS</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

**Figure 20**- Navigation system choice matrix.

Task 2.6: Ensure process security

It is worth emphasizing that the AGV system must carry out the loading and unloading movements of materials automatically and with security settings for any interventions of the medium along the way.

As shown in Figure 21 the automatic stop sensors were defined to be activated with a distance of three meters from obstacles, since their datasheet indicates the range of the protective field. Already its warning range allows the indication in eight meters. The response time must be on the verge of identification and reaches 8 milliseconds, adequate time for operation since it has direct interaction with obstacles, people and machines in its path.

On the other hand, Figure 22 shows the light signaling and the sound output that the sensor triggers. With a luminous LED column, the system indicates the stop signal due to an obstacle.

**Figure 21**- AGV safety sensor specification.
Task 2.7: Ensure equipment durability

Since talking about a current equipment in the area, it is necessary to implement a daily autonomous maintenance checklist. It competes on basic questions about the current conditions of the AGV and checkpoints crucial to its operation and safety throughout the day:

1. AGV has a charged battery.
2. AGV route has irregularities.
3. It was possible to place AGV on the route.
4. AGV is working on route.
5. Production line D-1.
6. Deliveries made by AGV D-1.

The professional preventive maintenance plan was created in order to ensure the durability of the equipment and the route implemented as shown in Figure 23.

Crucial points for the performance of the AGV must be considered and configured on a weekly, monthly, six-month, and annual basis. The mechanisms are divided into mechanical and electrical, which allows a better description and prevention of the activities that must be considered.

Task 2.8: Ensure team involvement

As a final action to make the project viable in the area, the standardization of the operation is carried out and the operators involved are trained in order to guarantee the complete delivery of the project. Training is essential since the area will be responsible for keeping the vehicle in operation. Figure 24 demonstrates the sheet created for the AGV standard procedure.

As the equipment comes to the industrial ambient as a transformation of operations and...
a novelty for the entire team, a user manual was created to guarantee a friendly interaction between man and machine. It contains the crucial points for use and guarantees a full understanding of all AGV mechanisms in case of doubts or problems, exemplified in Figure 25.

In order to guarantee the technical delivery of the new equipment, it is necessary to clarify the functionalities and its technical sheet. In Figure 26, the main characteristics in relation to movement and feeding are highlighted.
For the movement, the selected motor is the MKS GPA-R which has a voltage of 24 Volts, a current of 30 Amps to withstand the voltage and power of 750 Watts. The choice of engine characteristics was based on the required load capacity: 1,000 kilograms. Selected deep cycle gel batteries allow for superior charging autonomy compared to common batteries available on the market. The other characteristics (voltage of 12 Volts and capacity of 130 Ampere per hour) are common.

For the technical characteristics related to navigation and programming, Figure 27 demonstrates the choice of metallic tape as the direction for the acquisition of the lateral and central inductive sensors.

The range of each indicates the read level on the tape. The induction field formed for the first is 40 millimeters and for the second it is 30 millimeters. The frequency indicates the sensor reading speed: the higher, the faster the response. For the side it is 50 Hertz and for the center it is 300 Hertz. While the first performs the reading of commands with the tags, the second guarantees the permanence of the AGV on the route and must have a shorter response time. Figure 27 also demonstrates the characteristics of the programming PLC. The Siemens expansion module (Siemens S7-1200) guarantees a user-friendly human-machine interface to enter the code, change routes and visualize the logic chosen for the drives (speed, curve, stop).

In addition to being the language used for other initiatives in the company, which guarantees reliability and know-how for necessary interventions.

The technical characteristics presented were defined according to the configurations available on the market. The ones highlighted in the section are those that directly impact the operation of the tool. They are also the ones that guarantee the robustness of the operation, since the topics covered: handling, feeding, navigation and programming, are basic premises for the execution of the AGV.
3 IMPLEMENTATION FEASIBILITY

As a result, it is possible to highlight the achievement of a gain relationship with the cost of the project. The section provides calculations in order to obtain the financial return that the project would provide.

Task 3.1: Measure new process

To fully understand the benefit that the implementation of technology would provide for productive activities, it is interesting to map the new process.

As shown in Figure 28, revisiting the value stream map, a replacement of the loss activities that were performed by a man and a machine, now attributed to the AGV, is found.

Now the activities in red that are the losses become automatic the route of passage and two new activities of loss are identified: placing the AGV to load and positioning in the route to start the operation. With the use of the AGV, human intervention still exists for the shift change set-ups (activities: put to load and position on the route). Activities that make up 0.37 minutes and do not belong to the cycle time, as they are performed once a day. The automation in the flow of information and in the process guarantees greater agility to the process and a reduction of 5.8 minutes per cycle.
Task 3.2: Measure operation costs

When comparing the costs in the two states, it is necessary to evaluate what was given out of labor and material for the execution of the activity in the current state and in the proposed one. What used to divert a workforce and a tug with dedicated time per year (R$ 234,033.60), now has only the cost of a workforce to carry out simple activities during its work schedule. At the beginning and end of the workday: place it in the charging place, turn it off and on. The benefit can be calculated according to Table 2.

<table>
<thead>
<tr>
<th>Annual cost</th>
<th>State</th>
<th>Labor</th>
<th>Equipment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>R$</td>
<td>924.168,00</td>
<td>R$ 49,200,00</td>
<td>R$ 973.368,00</td>
</tr>
<tr>
<td>Future</td>
<td>R$</td>
<td>759.138,00</td>
<td>-</td>
<td>R$ 759.138,00</td>
</tr>
</tbody>
</table>

Table 2- Annual cost analysis of the current and future state.

The time dedicated to the operation is considered as the current cost of labor to the process in the year. To find the values in terms of labor, the time dedicated in the year is used and multiplied by the value of the labor (internal rate calculated from the costs of the operation in general). As for the equipment, it considers the value of the monthly rental cost (annual value of R$ 49,200).

Thus, the benefit reaches a reduction margin of R$ 214,230.00 for the operation. An activity that used to displace the company's resources and was 80% a loss is replaced by an application that needs human intervention within an hour between shift changes.

Task 3.3: Operationalize the variables and factors

The criteria for analyzing the project results takes into account factors that indicate the feasibility or not of its implementation - Financial Return (FR) and Return on Investment (ROI) - and the time of use of the AGV to carry out the logistics process - Capacity Productive System (CPS).

To calculate the ROI, the investment cost of the technology is considered: the purchase of the AGV machine, the materials needed to use the technology and the installation labor, and the revenue generated by the project.

On the other hand, the RF is calculated from the payback method. The cost and the financial return are considered to evaluate the time of recovery of the investment. Finally, the CPS is calculated from the effective productive capacity (CPE) and the hours available in the shifts. In order to be able to measure the transport capacity of the AGV in one day.

For the investment value, the depreciation value in the year must be considered. In the case of AGV, it is the policy of the company's financial controllership sector to consider ten years for the devaluation of the acquired asset. Thus, the investment takes a value of R$ 26,083. With the two values, it is possible to calculate the ROI of 7.2.

To calculate the RF, the value is verified by the payback value indicates how long the investment will return to the company, equivalent to three months. Next, to measure the maximum number of realizations of the AGV process, the CPS is used. As it is a machine, to consider the expected losses (maintenance, line stoppages and operator inefficiency) and provide richer and more faithful data to collect losses, the effective productive capacity (CPE)
is considered. To obtain it, an efficiency of 98% of the machine and an availability in the shift of 528 minutes are indicated.

The effective productive capacity of the system will be 517.44 minutes daily. To understand the total process hours, it is necessary to obtain the average speed of the AGV which, provided by the manufacturer, is 50m/min. As well as the distance that the program routes give to the equipment during the execution of the process: 270 meters.

With all the information described, it becomes possible to find the CPS value of 95.8. The result indicates that the AGV is capable of performing 95 moves in a single shift. When compared with the current capacity of 35 kits per day, the efficiency of the AGV is clear to the process and, also, indicates that it is possible to carry out other studies to improve the level of service with the integration of other routes.

4 RESULTS AND DISCUSSIONS

The implementation of the AGV proved to be essential to eliminate direct human interference in the operation, since 100% of the losses related to the feeding of the production line kitting were mitigated. It shows that the application of the tool in the industrial context comes with a great potential to, if not eliminate, at least drastically reduce the cost of activities that do not add value to the final product, in addition to the benefits related to flexibility and efficiency. Observing the current flow of the process, it is clear the poor use of the operator's workforce, given that there are technologies available to perform these operations.

Related to the collected value, the observation on the shopfloor (from the 5G tool) has showed to be essential to clearly understand the stages of the process that should change. With every stage of the tool, was possible to set the phenomenon of the process, in which one manpower and one machine are orientated to send parts unitarily to the assembly line. With the layout and route studies, it was possible to identify the constraints of the process: space to define fixed locations and turning radius along the entire route.

With the analysis of the system, it was possible to identify the points of the process that already had data automation and it was essential to create the data integration and serve as a trigger for the AGV. It is noted that standardization gives responsibility to the process, as it ensures that all actions have low levels of deviations from the team, and even with the internal process and training there are still flaws in the process. The daily actions were well defined with visual and clear tools, as the tool needs to be implemented as smoothly as possible.

The implementation of the improvement showed the particularities of the AGV and how it impacts the entire logistics flow. The organization of activities with the main lines of action proved to be successful for the methodology used. The formalization of the implementation of the Project in the area and its final report ensured greater commitment to the line, creating a sense of responsibility for the team. The implementation of the checklist also ensures a strong commitment to the equipment and validation of safety points (sensors, batteries) to ensure that the vehicle performs activities as expected.

To visualize the gains quantitatively, the KPIs found in the literature were calculated as a metric for AGV delivery and saturation. The labor numbers were collected, which shows that many activities that do not generate value can be underwritten by the AGV and, consequently, a link in the case of labor. In addition, it was also possible to reduce the cost of the equipment (tugboat) that was used to carry out the work in question. The cost of labor in the operation was reduced by 18% of the total annual value, while the reduced cost of equipment was 100%.

The cost of this study proposal is the price of the AGV and its annual maintenance. Thus, the total investment will be R$ 260,386. The value of the AGV represents 35% of the annual expenditure on labor and equipment rental. It was possible to qualitatively understand the impact of the AGV for the activity studied, measuring the collection and feeding made by
the vehicle and the financial return for the company.

5 CONCLUSIONS

The highlighted targets have been completed with success, once the AGV was implemented on the kitting line feeding to a production line, eliminating the activities that give the manpower losses on the process.

The study has given, in the RBS bases of analysis, 300 potential articles to analyze and filters that indicated that the biggest vacancies of the study and contextualization of the theme of this study.

It has been demonstrated in collecting shop floor data and using tools such as time and method analysis, Spaghetti charts, and operator filled loss collection. Several types of losses were verified, related to the efficiency of the workforce, such as, for example, attaching and disengaging the carts on the tugboat, its own movement and even the loss of equipment efficiency, such as battery recharge and others.

The AGV was implemented at the logistics processes, all the structure of the method allowed it to be as smooth as possible. The technical criteria were analyzed for the operations conditions and adapted in its function;

As the financial return, the benefit was around 41 kUSD, the return of investment (ROI) at 720%, the payback in only 40 months. As well as the increase of the operations efficiency, a shift with a labor and a tugger could make 35 movements, now the AGV can make 95 movements.

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