On the Integration of Industrial Data and Analysis with Simulation in a Company of the Cork Sector

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Abstract. Nowadays, companies are constantly seeking to develop tools to increase productivity, production flexibility and the quality of their products, or to reduce costs, delays and their exposure to risks. In fact, such improvements can be achieved in the scope of product as well as of process improvement. In industrial contexts, often, such improvements can be achieved by implementing tools to access the intended information in due time, such as Decision Support Tools. Aligned with the aforementioned, this project was developed in the context of a cork industry, dedicated to the agglomeration of cork and other materials, such as rubber, foams and recycled plastics, and the transformation of these same agglomerates into products, such as joints, footwear, floors, consumer goods, acoustic coatings and sports surfaces. More specifically, tools for the automated access to information were developed, namely, a reference search tool that meets the specified requirements of managers from the company, as well as a tool to search the available dimensions or production steps for a given product. Moreover, and infield of process improvement, a set of simulation models were also developed using SIMIO. First, there was a survey and parameterization of the critical factors of the line, so that the simulation could be elaborated, and afterwards the balancing of the system was studied, considering different scenarios. Depending on the type of roll to be produced and according to the type of packaging, the balancing of the system varies. Other scenarios were studied for when the system is not balanced, in order to avoid this occurrence. All in all, the set of tools that were developed led to a considerable reduction of the time spent by human resources on accessing critical information, as well as an improvement of the analysis of their industrial processes.

Keywords: Information integration, Cork Industry, Decision Support Tools, Simulation, Process improvement, Product Improvement.

1 Introduction

Companies are constantly aiming for the overall improvement of their products and processes. In fact, such constant pursue allows them to attain benefits such as the increase of productivity, production flexibility and the quality of their products, or the reduction of several costs, amongst others. Nevertheless, a critical barrier to such goals is often the access to critical industrial information in due time. As such, the conception of solid Decision Support Tools (DST) is mandatory, which should allow the access to the intended industrial information, as well as assist sound decision-making concerning industrial processes [1].

The scope of this work consists of a project conducted in the area of industrial and engineering management in a real company of the cork industry. In this company, the need to develop a set of tools that could facilitate and automate the access to industrial information, as a more efficient overview and analysis of certain critical processes arose. To address this need, tools for automation of information search were developed using standard and widely adopted tools in industry, such as Microsoft Excel, Microsoft Access and VBA (Visual Basic for Applications). As such, the purpose of this paper is to document this work, emphasizing the main faced difficulties in working in a real industrial environment, as well as in establishing the main benefits that were achieved.

Microsoft Excel is a widely popular spreadsheet due to its versatility. It is useful to analyze data, create charts, automate tasks with macros, among other functions [2], [3]. VBA allows automating, customizing and extending the functionalities of Microsoft Excel, through programming code. In this way, it allows the development of applications, such as functions and procedures that respond to the needs of data analysis [4].

In its turn, Microsoft Access allows the development of database management systems, is easy to use, access and distribute. Access is often the first choice of relational database software, since it is possible to quickly create useful database solutions, and is widely available for industry community. It may not have all the performance features of other software used by the community specialized in database management solutions, such as SQL Server, but for many situations it has the most frequently used or necessary features. In fact, there are many challenges that can be solved by Access, without having to invest in expensive and complex software [5], [6].

The design of a DST should address business problems and questions with well-defined purposes. However, the risk of developing muscle artifacts without added value is high and it is therefore important to have a considerable background in the area of industrial management, which represents an important advantage in the development of these artifacts. For example, the application of Lean principles and tools might allow the acceleration of the creation and development of software.

Regarding process improvement, the requirement to simulate certain production lines of rewinding and automatic packaging of composite agglomerated rollers for the study of system balancing, according to the characteristics of the roller and packaging, also arose. Simulation involves the generation of an artificial history of the real system and its observation and analysis, in order to extract data or conclusions (inferences) about the operational characteristics of the represented real system [7]. In fact, simulation is a very convenient methodology for assessing a possible solution, and the interactions between these elements over time, under stochastic conditions, due to its ability to study complex systems that involve a set of resources with their own characteristics, machines, human collaborators, random factors, availability of secondary material, energy, location of each of these concepts, movement of raw materials, warehouses, queues, and others. Through the simulation of the system, it was possible to analyze and study the balancing of several scenarios, according to the characteristics of the rolls and the packaging. For unbalanced scenarios, alternatives were studied to avoid this occurrence.

This paper is structured as follows. Second section discusses the materials and methods used in this research, i.e., it starts by identifying the relevance of the problem at hand, so that the adopted methodology can be explained thereafter. Third section describes the interaction with the set of tools developed for the access to product data under several dimensions. Fourth section describes the set of simulation models that were developed for the purpose of allowing a better analysis of critical processes, and, finally, last section discusses the main findings and establishes future research topics aligned with this research.

2 Materials and Methods

This section describes the materials and methods used in this research. The section starts by identifying the description of the critical situations that were observed whilst conducting the initial field observations. Bearing the most relevant issues and other aspects in mind, a methodology was established for this research, which is described in the second subsection.

2.1 Problem Statement

The issues that originated this research can be summarized as related to process and product improvement. As such, the first group of issues concerns the access to critical product information, hence allowing more efficient analysis to the products of the company. The second group consists of being able to better analyze the processes to which said products go through.

Access to critical product information.
In the operations section of the cork company, there are several departments, one of them is Engineering, which encompasses, in turn, other sub-departments: the Product Engineering, Design Engineering, Continuous Improvement and Circular Economy. Each of these departments is responsible for fulfilling the established tasks.

The Product Engineering Department, among other activities, is responsible for responding to information requested by customers from the commercial department. For example, information on which references can meet certain requirements and on the possibility of designing a new product.

A reference consists of a four-digit code and for each reference the components and their proportions used to obtain a given mixture are determined. From this mixture one can agglomerate blocks, cylinders and/or sheets cured with the required thickness (FCE). However, for each of the references it is established which molds can be used.

The requirements that customers can choose are, for example, material density, product dimensions and type of finish. The product engineering team has this type of information gathered in Excel files, or is contained in the memory of some collaborators.

When a customer requests a new product, it is also the responsibility of the product engineering to study the possibility of designing that product and associate an internal production cost. To this end, it is necessary to define the agglomerate to be used, to analyze the technical limitations of the equipment and, if the production of this new product is feasible, to define the production processes through which the material has to pass.

In order to answer which references, limitations were found in the reference selection work, as there is a dispersion of information in several files, which leads to more time spent in searching, retention of information in supervisors or other employees, that hinders access to this information and increases the possibility of human errors, and the absence of research automation tools that facilitate the search of information.

In order to study the possibility of designing a new product, the Engineering Department not only needs to know the characteristics of each reference, but also needs to know the technical limitations of the equipment and the various production flows that exist. This information is also dispersed in several files or is retained in the memory of some supervisors or other collaborators. These conditions, again, cause more time to be spent searching for information and a greater likelihood of human error. Moreover, the absence of research automation tools also makes it difficult to search for information.

Thus, to decrease the time of human resources spent in the collection, management and selection of information and to decrease the probability of occurrence of errors, tools for automation of information research will be constructed: a reference search tool that meets the intended requirements and a tool to search for available dimensions or production steps.

Analysis of critical processes.

The cylinders resulting from the agglomeration process can be rolled into rolls in the rolling mills. The automatic rollers rewinding and packaging lines contain an innovative technology that allows the rollers to be rewound and packaged automatically. However, they do not work completely alone, they need two collaborators. One employee is responsible for laminating the cylinders and the other employee is responsible for the entire packaging area.

In a first phase, the first collaborator places a cylinder in a mill, which laminates the cylinder to carry out the cleaning operation. After these setup operations, the already cleaned cylinder is rolled to the desired thickness and forms a continuous cork roller. This continuous roller advances to the rewinder, where it is rolled and cut, forming the final rolls to the desired length.

There are two lines of rewinding and automatic packaging of composite chipboard rolls in parallel. Each line contains a rolling mill, a rewinder and a conveyor belt. The same developer who performs the setup operations is also responsible for fine-tuning the thickness at which the cylinder is being rolled and for ensuring the correct functioning of the rolling mills and rewinders.

After the rewinding operation, the rollers follow the conveyors to the packing area, where the second collaborator is responsible for all the processes that take place here. The rolls can be packed in plastic, cardboard and/or box. If the roller is packed in plastic there is a machine that automatically performs this operation. If the roller is packed in carton, the packing process is manual, carried out by the second collaborator. After the roller is packed, the collaborator transports it to the pallet. After the pallet is complete with rolls, the pallet is packed. Finally, the collaborator moves the set formed by rails, to then be collected and puts a new pallet in the respective location.

On the automatic rewinding and packaging lines of composite agglomerated rolls there are several factors that determine the system's production cadence, namely, the thickness and length of the intended roller and the type of packaging used. The smaller the thickness of the rollers, the longer the rolling time of the cylinder, as greater control and precision of the machine is required. The rewinder, in turn, adapts the speed at which it rolls and cuts the rollers so that there is no material accumulation between the two machines. Finally, depending on the type of packaging, the cycle time of the packing station varies, and plastic packaging is the one that has the lowest cycle time associated, since there is a machine that automates this process.

The characteristics of the roller and packaging influence the functioning of the system. For this reason, depending on the production, the system may be balanced or not. When the system is not balanced, the packaging zone cannot give flow to the rollers that arrive upstream and the employees stop one of the lines to prevent the rollers from being piled on the conveyors. This happens when the cycle time of the first stations is less than the cycle time of the packaging area. Thus, in order to predict the system balance according to production and to study solutions that prevent this accumulation of rollers, a simulation of the automatic rewinding and packaging lines of composite agglomerated rollers was constructed [8], [9].

2.2 Methodology

This subsection addressed the methodology adopted for this work. In this sense, **Fig. 1** demonstrates the methodology used for the development of automation tools for information searching purposes.

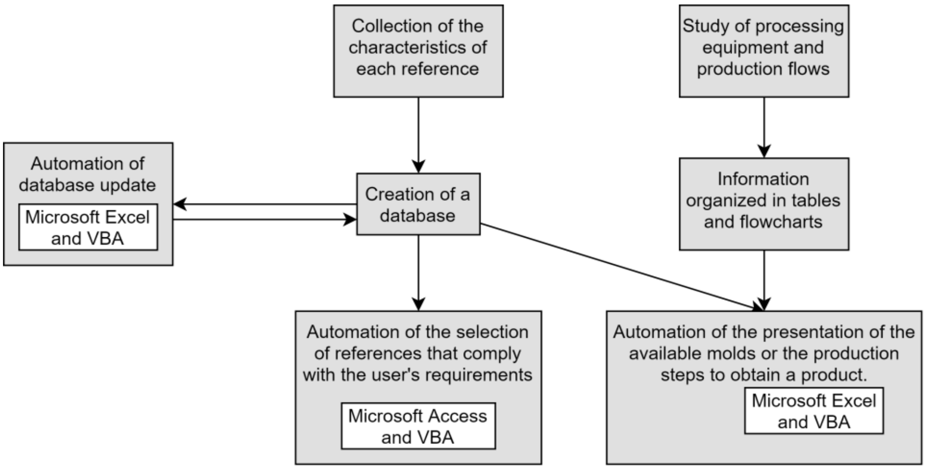

Fig. 1. - Methodology used for the development of information research automation tools

As the figure suggests, it was necessary to initiate with the collection and organization of a series of data [10], [11]. The characteristics of each reference were collected and organized in a database, and processing equipment and production flows were studied. This information was organized in tables and flowcharts. Subsequently, the presentation of the available molds or the production steps to obtain a product was automated, using Microsoft Excel and VBA, and the selection of references that comply with the user's requirements was automated, through Microsoft Access and VBA. In addition, the task of updating the database was automated, for the removal of obsolete references and the addition of new references.

In addition to the access to critical industrial information, it was also necessary to provide analytical tools to analyze complex systems, such as production environments. **Fig. 2** demonstrates the methodology used for the development of automation tools for information research.

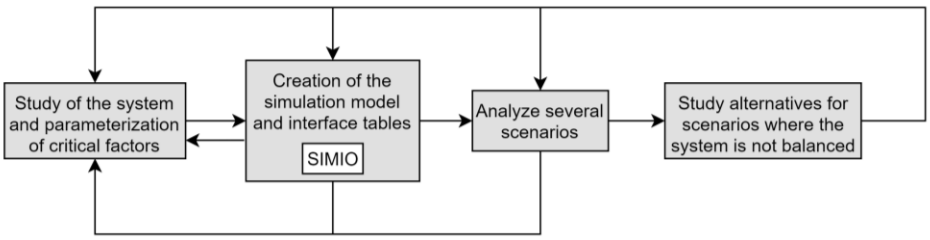

Fig. 2. - Methodology used for the development of simulation tool

As such, for the construction of simulation models – and in a first step -, the system was studied and the critical factors of the lines were surveyed and parameterized. From this information the simulation of the system was constructed, using the SIMIO software, which is a general purpose discrete-event simulation software based on intelligent objects. In this tool, users can blend animation and logic development in a single approach. Furthermore, the tool also allows users to specify the behavior of individual entities, hence allowing agent-oriented simulation [8], [11]. Then several scenarios were studied, and for the scenarios where the system was not balanced, alternatives were analyzed. Furthermore, as the figure suggests, it is possible to be in a stage of the work and have to go backwards in the process flow to any stage to reconsider some of the initial steps, due to the complexity of dealing with the behaviour of the system, as well as with the available data.

3 INFORMATION SEARCH AUTOMATION TOOLS

This section presents the main requirement fulfilled by the developed tools. In this regard, first, the tools are displayed searching for information of certain references. Thereafter, the tool is displayed searching for the available dimensions and production steps for certain products. Finally, a brief discussion in terms of the impact of the proposed set of developed tools for the company of this case study is addressed.

3.1 Search tool for references that meet the requirements

The tool developed in Access and VBA aims to streamline the information search process. After completing a form, the program selects and presents a list of references that meet the requirements entered in the form. The parameters taken into consideration are: product type, agglomeration type, density, rolling thickness and product dimensions. All tables have been imported from Excel files, which contain the entire database created. In addition, links have been established with these files, so that whenever an update is made to this database, the program is also updated. In the queries, all restrictions were established with logical expressions that allow the selection and presentation only of references that meet the requirements entered in the form. For example, **Fig. 3** shows the search for references that obtains a rubber board, with density between 1000kg/m3 and 1300kg/m3, with 5mm thickness, 900mm length and 600mm width (the interface of the tool is shown in Portuguese).

Moreover, **Fig. 4** presents a list of the references that meet the requirements entered and the indication of the molds that can be used, with the indication of yes or no. In addition, the yes* indicates which mold is most used for the agglomeration of the mixture in each reference.

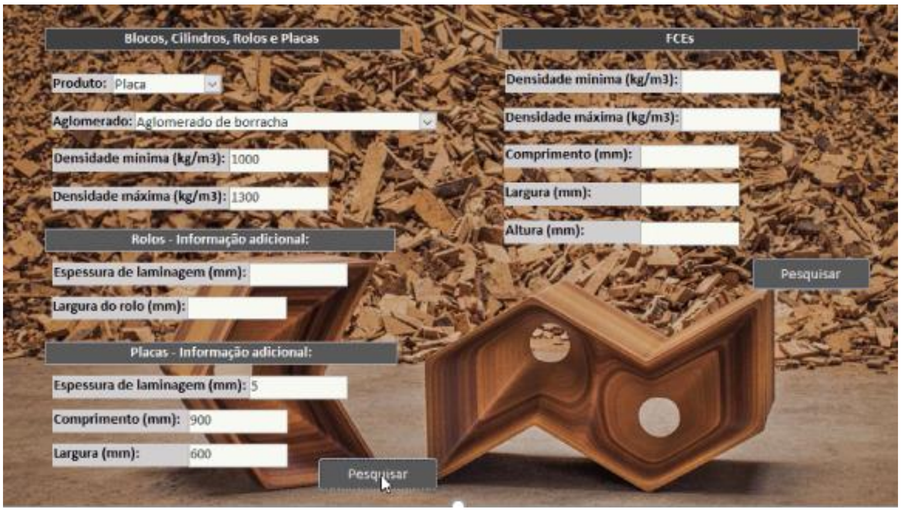

Fig. 3. – Interface Menu of the tool for searching references

Formulário | PlacasBL_AglBorracha

Referência	Área	Densidade	CAE(915x915mm)x6in	CAF(1000x1000mm)x6in	CAB(1270x660mm)x6in
1150	Aglomerado de borracha	1100,00	Sim	Não	Não
1177	Aglomerado de borracha	1025,00	Sim	Sim*	Sim
1302	Aglomerado de borracha	1100,00	Sim*	Não	Não
1310	Aglomerado de borracha	1000,00	Sim	Sim*	Não
3510	Aglomerado de borracha	1000,00	Não	Sim	Sim
AM89	Aglomerado de borracha	1250,00	Sim	Não	Sim
CM62	Aglomerado de borracha	1200,00	Sim	Não	Não
N733	Aglomerado de borracha	1050,00	Sim*	Não	Sim
NC80	Aglomerado de borracha	1015,00	Sim*	Não	Sim
RU04	Aglomerado de borracha	1030,00	Sim	Sim	Sim
S700	Aglomerado de borracha	1070,00	Sim*	Sim	Não
VC95	Aglomerado de borracha	1250,00	Sim	Sim	Não

Fig. 4. – List of the references shown after the research

3.2 Search tool for available dimensions or production steps

For the construction of the tool for available dimensions or production steps, interfaces have been developed that bridge the information entered by the user with the program, to present the requested data. These interfaces were created in the VBA User forms.

The user can search the available dimensions of molds for the agglomeration of cylinders and blocks for a given reference and can also ascertain whether a given product, plate, FCE roller, can be produced and, if it can, it indicates the production steps for obtaining that product.

In the main menu, the user can perform searches, delete or add references to the database and access the spreadsheets, where the database is located and where auxiliary calculations are performed. There are four buttons that perform these four tasks. **Fig. 5** shows the main menu.

Fig. 5. - Interface Menu of the tool for available dimensions or production steps

If the user wishes to perform a search, enter the reference code and select one of the five products: block, cylinder, roller, plate or FCE. After clicking the Next button, the program checks if the entered reference is actually present in the database. Then, either a new form is opened, or the requested information is presented, according to the type of product selected.

If the user wants to make any changes to the tool or access the database tables, the Open Sheets button must be clicked. Otherwise, if the user wants to delete a reference from the database, enter the reference code, then the Delete Reference button should be clicked. Clicking this button sends a message to the user to confirm the execution of this action. If the user wishes to remove the database reference effectively, then in all tables in the database the reference records are removed. Finally, if the intention is to add a reference to the database, the Add Reference button should be clicked, and a new form appears, which must be filled with the data of the characteristics of the new reference.

3.3 Results: Impact of information search automation tools

The members of the product engineering team measured the time they spent researching references that met certain requirements and researching available dimensions or production steps for a given product. First without the use of search automation tools and then with the use of tools.

The average time per search without the use of the tools is 12 minutes and 40 seconds and the average time per search with the use of the tools is 1 minute. Thus, it can be observed that there was a significant reduction of 92% of the average time performed by research. Thus, less time of human resources is spent on the collection, management and selection of information. Such time could, therefore, be used to perform other more added-value tasks, hence greatly improving the productivity of the company.

Moreover, the problems of information dispersion in the various files and the retention of information in supervisors or other collaborators ceased to exist, since the information is centralized. The tools also increase the reliability of the results, since the possibility of human errors is less.

4 Simulation

In this section, in a first phase, the objects and entities used to represent the system are presented. Thereafter, several examples of the simulation in operation are presented and discussed, for different types of rolls and packaging, in order to make an analysis of the system balance.

4.1 Simulation model development approach

To prepare the simulation of the area under study, the system with objects and entities was first represented. **Fig. 6** shows the realization of this first stage, in which there was a representation of the layout of the rewinding lines and automatic packaging of composite chipboard rolls.

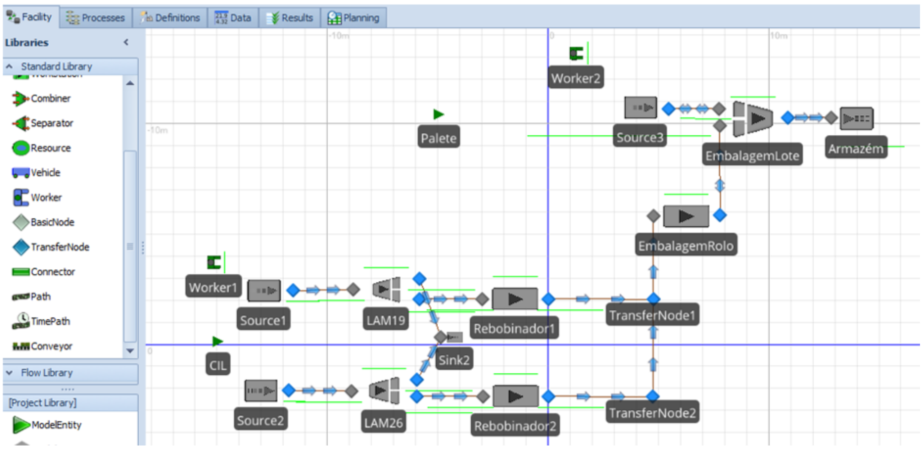

Fig. 6. – Overview of the representation of the system through objects and entities in SIMIO.

Two entities were created, the CIL entity and the Palete entity, representing, respectivelly, cylinders and pallets. To create such entities, two Source objects were used. Thus, such entities are then directed to the LAM1 or LAM2 Separators, which represent the mills. At this point, a worker performs the setup operations on each of the rolling mills and as a product resulting from the rolling process, a continuous roll and waste is formed. The waste goes to the Sink objects, and the roll is directed to a Server object that models the rewinder processes, where the rolls are rolled to the desired length. Then the rollers pass through the conveyors, to the packing area. Here, first the rolls are individually packaged by Worker2 in the EmbalagemRolo Server and then the Worker2 transports one roll at a time to a Combiner object that is responsible for packing the entities. Finally, entities of the packing type are also created to enable this process. When the number of rolls required to form a batch is gathered, a worker packs the batch in the Combiner object and these lots are afterwards collected and placed in the warehouse. **Fig. 7** shows a 3D view of the system under analysis during its execution.

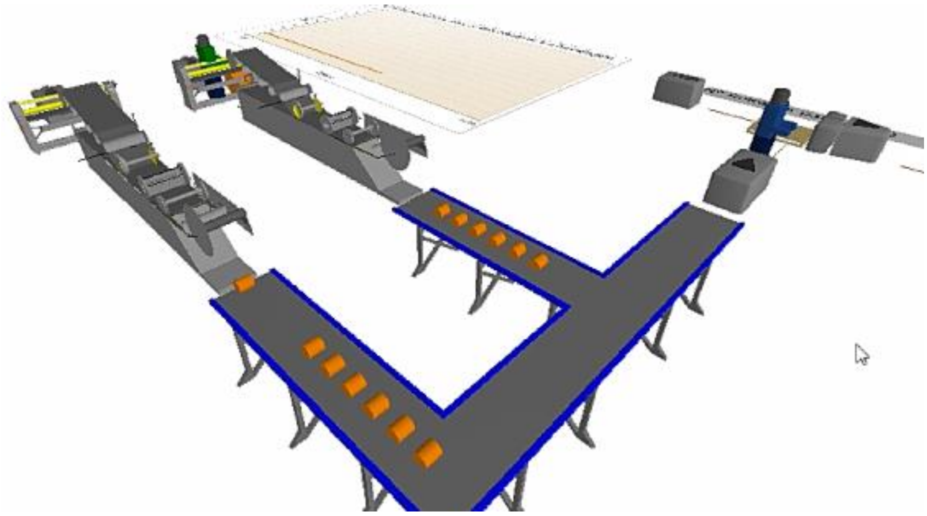

Fig. 7. - Representation 3D of the system using SIMIO software

Since there are parameters that influence the operation of the entire system, it was necessary to establish such parameters, which bridge the data entered by the user, allowing the respective variance in the simulation to occur. As such, the user has to insert the following information in order to setup each simulation scenario:

- thickness and length of the intended roller;
- how many rolls each pallet takes;
- whether the packaging of the rollers is made in plastic, cardboard or box;
- whether or not the pallet packaging carries wrapping tape

From these variables the simulation automatically calculates additional relevant variables for the execution of the simulation, enabling the correct representation of the real system. Furthermore, while additional parameters could be easily created, these were the ones that were considered to be the main ones, as per agreed with the remaining involved stakeholders.

4.2 Results: Analysis of various scenarios

The system of roll rewinding and roll packing lines may be balanced or not in accordance with the characteristics of the roll, length and thickness, and the packaging. For the purposes considered in this work, the system is considered to be balanced when there is no stock build-up between rewinding and packaging. Nevertheless, it should be noted that the main purpose of the display of this tool is not to analyze the results per si, but rather to demonstrate the possibility of using this tool to analyze this systems performance, its potentialities, as well as the benefits that can be obtained by developing this tool, in an environment where there was no system to centralize relevant industrial data. In this regard, scenarios in which rolls of 6 mm of thickness and 27 meters long were produced were considered. The following scenarios were considered for the sake of this work:

- Experiment A: Two rewind lines are considered;
- Experiment B: One of the two rewinding lines was blocked;
- Experiment C: The resources in the packaging area were doubled, two employees and two plastic packaging machines.

In its turn, **Table 1** represents three examples of scenarios that can be executed in the simulation.

Table 1. List of scenarios that were considered in this work.

Experiment	Stockpiling	Laminator Rate of Occupation (%)	Packer 1 Rate of Occupation (%)	Packer 2 Rate of Occupation (%)	N. º of rolls produced/ shift
A	Yes	82%	85%	-	280
B	No	41%	47%	-	155
C	No	82%	42%	26%	375

The system is balanced when there is no stock build-up between rewinding and packaging. It was found that the system is not balanced for experiment A, rolls 6 mm thick and 27 meters long, where the packaging of the rolls is in plastic and each pallet takes five rolls. From experiment A, other scenarios were studied, always keeping the characteristics of the roller and the packaging, but changing some features of the system.

In experiment B one of the two rewinding lines was blocked. As expected, the system was balanced, but it was found that workers' occupancy rates were below 50%, which represented very low labor utilization.

For experiment C, the two lines were kept running and the resources of the packaging zone were doubled, two employees and two plastic packaging machines. The system is balanced and there is an increase of 58.67% of production per shift compared to experiment B, which represents a significant increase of more than twice the production.

Analyzing experiment A again, with the simulation, it was found that as time passed there was stock accumulation, but the packing area was eventually able to give flow to the accumulated rollers, since the number of accumulated rollers always returns to zero throughout the shift.

Comparing the production of example C and example A, there is a 9% increase in the production of rolls. Thus, example C is the option that ensures higher roll production per shift. However, example A is the option that brings less costs, there is a greater use of existing manpower and equipment, but it is necessary to incorporate an intermediate buffer.

5 Conclusions

In industrial contexts, the continuously improvement of processes and products is a crucial aspect in the improvement of competitiveness. To achieve such goal, companies require proper access to information, as well as solid artefacts that allow the analysis of complex systems, such as industrial environments. In light of this, this paper documents the work conducted to develop a set of tools that integrate industrial data, hence contributing for the efficient distribution of information, which can serve several purposes, as discussed throughout this paper.

To sum up, tools for the automation of the access to product information were developed, namely a reference search tool that meets the specified requirements, as well as a tool for searching available dimensions or production steps for a given product. Microsoft Excel, Access and Visual Basic for Applications were used to build these tools. Furthermore, several simulation models were also developed so that allow several types of analysis to be conducted over complex systems.

The average time per search was calculated without and with the use of the developed tools and it was verified that there was a significant reduction of the average time required to access the intended information. Thus, less time of human resources is spent on the collection, management and selection of information, which can be used to work on more added-value tasks. Moreover, problems such as the dispersion of information throughout several files (and even in the minds of certain individual collaborators) cease to exist, since the information is centralized. The tools also increase the reliability of the results, since the possibility of human errors is less.

On another hand, while information search tools allow a streamline access to information, system simulation allows additional levels of analysis, since it allows users to observe behaviours and dynamics and test various scenarios. For this paper, certain scenarios of production lines of rewinding and automatic packaging of composite chipboard rolls were simulated using the SIMIO software. For this purpose, firstly, a survey and parameterization of the critical factors of the production line were conducted so that the simulation could be elaborated and then the balancing of the system was studied in the face of different scenarios. Depending on the type of roll to be produced and according to the type of packaging, the balancing of the system varies. Other scenarios were studied for when the system is not balanced, in order to avoid this occurrence. As verified, the simulation allows an improvement of the analysis of the system's behaviour, as well as key performance indicators to be estimated under given conditions. The visual aspect of being able to observe the dynamics of the materials, machines, workers and other elements throughout time was also a valuable output of the simulation models.

In terms of future work, other areas could be studied and included, such as associating costing to the production tasks. On the other hand, including optimization models to synergize with the simulation models could also be pondered, as well as evaluating the possibility of incorporating the projections outlined by the simulation results in the designed information tools, hence providing additional insights for decision-makers.

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