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Proposal for a Reference Model for Sales & Operations Planning and Aggregate Planning

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Abstract**—** *Companies are increasingly adopting practices aimed at improving the quality of management, with the main purpose of enabling them to act competitively in the present market characterized by high competition and strong organizational changes. Among the improvements developed, we highlight the adoption of Enterprise Resource Planning (ERP) systems. However, the high cost of deploying and maintaining this type of technology can be a barrier for small and medium-sized enterprises (SMEs) that want to achieve such advances. Therefore, it is essential to develop a reference model of typical business planning modules to support ERP implementation, aiming at reducing time and cost in the elaboration of a particular model. In this context, the main objective of this paper is to develop a reference model from the elaboration of the processes related to Sales & Operations Planning (S&OP) and Aggregate Planning (AP), important modules of Production Planning and Control (PPC). The methodology used for the elaboration of this work was divided in eight sequential stages: study of the functions of S&OP and AP, study of process modeling area, definition of reference model processes, choice of modeling notation, choice of modeling tool , development of the reference model, software development and results analysis. The modeling methodology employed in this work was the Business Process Model and Notation (BPMN), through the tool Bizagi Process Modeler version 3.1.0.011. The software was developed through the interface Delphi version 7.0 (Object-Pascal language) in order to apply the reference model in the support to the implementation of a business management tool. As results, from a formal documentation, the reference model proved to be a useful tool in understanding and communicating the business processes raised. It is also concluded that the implemented model is able to support the implementation of production management systems in real situations.*

Keywords — Reference model, Sales & Operations Planning, Aggregate Planning, BPMN.

I. INTRODUCTION

The organizations are progressively adopting practices aimed at improving the quality of management, with the main purpose of enabling them to act in a competitive way in the present market. Among the improvements developed by the companies, we highlight the adoption of Enterprise Resource Planning (ERP) systems [1].

A common aspect when adopting an ERP system is that most of these technologies require that the activities, functions, information and resources of the processes that are carried out by the company be surveyed and documented, that is, that the existing Business Processes be mapped in the organization.

In this sense, modeling the processes of a company provides a better understanding of the premises related to the management inherent to its systems and, also, evidences viable alternatives for the existing organizational activities, in order to provide an effective reference for the decision making process [2] . Based on a reference model, it is possible to analyze the best use of its industrial potential, in order to obtain more effective answers to the constant changes that have occurred in the market.

However, the business process modeling activity is not yet a common practice among organizations, which contributes to the increase in cost and time of system implementation or improvement projects, due to the need to develop new models related to their Business Processes [1]. If companies already had a reference model, this activity would not be necessary. Case studies have shown that the use of reference models can reduce the cost and time of implementation of organizational projects by up to 30% [3].

In the business context, one of the Business Processes essential for manufacturing companies is Production Planning and Control (PPC). This process is responsible for the good planning of activities and resources that will directly influence the guarantee of the availability of the final product to customers, as well as the economic aspects for the company, since it covers the purchase of inputs and

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the use of capital [4]. Among the basic concepts of the hierarchy of the PPC function, we highlight the Sales & Operations Planning (S&OP) and the Aggregate Planning (AP). These modules are seen as a long-term planning tool not only for production, but also for sales, aggregate demand forecasting and resource capacity planning [5].

Most small and medium-sized enterprises (SME) are aware that they should improve their production planning activities and thus achieve greater operational efficiency [6]. However, for the authors, these organizations simply do not know how to do this, since the vast majority of research and solutions for PPC is focused on large companies. Therefore, it is important to note that there is an academic gap regarding work to support the implementation of production management systems for SME.

Thus, the reference model presents itself as a viable tool for SMEs, allowing users themselves to adjust processes or modules of the system to the reality of their organization, comparing their activities with the proposals by the conceptual model and supporting in the implementation of management systems integrated businesses [7].

In view of the above, it is important to note that for the support in the development and implementation of a low-cost ERP system, it is essential to develop a conceptual reference model of the typical modules related to the Business Processes of companies focused on the activities of production planning, in which, from this model, organizations can build their own according to each institutional reality.

With the purpose of supporting SME in the development and implementation of ERP systems of the activities and typical information of production management, the present work has the objective of developing a reference model that addresses the Business Processes related to S&OP and AP. In addition, this work aims to develop a software prototype through the Delphi interface in order to generate a greater consistency between the abstraction of the reference model and its application in supporting the implementation and development of business management tools.

The paper is divided into the following sections: Literature Review; Methodological Aspects; Results and Discussion; Application in the Educational Model; and, Final Considerations.

II. LITERATURE REVIEW

2.1 Sales & Operations Planning and the Aggregate Planning

S&OP aims to reconcile demand with long-term supply capacity and at the lowest possible cost, in which equilibrium occurs in terms of volume rather than product mix. Demand management interfaces with the AP through demand forecasting and long term capacity planning (Resource Requirements Planning - RRP) is responsible for developing the feasible plan for resource availability. In this planning, the predictions are more accurate for families and groups than when we open for individual items [8].

The application of AP concepts is related to the grouping of the various products demanded by the market in families and, for convenience, also the processing capacity of production as a whole is added, not by productive unit [9]. The AP is part of the strategic decisions of the organization, having as one of its goals the directing of productive resources to the chosen strategies, giving consistency to the operational strategy [10]. Each strategy gives the organization a different flexibility in response to uncertain demand. To determine which strategy to adopt, one way is to take as a basis the total cost of each.

In hierarchical production planning systems, AP is designed to balance capacity requirements and production quantities for medium-term planning horizons [11]. Aggregate plans provide the basic input for new planning steps, such as Master Production Schedule (MPS).

The RCCP is a planning that supports the following decisions at the S&OP/AP level: anticipate the need for resource capacity that requires a relatively long term, in months, for its mobilization and procurement; and subsidize the decisions of how much to produce of each family of products, mainly regarding the limitation of capacity and resources, when it is not possible to fulfill all the sales plans [4] [12].

The identification phase of processes and hierarchical levels is considered the key step in process modeling, since it aims to identify all existing Business Processes in a particular activity of an organization.

The Figure 1 presents the model of the hierarchy of the PPC (Production Planning and Control) processes 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 the understanding of the basic concepts related to the levels of material planning, namely: Sales & Operations Planning (S&OP) and Aggregate Planning (AP); Master Production Planning (MPS); Material Requirements Planning (MRP) and Production Schedule (PS) [4][16]. This paper will be limited in the development of the reference model of the S&OP/PA and RRP.

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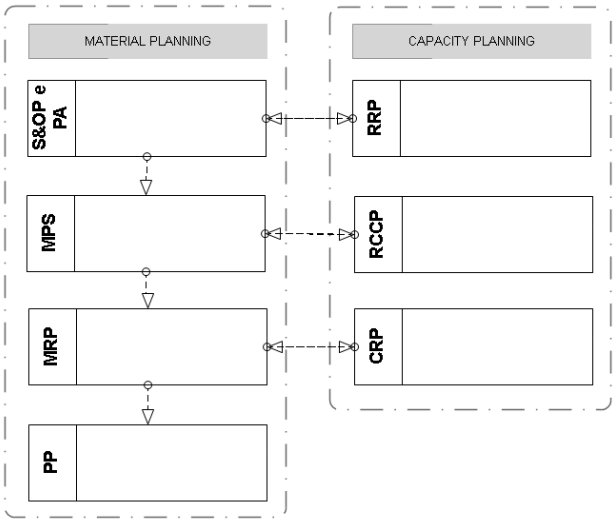

Fig. 1: Stages of research methodology

2.2 Reference Model

Reference modeling is defined as the process of formally documenting a problematic domain in order to understand and communicate stakeholders [13].

Reference models, which can be developed in real situations or in theoretical studies, document the various aspects of a business process [1] and distinguish between procedural or standard software implementation models, and business models such as as models for production management and product development [3].

The objective of the reference model is to provide the company with an initial solution for its Business Processes, so that, through it, the particular model of the company [1] is specified and detailed.

The advantages in adopting reference models are to reduce time and cost in the development of the particular model; comparing the activities of the company with the activities proposed in the model, that is, best practices; and better support in the implementation of integrated enterprise management systems [14].

III. METHODOLOGICAL ASPECTS

3.1 Definition of research 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 treated. In this way, future work can be based on the conclusions presented in this paper, 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 Production Planning and Control system, which was 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 Stages of research methodology

The methodology used for the elaboration of this work was divided into eight sequential steps, as shown in Figure 2.

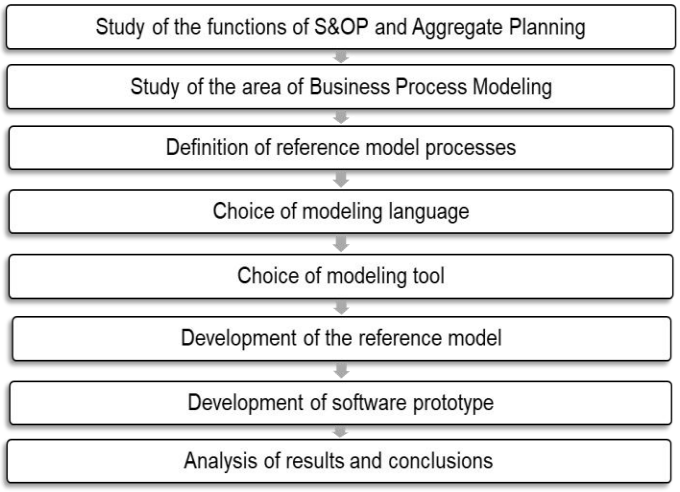

Fig. 1: Stages of research methodology

Initially, the bibliographical references related to the two main topics that covered the areas of knowledge of this work were studied: S&OP/AP and Business Process Modeling (BPM). The first is, in particular, concepts of functions and activities of production planning and the second about concepts, languages and reference models.

In the next step, the modeling language and, later, its tool were defined, in order to provide facilities in the understanding and visualization of the models, that is, the full understanding of the functions of a system. Based on the language and defined modeling tools, it was developed, based on theory and notation, reference models for the development of the S&OP/AP system module, in addition to the RRP, in Bizagi Process Modeler software version 3.1.0.011.

It is important to highlight that the success of business process modeling depends, above all, on the appropriate selection of the methodology used. Among the existing tools, BPMN is configured with one of the languages currently used by industry and universities [15]. However, it is observed in the researched literature that such notation is still little explored for the development of models for production planning.

Once the system model was elaborated, a software was developed with the purpose of applying the model, from the interface Delphi version 7.0, Object-Pascal language.

As a last step, the results presented in previous phases were discussed, as well as the conclusions obtained and suggestions for future work.

IV. RESULTS AND DISCUSSION

4.1 S&OP and AP model

S&OP is considered as a long-term planning instrument for production, sales and demand forecasting. Thus, the

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S&OP and Aggregate Planning model, as shown in Figure 2, presents the production planning of a particular family of products where, initially, it is necessary to perform the demand forecast calculation, based on the demand history of this product in the pre-established planning period. It is noted that the intrinsic objective of S&OP is to maintain an adequate balance between supply and demand.

The input and output information required to construct the reference model of the S&OP and AP module are shown in Table 1.

Table.1: Information about S&OP and AP.

Information	
Input	***Output***
Product family	Demand Forecasting
Long-term planning period	Aggregate production
Aggregate demand history	Projected Stocks
Production strategy	Sales forecast
Productive costs	Prediction of delay or loss of sales
Stocking costs	Gross Revenue
Cost of sales losses or delays	Return of investment
Initial inventory	Aggregate Production Plan
Unit selling price	
Salary	
Long-term capacity plan	

The reference model for the proposed S&OP and Aggregate Planning (Figure 2) brings, firstly, the definition of the product family, in which production will be planned [8] [9] [16]. Next, the long-term planning period is also defined [11] [12] [16] [17] [18] [19].

Then, according to the model developed, it is necessary to choose the demand prediction technique (simple moving average, weighted moving average, linear regression or exponential smoothing). From a data base on the demand history of the product family and the selected forecasting technique, the aggregate demand forecast is calculated [12] [19] [20] [21] [22].

In the planning production stage, it is initially necessary to define the production strategy to be adopted by the organization (constant production, demand monitoring or mixed strategy) [22] [23] [24]. Based on the strategy chosen and the long-term productive capacity emitted by the RRP, discussed in topic 4.2, the planned aggregate production is defined [16].

Once the aggregate production plan is defined, the projected inventories are calculated, which for this operation takes into account the initial stock present in the organization and also the estimated demand forecast [16] [21] [25] [26]. In the same way, taking into account these two variables (forecast of demand and aggregate production) is calculated the projections of sales losses and delivery delays.

In the production costs calculations phase, from the production plan issued, the company must carry out a survey of the costs organizations inherent to the production, considering the productive conditions, in addition to the normal ones, in extra shifts and, also, for the subcontracting of hand when necessary [16] [21] [25] [26].

After the calculation of productive costs, the total costs of wages are calculated, in which the value of wages and the quantity of labor is essential [16] [21] [25] [26].

In calculating raw material costs, information on the quantity of production in the family of products, as well as the unit cost of the raw material [16] [21] [25] [26] is required.

For the calculation of the storage cost, from the projection of inventories made, the organization must carry out a cost survey to maintain the inventory in the company. Following the same logic, it is also calculated the cost with sales losses and delivery delays [16] [21] [25] [26].

Next, the sales forecast calculation is carried out, which takes for computation purposes, the quantity of items produced, expressed in the aggregate production plan, and sales losses or delivery delays [16] [21] [25] [26]. Following this step, the gross revenue from the production of the planned product family is calculated based on the definition of the unit sales price of these products [18].

For calculating the projection of return on investments, the gross revenue calculated in the previous activity and the total calculated costs (production, storage and sales losses / delivery delays) are taken into account [21].

Finally, after the establishment of the production plan, projected inventory and return on investment, the aggregate production plan is issued. In case of need, it is possible to carry out a review of this plan elaborated. After the review, then, the consolidated plan of the S&OP and AP is issued [16] [25] [26].

4.2 RRP model

On the other hand, the RRP aims to calculate the need for resource capacity that require a relatively long term in months, and to subsidize the decisions of how much to produce of each family of products, mainly regarding the limitation of capacity and resources when it is not possible to meet sales plans. That is, it is a planning that aims to support the following decisions at S&OP and AP level.

The input and output information required to compile the reference model of the RRP module are shown in Table 2.

Table.2: Information about RRP

Information	
Input	***Output***
Product family	Planned normal capacity
Long-term planning period	Planned extra capacity
Working days	Planned subcontracted

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Daily working hours Amount of labor Quantity of subcontracted labor Overtime of daily work Aggregate production rate	capacity loading rate Value of man-hours worked Resource Requirements Planning	Aggregate production

In the RRP model, as shown in Figure 3, it begins with the definition of the product family [9] [15] [19] and the long-term planning time [4] [5] [19], according to with what was established by the S&OP and AP planning stage.

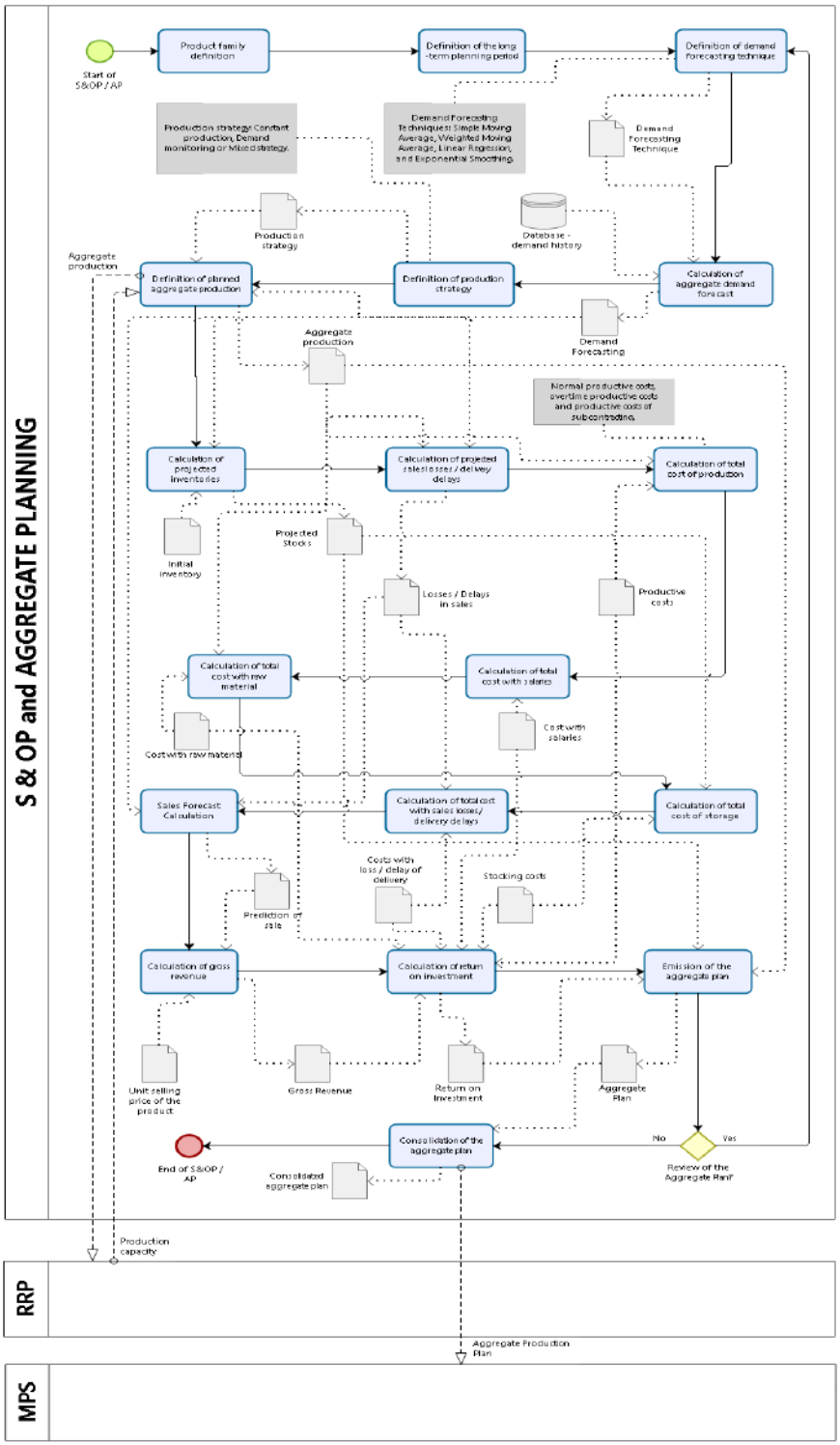

Fig. 2: S&OP and AP model in BPMN

Then, the planned capacity calculation is performed, which in this developed model was divided into: planned normal capacity, planned subcontracted capacity (subcontracting of labor) and extra planned capacity (overtime) [4] [11] 21].

According to the RRP model, for the calculation of the normal capacity planned it is necessary to collect the

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following information: quantity of labor, aggregate production rate, daily working day and working days of the planning period. Similarly to the previous evaluation, in order to calculate the planned subcontracted capacity, it is essential, in addition to the aggregate production rate, the daily working day and the working days of the planning period, the survey of the amount of subcontracted labor, if there is. In order to calculate extra-planned capacity, it is necessary to know the following information: quantity of labor, aggregate production rate, overtime and working days of the planning period [4] [11] [21]. From the calculation of planned normal capacity, planned subcontracted capacity and extra-planned capacity, the total planned production capacity is calculated.

Then, to calculate the loading rate, it is necessary to collect the production plan information from the planning stage of the S&OP and ÁP (total capacity required), as well as the total planned capacity [21].

Finally, in order to calculate the value of man-hours worked, it is essential to have information on the salary of each worker and also the working time of these workers, which includes the daily working hour, overtime and working days over the planning period [27]. After this last stage, the long-term capacity plan for S&OP/PA is issued. If necessary, a revision of this plan is possible [4] [11]. As previously seen, this information is required for the analysis and definition of aggregate production in the S&OP/PA step.

The reference model, in BPMN notation, referring to the RRP module is shown in Figure 3.

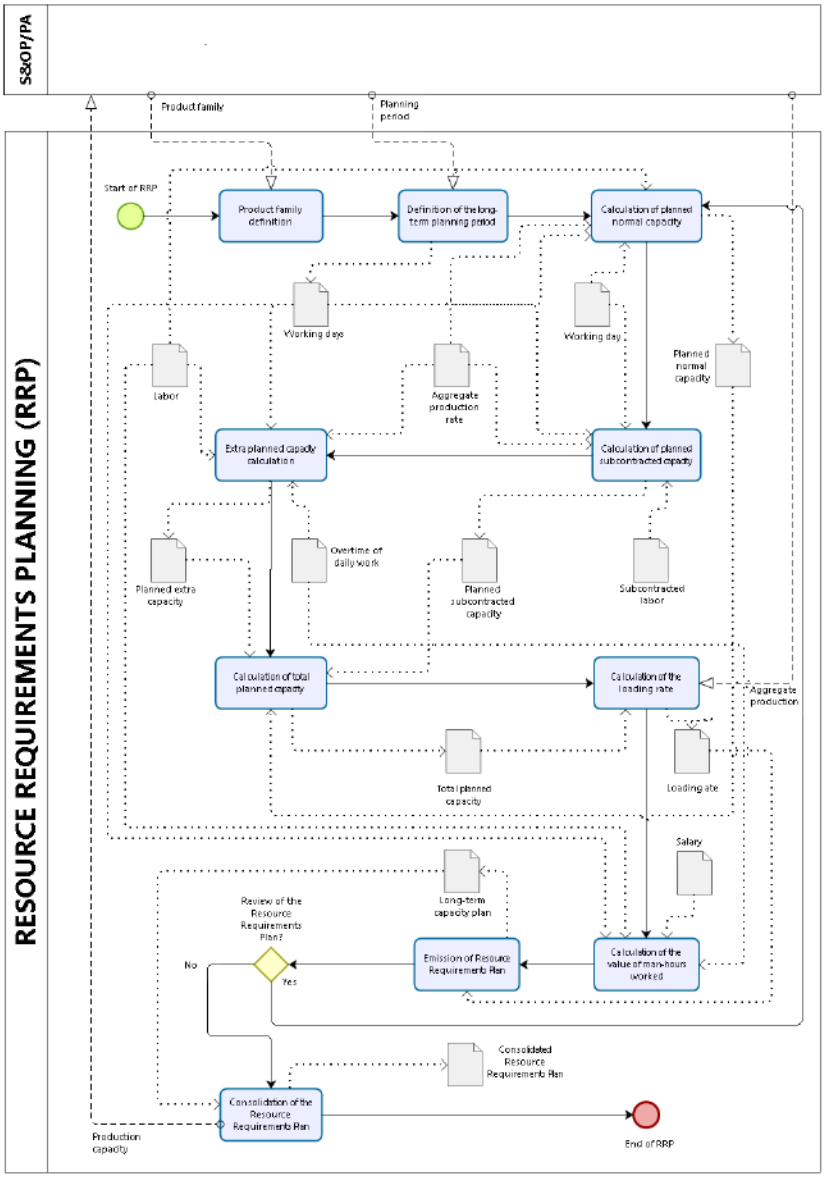

Fig. 3: RRP model in BPMN

4.3 Software prototype

With the intention of generating a greater consistency between the abstraction of the reference model and its application in supporting the implementation and development of business management tools, a software prototype was developed through the Delphi interface. Figure 4 shows the first screen of the developed business management software.

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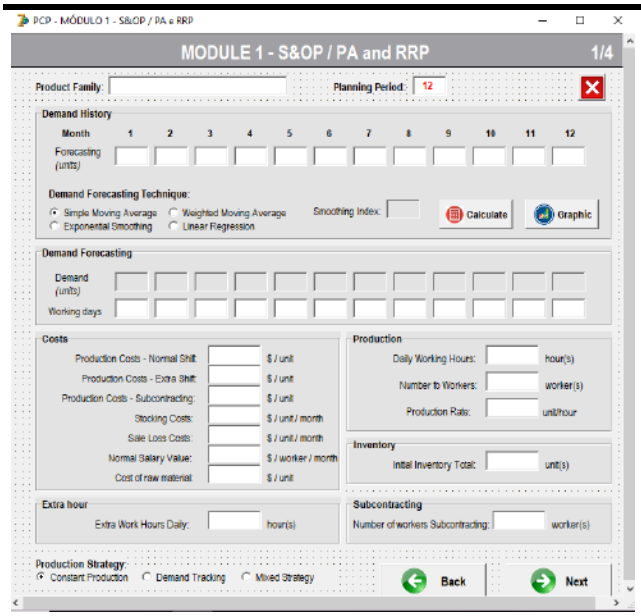

Fig. 4: First screen of the computational program of the MPS and RRP module

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

The results obtained by the computational program were compared with the results extracted manually and in electronic spreadsheets. In this way, software developed from the developed reference model proved to be reliable and apt to be used for the elaboration of aggregate production plans.

V. CONCLUSION

From a formal documentation, the reference model proved to be a useful tool in understanding and communicating the existing processes in S&OP/AP and RRP. 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, these processes should receive expertise from ERP systems, and users should be familiar with 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. Another application observed for the reference model is the teaching of PCP.

For future work, it is suggested, in a complementary way to the model constituted in this work, the development of a model approach in a holistic and hierarchical way the other modules of the Business Processes related to the PPC. For purposes of validation, it is suggested the dissemination and application of the software, developed from the reference model, in SMEs with activities focused on production planning.

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