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AGRICULTURAL MACHINERY AND IMPLEMENTS DESIGN PROCESS: GUIDELINES FOR SMALL AND MID-SIZED BUSINESSES

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ABSTRACT: This study aims at presenting the process of machine design and agricultural implements by means of a reference model, formulated with the purpose of explaining the development activities of new products, serving as a guideline to coach human resources and to assist in formalizing the process in small and medium-sized businesses (SMB), i.e. up to 500 employees. The methodology used included the process modeling, carried out from case studies in the SMB, and the study of reference models in literature. The modeling formalism used was based on the IDEF0 standard, which identifies the dimensions required for the model detailing: input information; activities; tasks; knowledge domains; mechanisms; controls and information produced. These dimensions were organized in spreadsheets and graphs. As a result, a reference model with 27 activities and 71 tasks was obtained, distributed over four phases of the design process. The evaluation of the model was carried out by the companies participating in the case studies and by experts, who concluded that the model explains the actions needed to develop new products in SMB.

KEYWORDS: product development process, reference model, prototypes.

PROCESSO DE PROJETO DE MÁQUINAS E IMPLEMENTOS AGRÍCOLAS: DIRETRIZES PARA EMPRESAS DE PEQUENO E MÉDIO PORTES

RESUMO: O objetivo foi apresentar o processo de projeto de máquinas e implementos agrícolas por meio de um modelo de referência, elaborado com o propósito de explicitar as atividades de desenvolvimento de novos produtos, servindo de diretriz na capacitação de recursos humanos e para auxiliar na formalização do processo em empresas de pequeno e médio portes (EPM), ou seja, até 500 funcionários. A metodologia utilizada abrangeu a modelagem do processo, realizada a partir dos estudos de casos nas EPMs e do estudo de modelos de referência descritos na literatura. O formalismo de modelagem utilizado foi baseado na norma IDEF0, que identifica as dimensões necessárias ao detalhamento do modelo: informações de entrada; atividades; tarefas; domínios de conhecimento; mecanismos; controles e informações produzidas. Essas dimensões foram organizadas em planilhas eletrônicas e esquemas gráficos. Como resultado, obteve-se um modelo de referência com 27 atividades e 71 tarefas distribuídas sobre quatro fases do processo de projeto. A avaliação do modelo foi realizada pelas empresas participantes dos estudos de caso e por especialistas da área, que concluíram que o modelo explicita as ações necessárias ao desenvolvimento de novos produtos nas EPMs.

PALAVRAS-CHAVE: processo de desenvolvimento de produtos, modelo de referência, protótipos.

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INTRODUCTION

In order for companies to survive and expand their market share, TOLEDO & SIMÕES (2010) indicate that the qualification in development of new products is necessary. MONTANHA JUNIOR et al. (2013) consider that the ability to develop new technologies that lead to new products is critical for increasing business competitiveness. To SCHELESKI (2014), improvements in design processes may offer subsidies and differential against competitors, however, OLIVEIRA et al. (2012) state that many companies in the industry lack management tools for product development process (PDP) that fit the national reality, especially in smaller companies. The study by TOLEDO & SIMÕES (2010) indicates that this lack of tools predominates in small and medium-sized enterprises (SMB) of the State of São Paulo, since little is known about their processes.

SIMÕES (2007) indicates that SMB face technical, financial and human limitations which directly influence the PDP management and structure. The difficulties encountered by SMB can be a result of their reduced number of employees, as in the SEBRAE classification (2012) companies with 20 to 99 are considered small businesses, and those with between 100 and 500 employees are considered medium-sized.

In contrast, there are well-defined and formalized processes only in large companies (NANTES & LUCENTE, 2009; ROMANO et al., 2005). Companies called world leaders are incorporating new technologies to agricultural machinery and implements, developing a new generation of these products (REAME JÚNIOR, 2008).

The study by BERGAMO (2014) points out that the use of process management systems is convenient for the SMB in the industry, reducing design time, production costs and providing consumers with equipment which allows the use of technology in favor of modern agriculture. For that, these companies require conditions to compete in the market with satisfactory functional performance products in carrying out agricultural operations, encompassing innovation and technology, combined with low production costs (ROMANO, 2013). Thus, agricultural mechanization requires the use of agricultural machinery and implements with greater power and technology incorporated to meet the needs of agricultural activities (PIACENTINI et al., 2012). These features makes the agricultural machines and equipment complex in their development, making it necessary to advance in research and development of new products, where technical and project management methods are essential (REAME JÚNIOR, 2008).

According to BACK et al. (2008), project is defined as a predominantly cognitive activity, based on knowledge and experience, directed to the search of optimal solutions for technical products in order to determine the functional and structural construction and create documents with accurate and clear information for manufacturing. Accordingly, the realization of systematic processes of product developments occurs by formal particular models, where the term "model" can be used to characterize features and structures that represent objects or scenarios (BAIO et al., 2013). Reference model is defined by VERNADAT (1996) as a partial model or not, which can be used as a basis for the development or evaluation of particular models and particular model corresponds to the model dedicated to an aspect of a particular company or system. To ROZENFELD et al. (2006), a reference model enables everyone involved in the PDP to have a common view of the process, know the results, which activities should be carried out, the conditions that must be met, valid information and decisions to be taken. Likewise, SALGADO et al. (2010) indicate that a reference model for the PDP can contribute to the understanding and communication of product design, assisting in management decisions, such as planning and organization. According to MARINI & ROMANO (2009), using a reference model allows the realization of a systemic and structured project, facilitating the development of new solutions and providing increasing business competitiveness.

The benefits that formal project models provide in many companies, especially in small and medium-sized ones, are not used due to their structural characteristics, as they have a small number of people dedicated to the PDP, little expertise in project management and lack of systematization and management of their processes.

In this context, the aim of this paper is to present a model of agricultural machinery and implements process design, designed to cover the structural characteristics of small and medium-sized Brazilian companies, thus defining the main guidelines for the development of new products.

MODELING METHODOLOGY

A sample of 10 particular models of product development process of micro, small and medium businesses of the Rio Grande do Sul state was considered in the preparation of the reference model. The particular models had their activities and tasks analyzed and compared to each other and in relation to the reference model for the agricultural machines development process (MR-PDMA) of ROMANO (2013). The comparative analysis of the particular models enabled the identification of what were the activities, tasks and knowledge domains identified from the functional departments of the companies, necessary for product design in small and medium-sized companies (SMB). Comparison of particular models in relation to the MR-PDMA aimed to identify gaps in the processes practiced by the companies, assisting in the identification of modeling dimensions, such as activities, tasks, mechanisms and controls inherent to the process and necessary for the development of the reference model, providing a complete view of the PDP.

In the graphic and descriptive representation of the reference model, the structure of reference models representation proposed by ROMANO et al. (2003) was adopted, whose formalism in modeling is based on the IDEF0 standard (NIST, 1993) (Integrated Definition for Function Modeling). The model representation was carried out through graphic schemes, where activities and tasks performed at each stage of the project are indicated.

In the descriptive representation of each phase of the MR-PDMA-EPM electronic spreadsheets were used to store the defined activities and tasks. Each activity and task was configured in the spreadsheet according to the logical sequence for carrying out the project, ordered in a continuous workflow.

The following dimensions are defined in the description of the activities and tasks: i) inputs: information or physical objects; ii) knowledge domains covered; iii) mechanisms: methodologies, techniques and tools; iv) controls: information and/or resources; v) outputs: results produced in the form of information or physical objects.

Each phase of the agricultural machinery and implements design process was organized in different tabs of the spreadsheet, totaling four tabs that refer respectively to the phases of informational design, conceptual design, preliminary design and detailed design.

REFERENCE MODEL FOR PROCESS DESIGN

The MR-PDMA-EPM provides the conceptual basis for the formalization of the design process practice. The model, by describing the steps required for the design of new products and improvement of existing products, can be used both as a tool in academic and continuing education of professionals, and as a basis for the adjustment and improvement process carried out by the companies, contributing in this case, to: a) the formalization of PDP; b) systematization of activities and tasks performed in the projects; c) encouraging innovation and diffusion of knowledge; d) process planning and controlling, which facilitates work, reduces time and supports decision making.

The model developed for the design process of agricultural machinery and implements is part of a larger model, whose purpose is the complete product development (MR-PDMA-EPM), ranging from the idea of producing an agricultural machine to its market launch. This entire process is performed by executing 49 activity decomposed into 134 tasks, over seven phases. The grouping of these phases defines three macro phases: planning, designing, and implementation. This article presents the modeling performed to define the design macro stage, responsible for the action of designing the product and its manufacturing process. The name design is the same used by ROMANO (2013).

The macro design stage, illustrated in Figure 1, is of the phases and evaluations type. At the end of a project phase, results are evaluated using criteria for decision making on progress to the next stage. Designing consists of four phases: (i) informational project; (ii) conceptual design; (iii) preliminary design; and (iv) detailed design.

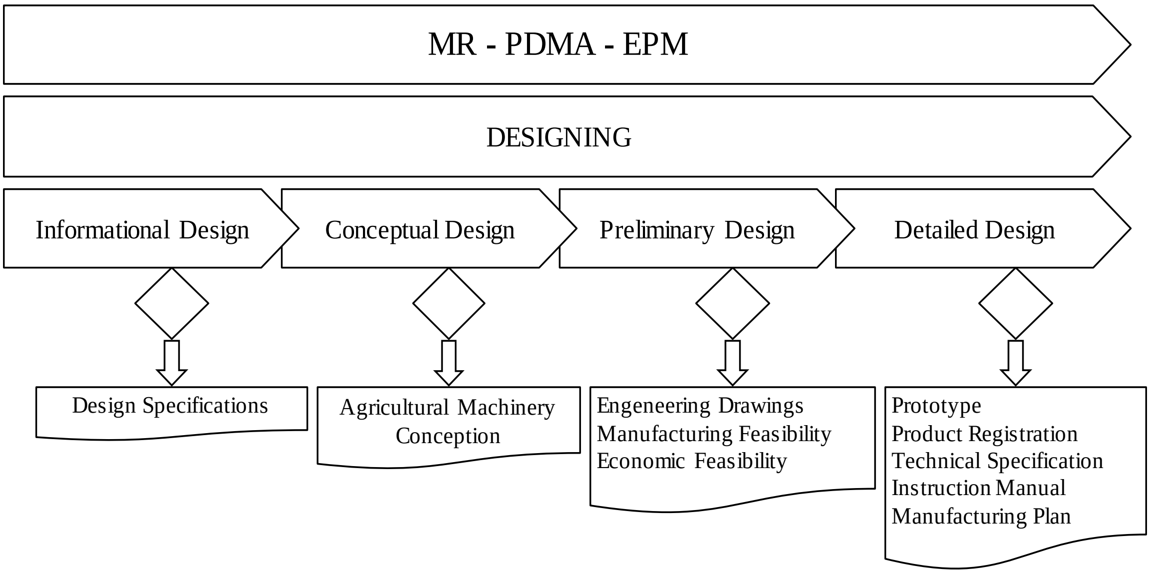

FIGURE 1. Graphic representation of the macro design stage of MR-PDMA-EPM.

The model stages are formed by a set of activities, which are defined by a subset of tasks. The design accounts for approximately 50% of the activities and tasks of MR-PDMA-EPM, possessing 27 activities and 71 tasks distributed over its four stages. Thus, the model was created with the definition of 5 activities and 13 tasks for the informational design stage, 4 activities and 11 tasks for the stage of conceptual design, 6 activities and 19 tasks for the preliminary design stage, and 12 activities and 28 tasks for the stage of detailed design.

The tasks described in the model are classified according to the areas of knowledge necessary for their achievement. This classification allows the identification of those involved and those responsible for carrying out the activities and tasks. The knowledge areas covered are described in Table 1.

TABLE 1. Knowledge domains present in the MR-PDMA-EPM.

Knowledge domains/areas	Abbreviation	Knowledge necessary for the design process activities
Administrative financial	AF	Administrative, accounting and financial economic sciences.
Commercial Department	CD	Marketing, including market research, product planning, publicity, advertising, launching, sales and aftersales.
Business management	BM	Company strategic management and project management, including decision processes of evaluation, approval and authorization of stage passage.
Product and manufacturing design	PM/P	Product technical development, prototype, manufacturing and assembling process.
Production	PR	Production management.
Safety	SE	Ergonomics and safety for the company’s product and productive processes.
Supply	SU	Sales administration and supply control, supply chain, negotiations and contracts.

The informational design phase aims to establish the product design specifications by carrying out two sets of activities and tasks (Figure 2) which primarily include a collection of information, then its treatment in order to define the project metrics.

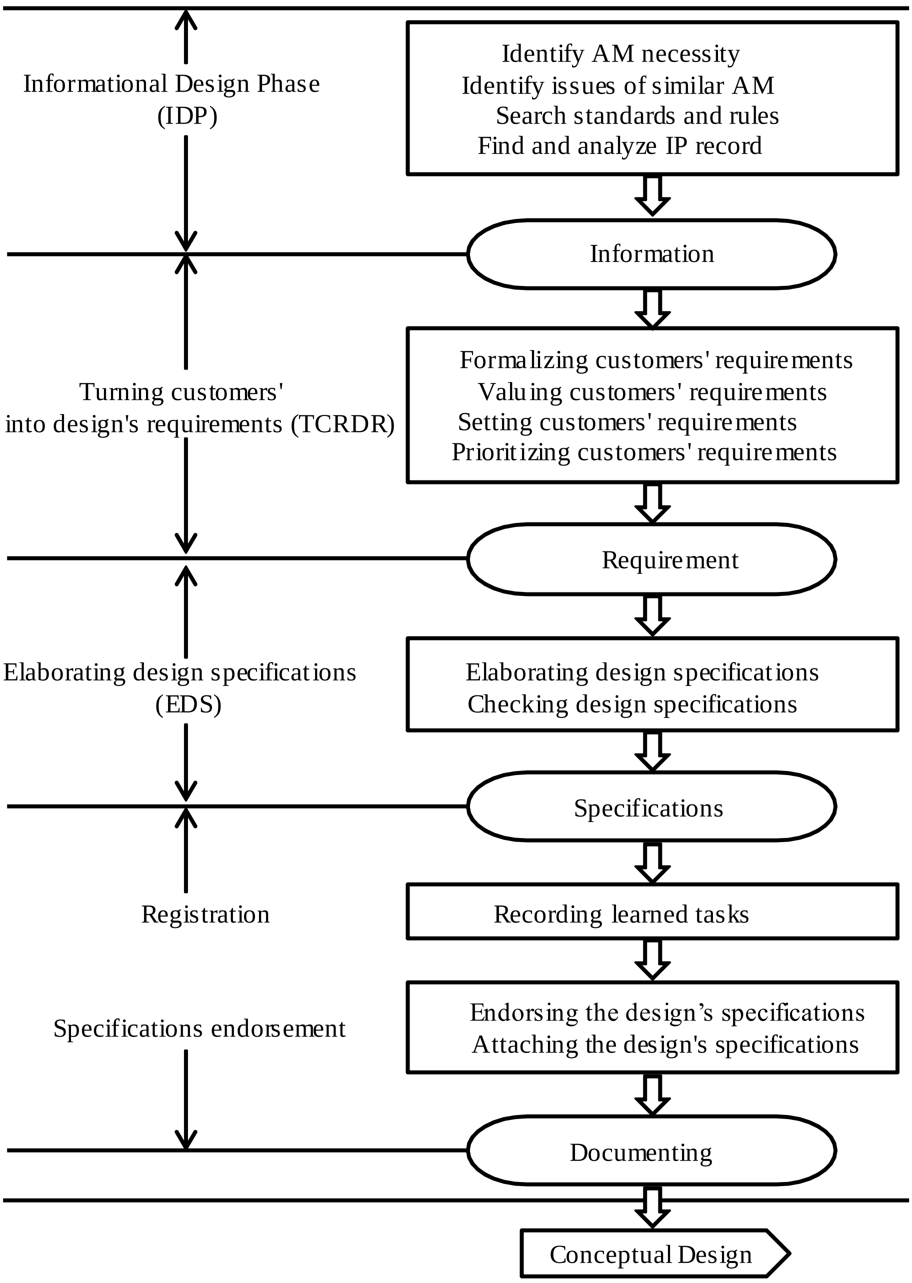

FIGURE 2. Scheme of the informational design phase.

Information gathering seeks to identify, from the original customer information, a list of the requirements to be met by the product to be developed (e.g., the machine should be light so as not to compact the soil). It is observed that the customers mentioned include those who have some kind of relationship with the product throughout its life cycle, either project or economic (ROZENFELD et al., 2006). According to this, the classification presented in ROMANO (2013) regarding the types of customers is adopted: (i) external: users and experts; (ii) intermediaries: people responsible for distribution, marketing and after-sales; and (iii) internal: people involved in the design and implementation of the product under production. Besides these, other information should be collected in order to do the analysis of similar agricultural machinery, incidence of legislation, regulatory standards and search for patents.

Processing of the information collected results in the formalization of project requirements, i.e. the definition of metrics that will guide the development of the agricultural machine or implement in order to meet the needs for which the project was created. For this, it is started from a list of customer requirements (e.g. having low weight), which express the customers' needs and/or desires of the product life cycle, and its conversion into design requirements, metrics, (e.g. weight, kilograms measurement unit). Such requirements will be partly conflicting, suggesting occasionally the need for valuation (e.g. by the method of Mudge diagram) and hierarchy (e.g. for quality function deployment method - QFD), respectively. For ROZENFELD et al. (2006), the valuation of customer requirements is an important and indispensable task, especially if there is a need to prioritize the design requirements with the quality function deployment (QFD) method. According to BACK et al. (2008) and ROMANO (2013), the design requirements are defined taking into account different attributes such as functional, ergonomic, reliability, among others. With these requirements established, the design specifications can be developed (e.g. weight <250 kg), whose definition will guide the design solution. The specifications shall be subjected to the business management approval for the project to continue on to the conceptual design phase. It is observed that at all stages of the product design process of the MR-PDMA-EPM, the lessons learned are registered. These records aims to document the recommendations of the best practices employed in the activities and tasks, thinking about the use in the next projects. Best practices result in a knowledge gain for the company (ROMANO, 2013). According to ROZENFELD et al. (2006), the record of the lessons learned during the design process is considered an important source of information for the PDP improvement.

The conceptual design phase has its activities and tasks presented in Figure 3. Its purpose is to generate the agricultural machinery conception. The phase begins with the base product analysis, i.e., the current product that will be redesigned by identifying and graphically representing the existing functions, defining which will be maintained, withdrawn or even added to the new product, according to the design specifications.

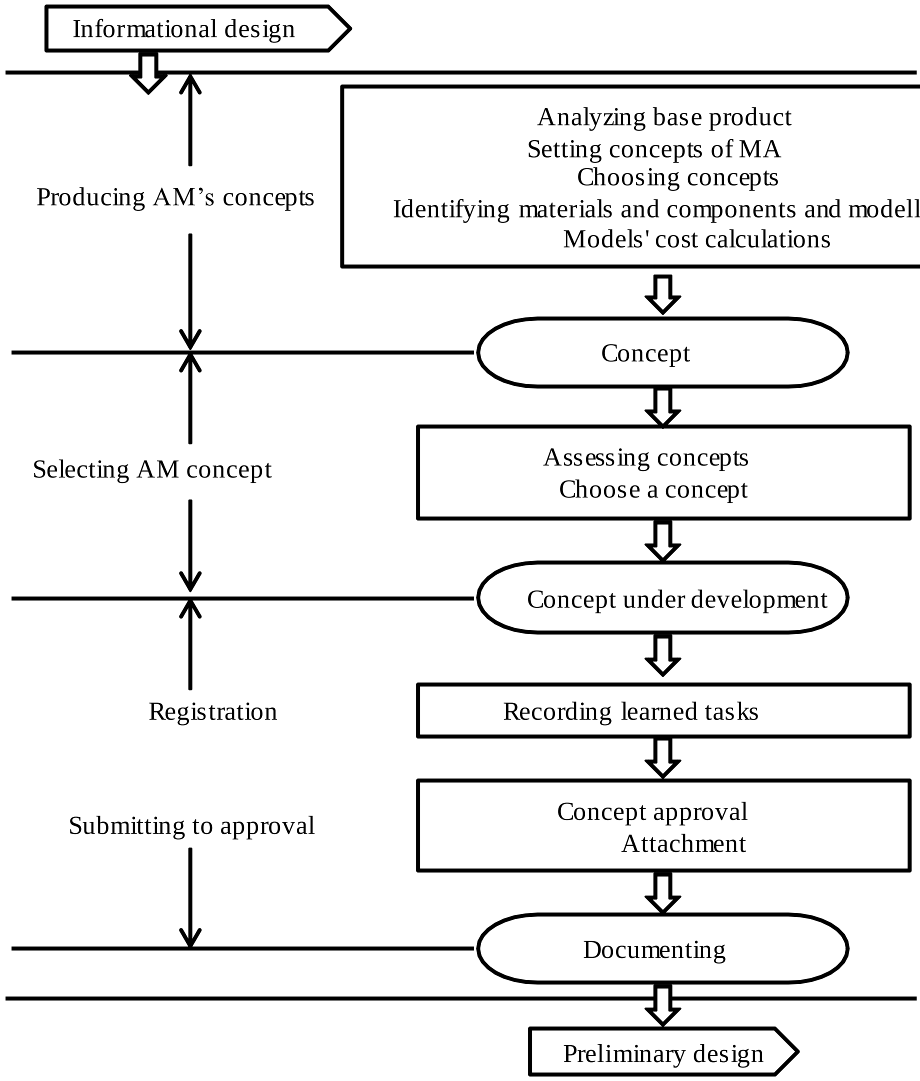

FIGURE 3. Scheme of the conceptual design phase.

The overall function of the agricultural machine should be identified, as well as the lower-level sub-functions in order to obtain the product functional structure, according to the prescribed BACK et al. (2008) and ROMANO (2013). In the same direction, ROZENFELD et al. (2006) confirm that the so-called functional structure describes the operation of the product in abstract terms, without restricting it to a single solution, enabling the search for a better solution of the problem. This strategy makes room for product innovation. After defining the functional structure and the solution of principles of design for the elementary product functions, the outlines of the conceptions of the agricultural machine or implement is generated in a first level of product modeling, sufficient to determine the main components with the purpose of estimating the initial cost of each conception.

The following activity of the conceptual design phase involves the study and analysis of concepts developed to support the decision making on the design chosen in relation to customers' requirements and design specifications, which determine technical and economic criteria. The design chosen is, then, submitted for approval before the GE, who authorizes the project to proceed to the next stage.

The preliminary design phase (Figure 4) is intended for the complete specification of the agricultural machine or implement components, implying in the evaluation of the manufacturing capacity and economic feasibility of the product.

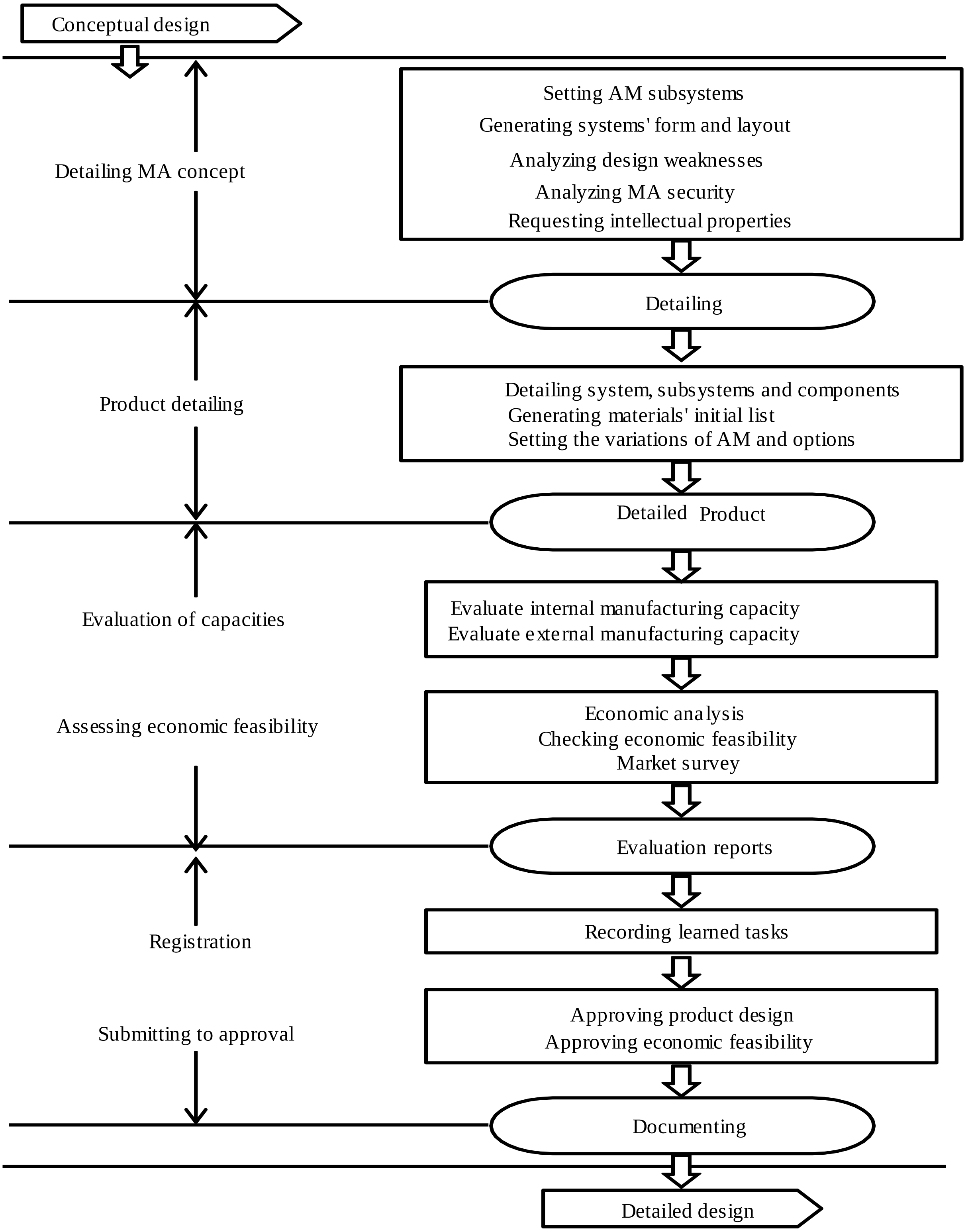

FIGURE 4. Scheme of the preliminary design phase.

This includes the definition, design and analysis of systems, subsystems and components (SSC) that compose the product and that will determine the product final form and layout, supported by the principles of safety, ergonomics, aesthetic, and expression and which affect the product operation. The analysis of the SSC include the identification of the product critical aspects related to the operation, manufacturing, installation, performance, quality, cost, use, maintenance, disposal, among others. This approach converges with that described in ROZENFELD et al. (2006), for the SSC analysis marks a crucial moment of the project, where the impact on the product life cycle is verified.

With the agricultural machine shape and layout set, the list of materials is obtained (initial) for the product and the variants (versions) can be set, which can be assembled from the product, its options and accessories, of course according to the demand defined by the commercial area.

The definition of versions, options and accessories take into account the marketing definitions (ROMANO, 2013) and the company's products portfolio. By defining the list of materials and the SSC design, there will be data an information for the assessment of manufacturing capacity and thereby definition of the items that will be produced internally (manufactured) or externally (purchased). From these analyzes follows the estimate of the necessary investment in production tooling, the budget of items purchased externally and the verification of the need to develop new suppliers if necessary.

With this, an update of the product cost must follow, in which the expenses incurred and the estimated investment in tooling are considered, comparing it with the target cost set at the verification of the product current demand, as a reference in determining the economic feasibility of the agricultural machine. These results include the main outputs of the preliminary design phase, which are submitted to approval along with the product design before the business management and commercial department, who authorize the continuation of the project to the next stage. For ROZENFELD et al. (2006), it is ideal for constant monitoring of the project/ product economic and financial feasibility, always attentive to market conditions.

The detailed design phase aims to build the agricultural equipment prototype, perform tests and define the product-manufacturing plan (Figure 5). It starts with the preparation of the manufacturing plan and prototype testing. With the progress of the phase, the prototype assembling occurs and lab or field tests start, in which the product performance, occurrence of failures, its resistance and meeting of customers' needs will be evaluated. After testing, it is recommended to disassemble the prototype for individualized assessment of its components, in order to identify premature wear and other failure modes. The components that present problems should have their design fixed.

After obtaining the prototype approval, comes the elaboration of the technical product documentation, with the formalization of specifications and description of the instruction manual. At this stage there is the detail of the product manufacturing plan, which involves the definition of the manufacturing process and the development of manufacturing tools. According to ROZENFELD et al. (2006), the process planning does not occur in a linear fashion, having some interdependence in its information, which involves how the product will be manufactured and assembled from a technological point of view. With the end of the tooling project there is an updating in the development cost and the release of amounts spent on all activities of the stage, in the project cost center, then submitting the manufacturing plan for approval by the GE, which by approving, authorizes the start of the preparation phase of production and release.

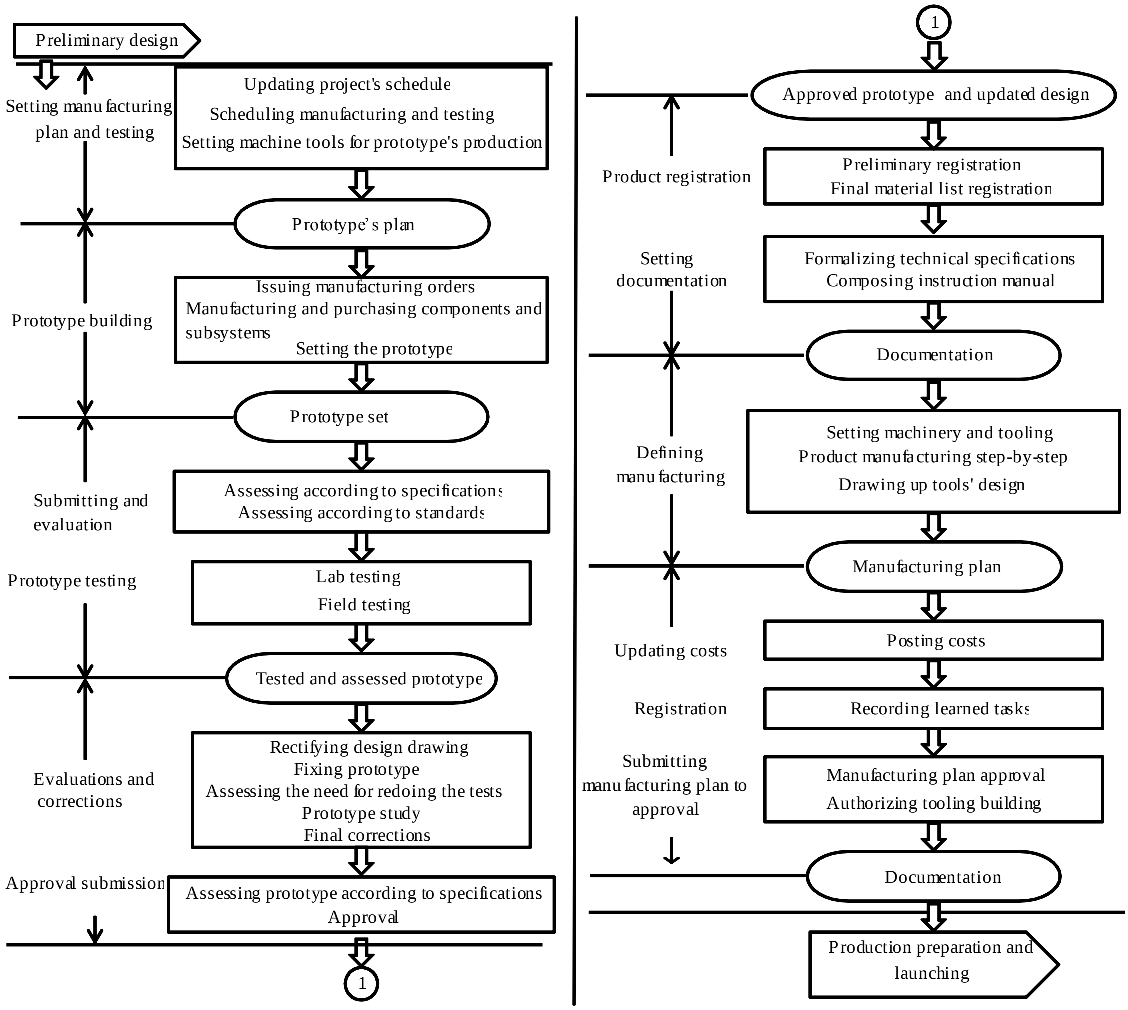

FIGURE 5. Scheme of the detailed design phase.

CONCLUSIONS

The macro design stage, from the Reference Model for Agricultural Machinery Development Process for Small and Medium Businesses explains the activities and tasks required for PDP, assisting in the management and formalization of the design process.

The MR-PDMA-EPM provides companies with a small number of people dedicated to the PDP and which have low project management qualification a more systematic process, facilitating work, reducing time and aiding in decision making.

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