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Reference Model in BPMN Notation for a Production Scheduling System

Tulio Cremonini Entringer[1], Ailton da Silva Ferreira[2], Denise Cristina de Oliveira Nascimento[3], Luciano Jose de Oliveira[4], Oscar Lewandowski[5], Paulo Mauricio Tavares Siqueira[6]

[1]Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF), Campos dos Goytacazes, Rio de Janeiro, Brasil
Email: tulio_entringer@hotmail.com
[2]Universidade Federal Fluminense (UFF), Macaé, Rio de Janeiro, Brasil
Email: ailtonsilvaferreira@yahoo.com.br
[3]Universidade Federal Fluminense (UFF), Macaé, Rio de Janeiro, Brasil
Email: denise_cristin@yahoo.com.br
[4]Universidade Federal Fluminense (UFF), Macaé, Rio de Janeiro, Brasil
Email: lujoliver@yahoo.com.br
[5]Universidade Federal Fluminense (UFF), Macaé, Rio de Janeiro, Brasil
Email: oscarester@terra.com.br
[6]Universidade Federal Fluminense (UFF), Macaé, Rio de Janeiro, Brasil
Email: paulomauricio@id.uff.br

Abstract ***—*** *Companies are progressively investing in practices aimed at improving the quality of management, with the main purpose of enabling them to operate competitively in the present market. For this, it is necessary to document the activities and information of the existing business processes in the organization, aiming at reducing time and cost in the elaboration of the particular model. In this context, the objective of this work is to develop a reference model of the Production Scheduling (PS) processes, an important module of production planning and control (PPC). The research methodology used in this work was divided into the following stages: study of PS and business process modeling, definition of reference model processes, choice of methodology and process modeling tool, development of reference model and prototype of the software and, finally, analysis of results. The modeling notation used was the BPMN, since it is considered a standard language in the field of process modeling. The prototype was developed through the Delphi interface in order to apply the model to support the implementation of business management programs. As results, from a formal documentation, the model proved to be a useful mechanism in the understanding of the processes raised and appropriate in the support to the implantation of production management tools.*

Keywords — Reference Model. Production Planning and Control. Production Scheduling. BPMN.

I. INTRODUCTION

Organizations are progressively investing in business quality practices such as reengineering processes, adoption of an integrated management system (ERP), ISO certifications, lean production, costing by activities, among others. However, most of the high-investment and long-term investment actions, for example, in the adoption of ERP (BREMER; LENZA, 2000; CORREA; SPINOLA, 2015).

Quality management and process management units that are carried out, which are raised and documented Existing Business Processes in the organization.

However, a business process modeling activity is still not a common issue among organizations (THURER; FILHO, 2012), which is responsible for increasing the cost and time of implementation of the system or projects to improve the development of new models related to Business Processes (BREMER; LENZA, 2000). As a company already had a reference model, this activity would not be necessary. According to Scheer (2000), case studies using reference models can reduce the cost and pace of deployment of organizational projects by up to 30%.

In the business context, Business Processes are important for the expansion process, such as Brazil, where production activities are more pronounced than product development, and Production Planning and Control (PPC). This process is done by surveying demand, planning production, planning capacity, producing

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materials, scheduling production, etc. (FERNANDES; GODINHO FILHO, 2010; MUKHOPADHYAY, 2013).

The basic exercises of the PPC hierarchy, related to Material Planning, are the Production Scheduling (PS). PS is an important decision-making process in a PPC system, widely used in industrial production, management and computing (SETHY; BEHERA, 2017). The PS aims to distribute the tasks to the resources over time, in order to meet all agreed deadlines at an acceptable cost (SILVA; MORABITO; YAMASHITA, 2014).

According to Thurer & Filho (2012), most companies, especially small and medium-sized companies, have a science that their PPC activities can be closed and that "processing time" and "work in progress" higher operating energy. However, the authors, as they simply do not know how to do this, are a vast majority of research and solutions for the PPC is focused on large and complex companies.

Therefore, it is important and growing attention, both the academic environment and not to undertake, there is no development of models that support any planning of entrepreneurial resources (CORREA; SPINOLA, 2015). However, these studies were designed to investigate PPC models and are mostly focused on industrial purposes and that address modules of specific production management activities.

In order to become companies, especially small and medium enterprises, in the development and implementation of business management actions, the present work aims to develop a reference model that addresses the related Business Processes as PS activities.

In addition, this work also aims to develop a software prototype through the Delphi interface (Object-Pascal language), in order to apply the reference model to support the implementation of business management systems.

The article is organized as follows: a section 2 addresses a literature review on model reference and PS; a section 3 presents the methodological procedures used in this study; a section 4 presents results obtained; and finally a section 5 presents as final endings.

II. LITERATURE REVIEW

2.1 Reference Model

Reference modeling is defined as the process of formally documenting a problematic domain in order to understand and communicate stakeholders (SIAU, 2004; SIAU; ROSSI, 2011).

The reference models, which can be developed in real situations or in theoretical studies, document the various aspects of a business process (BREMER; LENZA, 2000). According to Scheer (2000), one can distinguish between procedural models or standard software implementation, and business models such as models for production management and product development.

According Vernadat (1996), a reference model must contain a certain degree of generality and be customizable. Therefore, it should serve as a basis for discussion, a formal or semiformal suggestion for the elaboration of specific models, bringing information regarding the design of a business process. Keller & Teufel (1998) understand that reference models can be applied in cases of accumulated experience in a business type, and in business process solutions implemented and executed in business management software.

Vojislav & Leon (2000) propose that choosing the right reference models helps to minimize possible errors in the early stages of modeling and deploying management systems. This allows the design of a process or system to begin with the appropriate choice of requirements and with the establishment of appropriate characteristics given by the reference model.

According to Bremer & Lenza (2000), the objective of the reference model is to provide the company with an initial solution for its Business Processes, so that, through this, the particular model of the company can be specified and detailed. According to Climent, Mula & Hernández (2009), reference models are useful in the description and graphical representation of the important aspects of a particular process, distinguishing, for example, people, departments and the connection between them. Additionally, Vergidis, Turner, & Tiwari (2008) models adequately portray and represent processes, emphasizing those aspects that need to be communicated and addressed.

Bolloju & Leung (2006) suggest that during the analysis phase of an information system development, the conceptual model can be used to capture and represent the development and deployment requirements of such technologies. For Scheer (2000), the use of reference models can reduce the cost and time of implementation of organizational projects, for example in the adoption of ERP.

In a review elaborated by Hernandez, Mula & Ferriols (2008), it was proposed that a reference model describe the social and physical aspects of the world in order to understand and communicate. In addition, it was also described that the reference model should go beyond the terms "specifications" and "requirements" and apply three linguistic concepts (syntax, semantics and pragmatics) to four aspects of modeling: language, domain, model and participants.

In summary, according to Vernadat (2003), the advantages of adopting reference models are to reduce time and cost in the development of the particular model; comparing the activities of the company with the

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activities proposed in the model, that is, best practices; and better support in deploying integrated enterprise management systems.

The model to be developed in this work will give greater emphasis to the information and activities that compose the PPC process, because its main objective is support in the implementation of organizational improvements, such as business management systems (Figure 1).

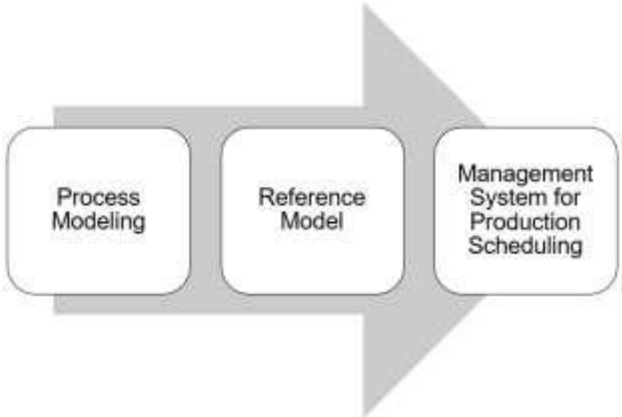

Fig. 1: Process of elaboration of the reference model

2.2 PRODUCTION SCHEDULING

Production Scheduling is an important decision-making process in a PPC system, widely used in industrial production, management and computing (SETHY; BEHERA, 2017). This process seeks to define (PLITSOS et al., 2017):

i. What productive tasks to perform (or orders / work instructions);
ii. Where to process the production tasks and in what sequence; and
iii. When to carry out productive activities.

Usually, these decisions are strongly coupled and, ideally, are taken simultaneously (HARJUNKOSKI et al., 2014). The PS aims to distribute the tasks to the resources over time, in order to meet all agreed deadlines at an acceptable cost (SILVA; MORABITO; YAMASHITA, 2014). Its level of aggregation of information is about product components and its planning horizon is very short term, usually in weeks, in productive environments with a great mix of products and many alternatives of roadmaps (GIACON; MESQUITA, 2011). In this scenario, companies, through tools that can assist them in this task, seek to increase productivity, reduce inventories, reduce costs and achieve greater flexibility.

In addition, Muthiah & Rajkumar (2017) affirm that the objectives of the Production Schedule are:

iv. Deliver the products on the agreed date;
v. Minimize stock in process;
vi. Decrease delivery time;
vii. Minimize the use of resources; and
viii. Maximize operational efficiency.

For Sethy & Behera (2017), PS is a typically operational activity, which can reduce costs and material handling time by optimizing the procedure. Its scope is restricted in the time horizon, contemplating from hours to a few weeks, due to the dynamism in the production environment (LUSTOSA; MESQUITA; OLIVEIRA, 2008). Thus, developing good programming for particular production order sets can help the organization to effectively control workflows and provide solutions for job sequencing (SETHY, BEHERA, 2017).

Several classic formulations and different approximate methods have been used to address the problems of production scheduling in various industrial contexts, such as in the beverage industry (FERREIRA; ALMADA-LOBO; MORABITO, 2013); in the animal nutrition industry (AUGUSTO; ALEM; TOSO, 2016); in the packaging industry (MARTÍNEZ et al., 2016); in the metalworking industry (LOEBLEIN et al., 2013); in the textile industry (RAYMUNDO; GONÇALVES; RIBEIRO, 2015); among others.

Silva, Morabito & Yamashita (2014) carried out a study of a practical case of production scheduling in the aeronautical industry. The computational experiments showed that there is potential for productivity gains when using these models to optimize the assembly schedule. Compared with company practice, the results indicate that it is possible to reduce labor costs by up to 30%, without significantly jeopardizing compliance with the established deadlines

It is worth noting that, depending on the complexity of the production system, the area of production management or operation management will have greater difficulty in managing it (FUCHIGAMI et al., 2015). Thus, the internal performance of an industry, in turn, conditions the external performance of the company (that perceived by the customer).

Plitsos et al., (2017) point out that due to the complexity and the increase in production volumes, decisions taken from PS can not be approached without automated optimization support. This functionality is generally considered part of a Manufacturing Execution System (MES) and is usually supported by an ERP system (HARJUNKOSKI et al., 2014), usually of high cost mainly for small and medium enterprises.

Novas & Henning (2010), in a review of existing knowledge-based techniques for Production Scheduling, have found that the inherent presence of uncertainties on the shop floor creates the need to constantly adjust schedules through operational control.

Thus, Framinan & Ruiz (2010), to address this problem, affirm that these systems should include support for a series of activities, such as: monitoring and execution of

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planned schedules; accurate representation of the shop floor model, including all of its restrictions; use of adequate techniques to solve the problem of generation of schedule, that is, the algorithm; assessment of the proposed solution, which should satisfy all possible constraints; ability to be reactive and respond to events that could prevent the completion or feasibility of the schedule; capacity analysis; and ability to integrate with various existing information systems within the company

Therefore, PS is in practice a dynamic activity in which information gathering and constant monitoring occur before and during the generation and execution of the schedule (ROMERO-SILVA; SANTOS; HURTADO, 2015).

Priority rules, also known as sequencing rules, are extremely important procedures in practice. They are technically simple, easy to understand and require little effort to be applied. Generally, the use of priority rules is sufficient for programming in multiple production environments. Moreover, such rules are easy to code in modern programming languages and their calculations are quite fast (Fuchigami et al., 2015). For some specific problems, these rules generate optimal solutions, but in general, they are heuristic methods that in their simplicity do not guarantee the complete optimization of the PS problem (LUSTOSA; MESQUITA; OLIVEIRA, 2008)

The need to define a sequence of tasks is most evident in pushed production systems, where predetermined criteria are used to issue purchase, manufacturing and assembly orders. In the pull systems, kanbans are usually implemented to manage production (FUCHIGAMI et al., 2015). For these reasons, research with priority rules for such complex production scheduling problems is an important topic and requires careful attention.

Table 1 presents some of the more usual rules. It is worth remembering that in the attempt to obtain better results inside the factory floor, it is possible to apply more than one rule simultaneously.

Table 1: Common rules for task sequencing.

Initial	Specification	Description	Priority of Production Orders
FIFO	First in first out	On the same order of arrival on the machine.	Priority to orders that will arrive first. It seeks to minimize the variance of the machine's dwell time.
LIFO	Last in first out	In the reverse order of arrival of the machine.	Priority to orders that will arrive last. It seeks to minimize the variance of the machine's dwell time.
LPT	Lower manufacturing/ processing time	In increasing order of processing time in the resource.	Priority to orders of shorter time, leading to reduced queues and increased flow.
LDD	Lowest delivery date	In ascending order in promised delivery period.	Priority to the most urgent orders, aiming to reduce arrears.
LTO	Less time off	In ascending order of clearances (promised date less total processing time).	Priority to the most urgent orders, aiming to reduce arrears.

It should be noted that the Gantt Chart is widely used for the graphical representation of a schedule of tasks to be performed in a previously established period of time. It is used to represent several types of tasks, such as a production program, an event planning or the stages of a project (LORENZI et al., 2015).

This graph consists of a graph where the rows represent the tasks to be performed and the columns the execution time of the tasks. They usually also provide other information such as: who or where each operation will be performed, total and partial operation time, critical process points, follow-up lines, etc.

III. RESEARCH METHODOLOGY

3.1 DEFINING THE SEARCH METHOD

The reference model was developed from theoretical studies. Thus, this research uses the procedures of bibliographic research, since it was developed from previous works such as dissertations, articles and books on the subject matter. In this way, the future work can be based on the conclusions presented in this article, and elaborate hypotheses aiming to deepen the study on the subject or related specific aspects.

On the other hand, this research can also be classified as experimental, since it is based on the creation of a reference model of a PS system, modeled through software. Thus, with the objective of developing a reference model and exposing the way it was developed from the analysis of the activities involved in the processes, allow this work to be classified as a descriptive research.

3.2 SCOPE OF RESEARCH

The phase of process identification and hierarchization

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levels is considered the key step in process modeling, aiming to identify all existing Business Processes in a particular activity of an organization.

Figure 2 presents the model of the PPC Process hierarchy relating the planning of the capacity of its resources with the planning of the needs of its materials. The hierarchical decomposition of the PPC function starts from understanding the basic concepts related to material planning levels, namely: Sales & Operations Planning (S&OP) and Aggregate Planning (AP); Master Production Planning (MPS); Material Requirements Planning (MRP) and Production Scheduling (PS) (CORRÊA; CORRÊA, 2012; MUKHOPADHYAY, 2013). This work will be limited in the development of the PS reference model and its respective capacity planning. The modules of the Production Planning and Control function related to Capacity Planning are Resource Requirements Planning (RRP), Rough Cut Capacity Planning (RCCP) and Capacity Requirements Planning (CRP).

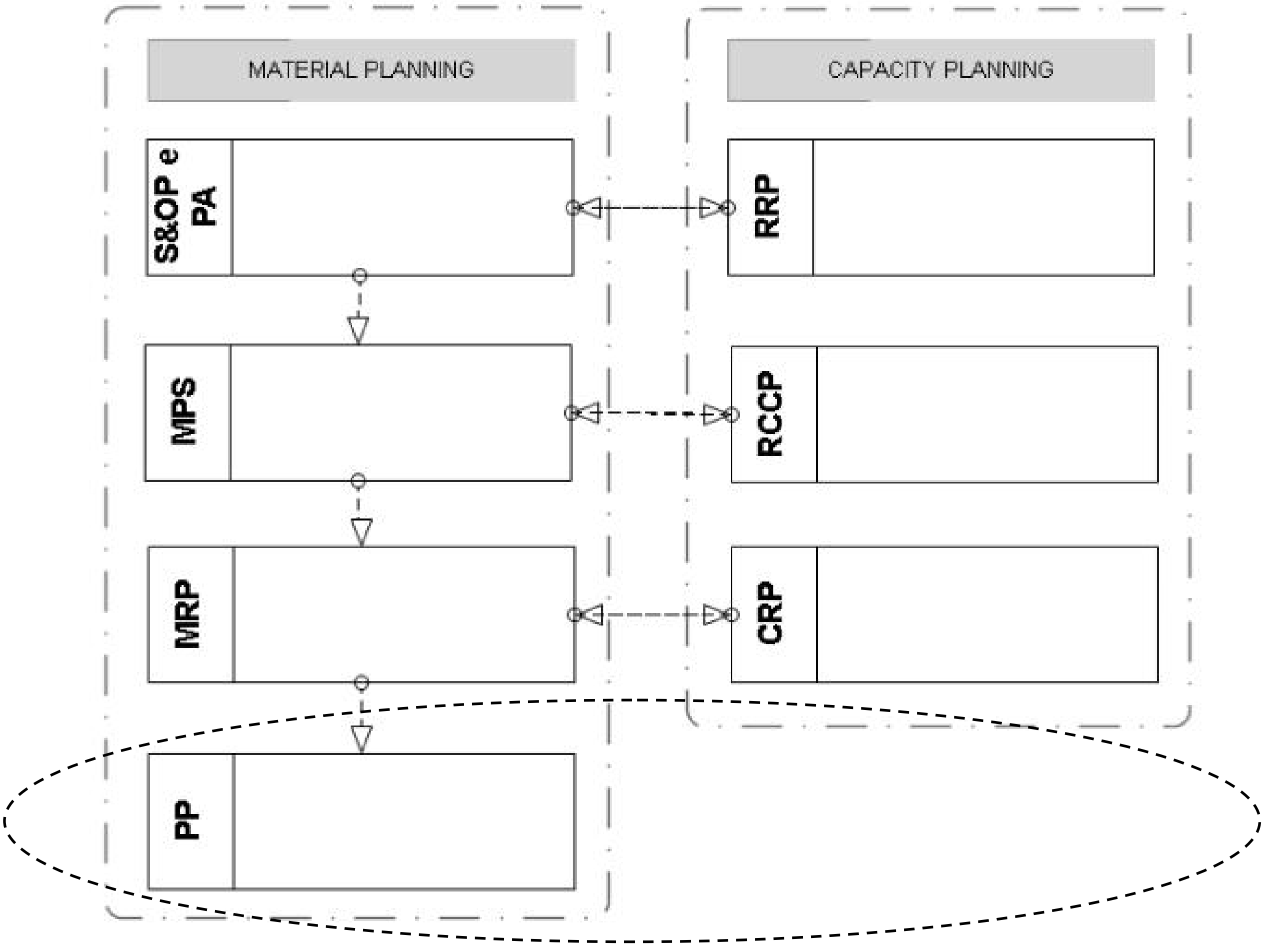

Fig..2: Hierarchy of production planning and control

3.3 STAGES OF THE RESEARCH METHODOLOGY

The methodology used for the elaboration of this work was divided into eight sequential stages, as shown in Figure 3.

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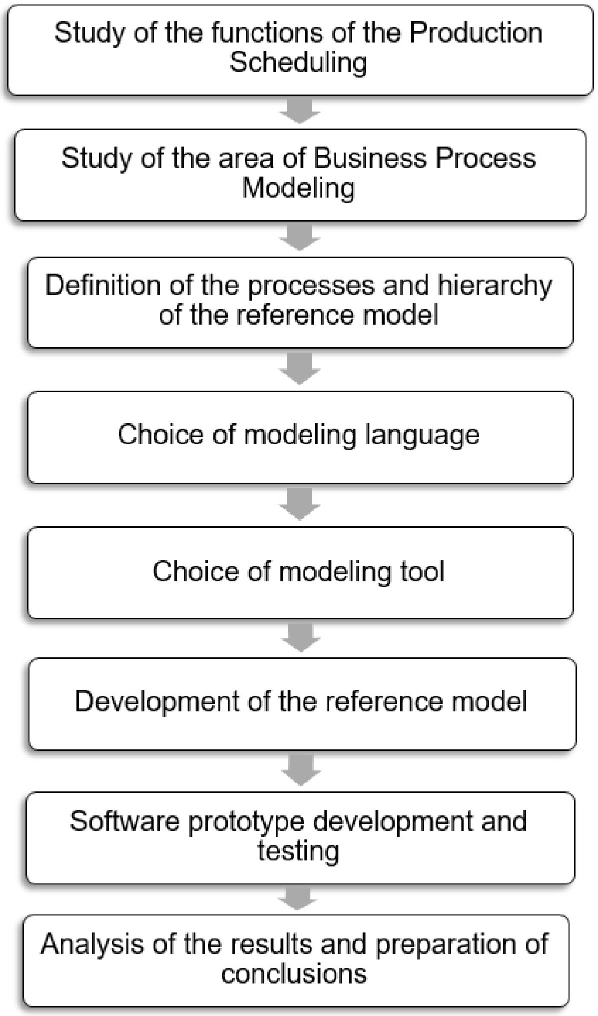

Fig. 3: Stages of the research methodology

- *Step I* - Study of Production Planning and Control Functions: In this stage, according to bibliographical references related to the topic of study, concepts, activities and information and functions of a typical production planning hierarchy were raised and studied;
- *Step II* - Study of the Business Process Modeling area: In the second stage, the concepts and languages regarding process modeling, as well as reference models, were studied and analyzed from the scientific literature;
- *Step III* - Definition of the processes and hierarchy of the reference model: In this third step, after the phases of the bibliographic review, the processes and hierarchy that will make up the reference model of a PPC system were defined;
- *Step IV* - Choice of the modeling language: In this fourth stage, the modeling language used for the development of the reference model was defined. The modeling notation selected was BPMN;
- *Step V* - Choice of the modeling tool: In this step, the modeling tool was defined, in order to provide facilities in the understanding and visualization of the model, that is, the full understanding of the functions of a system. The modeling tool selected was Bizagi Process Modeler version 3.1.0.011;
- *Step VI* - Development of the reference model: In this step, based on the language and defined modeling tools, the reference model of a PPC system was developed based on BPMN theory and notation;
- *Stage VII* - Development of application software and tests: In the seventh stage, once the reference model of the PPC system was elaborated, a software prototype was developed with the purpose of applying and validating the model, from the Delphi version interface 7.0, which used the Object-Pascal language;
- *Step VIII* - Analysis of the results obtained and conclusions drawn: In the last step, the results presented in the previous phases were analyzed and discussed, as well as the conclusions obtained and suggestions for future work

IV. RESULTS AND DISCUSSION

4.1 PS MODELING

PS is a typically operational activity that aims to reduce material handling time by optimizing the procedure, and consequently reduces costs. In this way, it seeks to deliver the final product at the right time, minimizing delivery delays to the maximum. Its scope is restricted in the horizon of very short time, contemplating from hours to few weeks, due to the dynamism in the production environment. As the orders arrive at the same time in the work centers, decisions about the sequence in which they will be executed become very important. The input and output information needed to construct the reference model of the PS module are shown in Table 2.

Table 2: PS information

Input	*Output*
Material Requirements Plan	Production Sequencing
Very short-term planning period	End time of production Production delay time
Production time of components	
Delivery time of components	Gantt Chart
Production sequencing rules	Production scheduling

The activities related to this module of the PS are presented, with their respective theoretical references, in Table 3.

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Table 3: Sequence of PS activities

#	Activity	Theoretical Framework
1	Product definition and production scheduling component, as specified in MRP.	Corrêa e Corrêa (2012).
2	Definition of the short-term planning period of production scheduling.	Corrêa e Corrêa (2012), Giacon e Mesquita (2011) e Lustosa, Mesquita e Oliveira (2008).
3	Calculation of the production time of each component or product, according to the required capacity specified in the MRP.	Muthiah e Rajkumar (2017) e Tubino (2007).
4	Definition of the delivery time of each component or product.	
5	Sequencing the components or products in the production line according to the adopted rule.	Framinan e Ruiz (2010), Lustosa, Mesquita e Oliveira (2008) e Tubino (2007).
6	Calculation of the final production times for each sequencing rule.	Muthiah e Rajkumar (2017), Sethy e Behera (2017) e Silva, Morabito e Yamashita (2014).
7	Calculation of production delays for each sequencing rule.	
8	Select the sequencing method according to company objectives.	Lustosa, Mesquita e Oliveira (2008), Tubino (2007) e Metaxiotis, Psarras e Ergazakis (2003).
9	Elaboration of the Gantt chart and emission of the production schedule.	Plitsos et al. (2017), Sethy e Behera (2017), Lorenzi et al. (2015), Silva, Morabito e Yamashita (2014) e Framinan e Ruiz (2010).

The reference model for the Production Scheduling module proposed firstly identifies the components of the final products specified in the MRP stage.

Then, according to the proposed model, the definition of the planning period (very short term) is carried out, and this period must come from the period that was established in the material requirements plan.

From the computation of the necessary capacity calculated in the planning stage prior to this, the production time of each of the components relating to a final product is calculated, which includes the final assembly of the product. Likewise, from the installed capacity specified in MRP, the final delivery time of these components is defined.

Once the production and delivery time of each of the components is defined, possible production schedules are performed according to each sequencing rule adopted by the organization. In this model, the following rules were specified: FIFO, LIFO, LPT, LDD and LTO. For the definition of the LDD sequencing, it is necessary to calculate the clearance times before this step.

For each production sequence established according to the rules, the final production time and the total production delay time are calculated, with the purpose of supporting the decision making of the best production-sequencing rule to be adopted by the organization.

After selecting the sequencing method, the Gantt chart is drawn. Then the production schedule is issued, thus finalizing this last stage of the planning.

The reference model, in BPMN notation, referring to the PS module is shown in Figure 4.

4.2 SOFTWARE PROTOTYPE

After the elaboration of the production planning system module for PS, a software prototype was developed through the Delphi interface, with the intention of generating a greater consistency between the abstraction of the reference model and its application in the support of implementation and development of enterprise management tools, a software prototype was developed through the Delphi interface.

The first screen of the prototype for PS is being shown in Figure 5.

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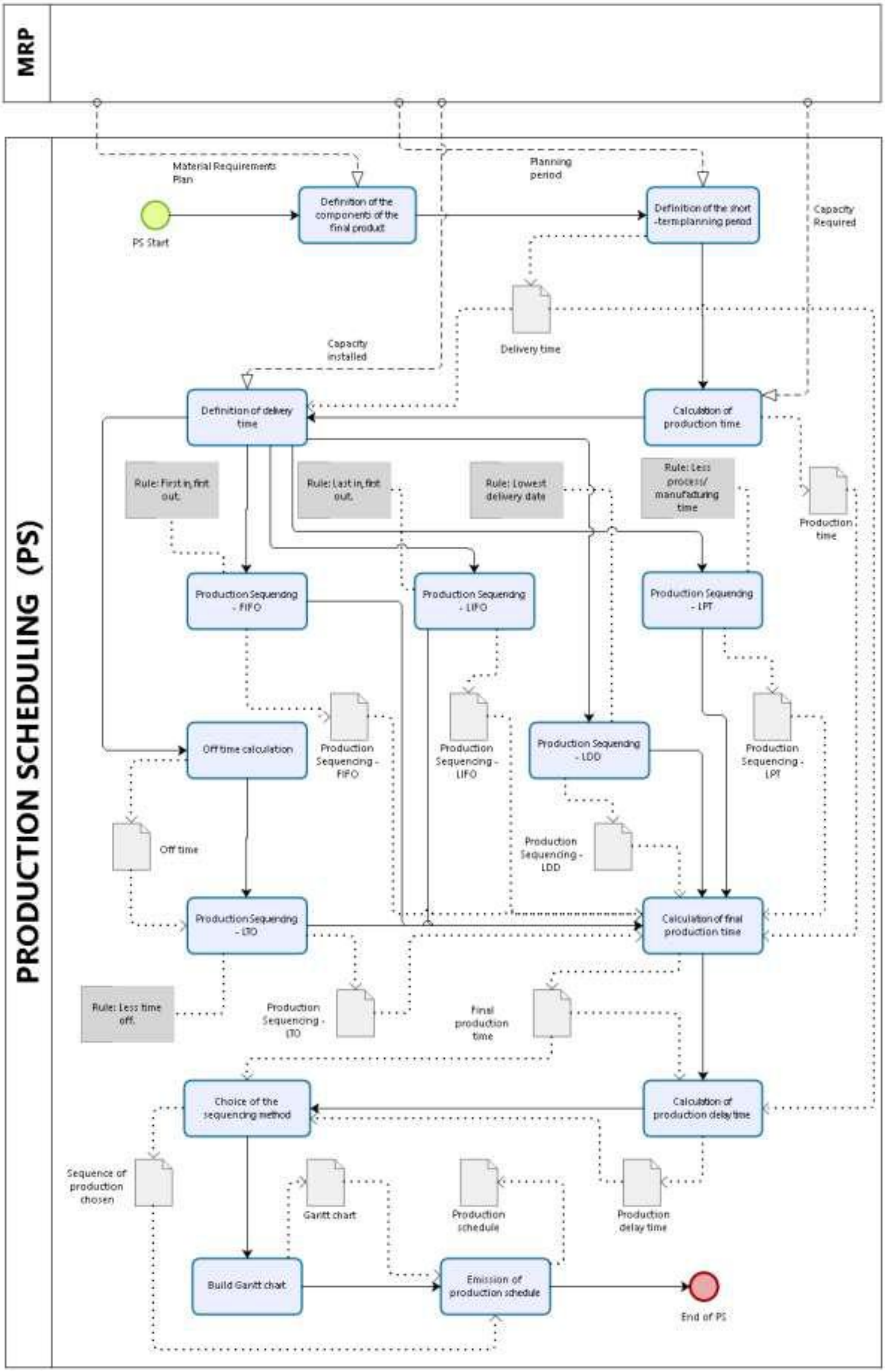

Fig. 5: Modeling of MRP in BPMN notation

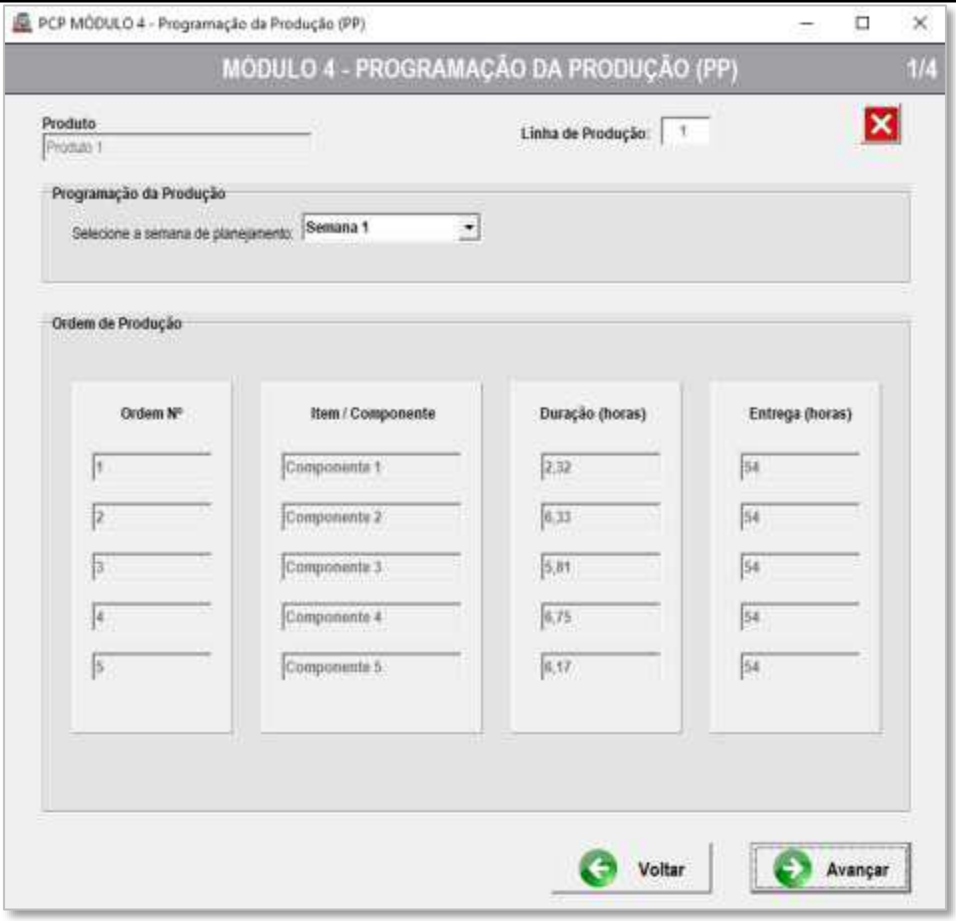

Fig. 5: First screen of PPC software prototype of PS module.

In the developed software, one must choose the week of production scheduling (very short term planning) of the components and the final product that was selected in the MRP stage. As a limitation in the development of the software prototype, in order to facilitate programming, only 1 production line was pre-established.

In the first screen (Figure 6), the production orders, identified by numbers and component names, are also shown, as well as the production duration and delivery time in hours.

When you click on forward, the calculations of the total manufacturing time and delivery delay for each of the sequencing rules are started.

In the second screen the results of the calculation of the total manufacturing time and delivery delay for the FIFO and LIFO sequencing rules are displayed.

In the third screen (Figure 7) the results of the calculation of the total manufacturing time and delivery delay for the LPT e LDD sequencing rules are displayed. From the form table, as in the previous screen, the calculations of the total manufacturing time and delivery delay are also exposed.

In the fourth and last screen of the prototype PPC software for the PS module is shown in Figure 8. For the sequencing of the production orders of the components for the LTO rule, it is necessary to calculate the time off, in hours, in order to order them more and more.

In order to assist the user in choosing the best sequencing rule for production scheduling, a graph comparing total manufacturing times and total delays is presented in the fourth screen of the PPC prototype of the PS module. With this, the user must select the desired sequencing, according to the company's goals and strategies, to create the Gantt chart for a better visualization of the schedule.

Figure 9 shows the prototype screen of the PPC software with the Gantt chart for the PS module.

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Fig. 6: Second screen of PPC software prototype of PS module.

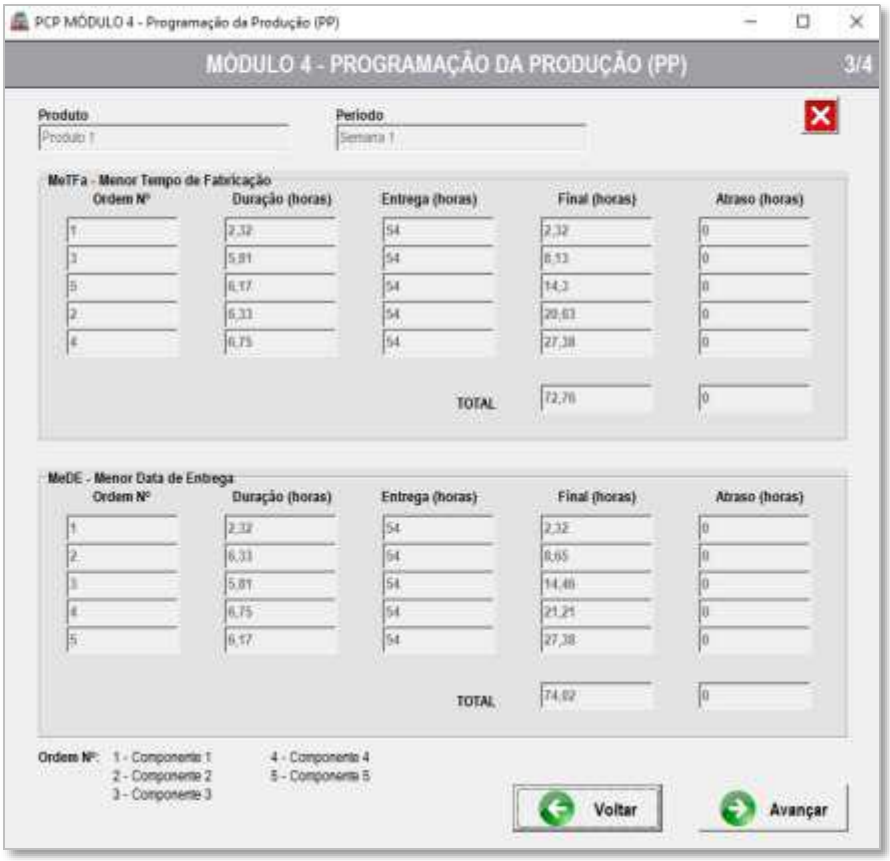

Fig. 7: Third screen of PPC software prototype of PS module.

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Fig. 7: Fourth screen of PPC software prototype of PS module.

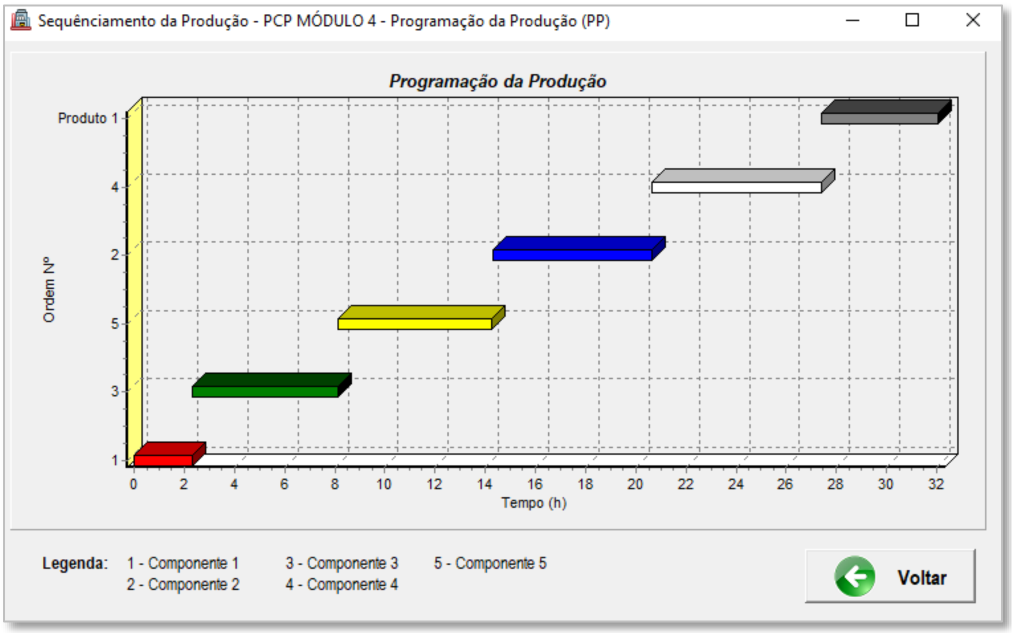

Fig. 8: Screen of the PCP software prototype with the Gantt chart for the PS module.

In order to validate the software prototype, several tests were carried out, with different planning scenarios and production strategies, in order to verify the activities, information, accuracy and precision of the calculations used to prepare the final master plan.

The results obtained by the computational program were compared with the results extracted manually and in electronic spreadsheets. Thus, the software prototype developed from the developed reference model proved to be reliable and apt to be used for the preparation of production material requirements plans.

V. CONCLUSION

Currently, we are seeing increasing attention in the support to the development and implementation of actions of improvements of the business management. However, most research and solutions for production planning are focused on large and complex organizations, highlighting an academic gap regarding work to support the implementation of management systems, especially for small and medium-sized enterprises. Therefore, the reference model developed in this work may provide these companies with an initial solution for their business processes, in order to specify and detail the particular model with a reduction in cost and implementation time.

Thus, this work sought the development of a reference model, in BPMN notation, that addresses the business processes related to PS, one of the modules inherent in the PPC. In addition, we also aimed to develop a software prototype with the aim of applying this model in systems and management tools.

As a result, from a formal documentation, the reference model proved to be a useful tool in understanding and communicating the existing processes in PS. It was also verified that this developed model is able to support the implantation of production management systems in real situations. However, for use in corporate environments, such as ERP adoption, these processes should receive the expertise and the users should have knowledge of the terms and variables involved in the reference model.

It is worth mentioning that the reference model has been configured as an important tool for knowledge management, since it is capable of storing and documenting existing knowledge in the business processes and serves as a basis for planning the development of new knowledge, always being guided by the strategic objectives of the company.

As a continuation of this work, a model is being developed that approaches in a holistic and hierarchical way the other modules of the Business Processes related to the PPC. Thus, this reference model seeks to fill gaps in the scientific literature and to advance in relation to international models, since there is a lack of work on reference models for the activities of the PPC.

For the purposes of validation and evaluation, it is suggested the dissemination and application of the software, developed from the reference model, in small and medium-sized enterprises with activities focused on production planning.

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