PARTIAL MODEL OF THE PRELIMINARY DESIGN PHASE FROM BAJA SAE

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Abstract. *The Preliminary Design phase is the step of the project which aims to establish the final layout of the product being initiated from a conception selected in the phase of Conceptual Design. In this step decisions are made regarding the product's architecture, design of components, construction materials, etc.., producing improvements in the product's form mainly targeting its manufacturability (fabrication and assembly) and maintainability. Currently, there are numerous reference models for project activity in various industries sectors, covering from the Informational Design up the detailing to the manufacturing process - Detailed Design. However, by its comprisement, these methods provide the development of specific models for certain products, according on the characteristics of uniqueness that each product presents. Under this scope, this work aims to present a partial model for the Preliminary Design phase of the BAJAS SAE. Thus we seek to minimize the probability of failure, avoiding the possible need of rework or redesign futures, yet at the stage of Preliminary Design.*

Keywords*: engineering design, product development process, reference model, preliminary design, BAJAS SAE*

1. INTRODUCTION

For a long time, the idea that the project activity didn't require a scientific formalism, predominated in the industrial segment. Today, however, it is considered that the development of this activity must be based on principles, methods, methodologies or models that will guide the process. In the absence of guidance mechanisms, the project activity is dependent on the individual ability and experiences (Romano 2003[b]).

Despite the informality of design activity in the past, through the empirical process, large and important works were created, however, it is believed that the experience gained by these designers was not fully transmitted to subsequent generations (Cross, 1989). When knowledge is not documented nor structured, each generation has to acquire experience in itself.

Although there are currently several models for a wide variety of industries and products, in certain applications it's required that these methods are interpreted, adapted and deployed, depending on the characteristics of uniqueness that each activity and/or product features.

Inserted into this reality, this work aims to define a proposal for a partial reference model for the Preliminary Design phase (PD) of the Baja SAE. By developing this methodology seeks to generate competitive advantages - for the teams - in this stage of the project, through streamlining and synthesizing activities with the intent of ensuring that the resulting product meets the scope, quality, costs and timing.

1.1. Problematic

The biggest challenge in projecting a Baja SAE is the need to maintain the designer immersed in successive technical analysis of the process, and still retain the ability to evaluate the overall system design. Added to this, the increasing complexity involved in the development of Minibajas, occurred in the face of progressive increase of requirements by the agency that regulates the competition and, considering the tendency of progression of this factor, it is important to approach the reference models project activity of the cars.

These reference models are important in overcoming the difficulties related to design activity, facilitating the interpretation of complex, with wealth of detail required, and allowing the representation of multiple views from the object, adjusted to the context of decisions during the process. However, the use of ready solutions, broadcast on sophisticated modeling, without the critical view of pertinency from model to specific problem of the Baja SAE, may become a hindrance to his understanding, and their use. For this reason, and depending on the coverage that these models reference presents, it's appropriate the development, from them, of derived methodologies to specific product, considering the peculiarities of the development process inherent in each.

To achieve this purpose, first obtain a common vision of the process of product development, which has generated a growing number of papers, in different industries such as aerospace, automotive, consumer electronics, agricultural machinery, building among others (Rozenfeld (1997); Valeri *et al.* (2000), Araujo *et al.* (2001); Estorilio and Sznelwar (2001), Romano (2003[b]), Romano (2003[a])).

Within this context, this work seeks to develop a partial reference model, suitable for application during the Preliminary Design phase of a Baja SAE. For this, it will be use as reference the RM-AMDP (Reference Model for the Agricultural Machinery Development Process, created by Romano (2003[b])), which is based on the methodology developed by Pahl and Beitz (1988). The partial modeling of the methodology proposed here, from the RM-AMDP, is through by adapting of the Preliminary Design phase, which composes it's Designing macrofase, since this includes the step of establishment of the final layout of the product.

Although this is a model created in the beginning specifically for the agricultural machinery sector, the methodology was subsequently transcribed by Back *et al.* (2008) with the name PRODIP (Process Model Integrated Product Development), in which the authors validate their adoption for the design of generics products.

2. HISTORICAL EVOLUTION OF THE APPROACH TO THE PROBLEM

According to Pahl and Beitz (1988), possibly a precursor between the researchers in the area, was Erkens (1928) in the 20s of last century. Erkens proposed a step by step approach, based on a constant process of evaluation and testing, with the sense of satisfying various demands, a process that is maintained until a stream of ideas (the project) arises.

In the 40s, Kesselring (1942) proposed a process of successive approximations based on technical and economic criteria, where the four main criteria constituted: minimal cost, minimal weight, minimal space and losses.

In the following decade, Tschochner (1954) stated that there are four design factors that are interrelated, where final product depend them: a method of execution, material, shape and size. According to the author, project begins with the choice of execution method, followed by material selection and form and, finally, determining the dimensions.

One of the most interesting and innovative proposals for the season, according to Pahl and Beitz (1988), was of Niemann (1950) that in the same decade, considered that the project should be composed by the beginning, which corresponded to the drawing scale, proceeding then with the definition of the task and analysis of alternative solutions, and ending with the selection of the optimal solution.

Rodenacker (1970) considered the design process as a method of transforming abstract information into concrete. For this author, the design results of the application of the following rules, in chronological order: clarification the problem, establishment of the structural function, establishment of physical dimensions; determine the construction process, eliminate errors, and materialize the solution and revise the solution.

For Roth *et al.* (1971) the design process could be divided into four stages, each comprising a set of steps, which according to the result obtained, should or not be repeated. The first step was the analysis of the product environment to conduct a precise definition of the problem. The next step consisted of defining the function. The third stage corresponded indeed definition of products. And finally, the making of drawings and documentation of the final product. The most interesting feature of this proposal, according Pahl and Beitz (1988), is the fact considers the design process as an iterative process.

More recently, in the late 80's, Pahl and Beitz (1988) said that the design process is in essence a process of problem solving and decision making. As a work methodology, the authors proposed a schema that relies on four main phases: clarification of the task, followed by conceptual design, after the preliminary design and, finally, detailed design.

The model developed by Pahl and Beitz (1988) reflects a line of thought much widespread in the area of product development, which is proven by numerous studies conducted in this area in recent years, which adopted this methodology as the baseline model. Among these, one can cite the RM-AMDP.

For Romano (2003[b]), author of RM-AMDP, whatever the industrial product to be developed, each design typically involves several phases, which lead the progressive development of the product, from initial idea to the complete definition of specifications and their characteristics, culminating with the release of the product on the market. This process, according to the author, is accomplished through three macrofases planning, designing and implementation, which in turn are decomposed into eight phases: design planning, informational design, conceptual design, preliminary design, detailed design, preparation of production, release and validation, this constituting the path between the detection of a business opportunity and the launching a product to market.

Both the model proposed by Romano (2003[b]), as the others, are appropriate for use in the vocational training in undergraduate and graduate engineering, promoting, too, the opportunity the derivation of specific methods for certain products.

Within this reality, considering the notorious informality of the development process from Baja SAE, it's envisioned an opportunity for the development of this research. Considering the peculiarities surrounding your project, depending on the requirements established by regulation, which delimit some features of the prototype, its development is restricted to the design of the suspension, brakes, steering and transmission, since the concept of car and motor are standardized. Considering this factor, we observe that this restricts the use of a complete reference model, where they are considered all stages of a project, limiting their approach to Preliminary Design phase.

Thus, this work is restricted to the development of a model including only the detailed design phase, which is formulated having with reference the corresponding phase of the RM-AMDP, which is described in the sequence.

3. THE PRELIMINARY DESIGN PHASE

According Romano (2003[b]) and Romano (2005), the Preliminary Design phase is intended to establish the final layout of the product and determine its economic viability (Fig. 1).

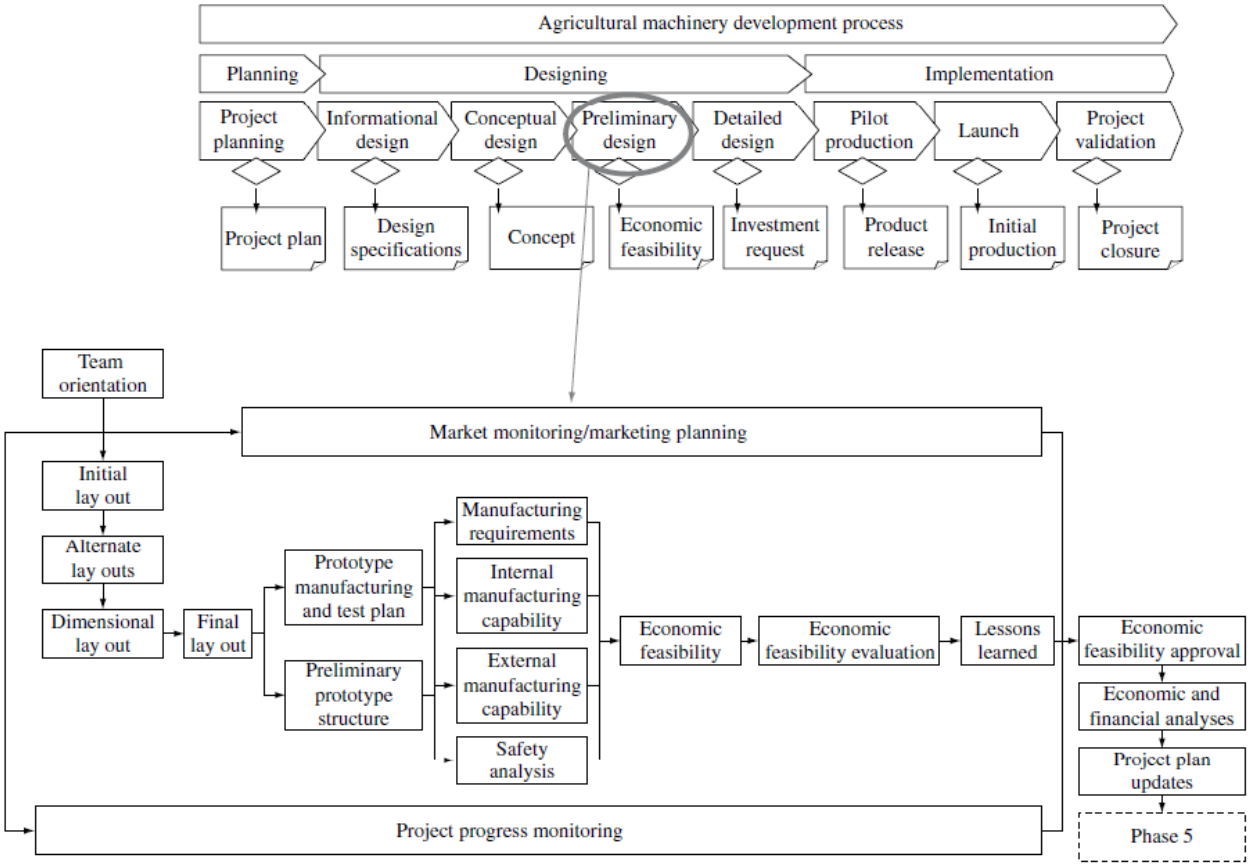

Figure 1. Flow of activities/documents of the Preliminary Design phase to the RM-AMDP (Romano, 2005)

Thus, in accordance with to the author, in order to establish the final machine layout, the process is always started from an initial proposal, called initial layout. Its delineation is done from the analysis of the design specifications, and involves the following activities:

- Identification of the design specifications that define the form requirements and determine the main product dimensions and the considered requirements in the layout development, such as, materials, safety, ergonomics, manufacturing, etc;
- Elaboration of a schematic diagram of the machine construction elements, its, of product parts represented by chosen solution principles, by existing elements and/or non-determined functions;
- Grouping of construction elements in modules, obeying to the limits defined by the design requirements;
- Layout and form definition for the construction elements of each module, for definition of their main dimensions;
- Identification of interactions and interfaces among the construction elements and/or modules, for establishing adequate solutions for them; and,
- Analysis of main interactions among construction elements, corresponding to the generation of nondesirable, disturbing, effects (e.g. vibration, noise, heat, etc.) of an element upon another, that doesn't cause functional compromises, as well as the secondary interactions, it is, those generated by the raising of the non-desirable effect levels, which provoke machine failures or functional compromises.

Established the final layout, starts the development of manufacturing plan and prototype testing beyond the development of the primary structure which serves as a starting point for the cost calculation. From this point, the requirements for manufacturing the prototype are defined, the internal and external ability to manufacture of components is evaluated, and performed security analysis on the final layout. Subsequently, the economic viability of the equipment is determined. To shut the preliminary design phase, the economic viability is submitted for approval to progress to the next stage.

Considering the differences in design of different products (in this case, Agricultural Machinery and Baja SAE), will use the same structure of preliminary design phase form RM-AMDP, by making changes in the nature and sequence of tasks, adapting to the development of Minibajas. Thus, the discussion below shows the proposed model.

4. PROPOSED OF MODEL FOR THE PRELIMINARY DESIGN PHASE OF BAJAS SAE

The Preliminary Design phase of BajaSAE aims basically establish its final layout and its manufacture, being the activities of this step conducted in accordance to the flowchart presented by Fig. 2.

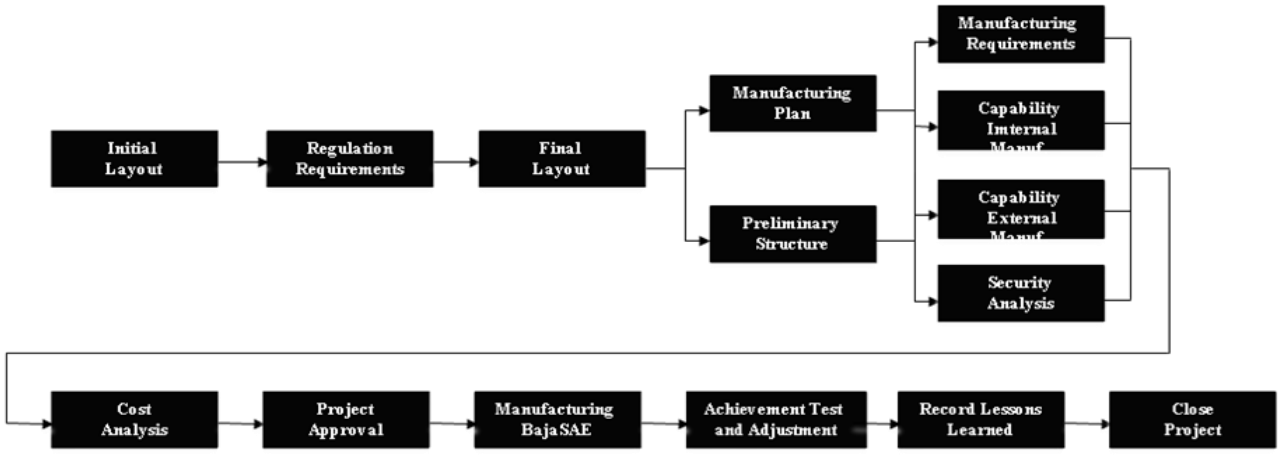

Figure 2. Flowchart for Preliminary Design phase

To define the final layout of the BajaSAE, if part of an initial proposal for the same, resultant of projects developed in previous competitions, it from which will be derived the final layout BajaSAE (Table 1).

Table 1. Establishment of the final layout from the initial layout

Input	Activities	Tasks	Mechanisms	Outputs
Initial layout	Establish the final layout of BajaSAE	List the requirements provided by regulation	Analysis of the regulation	Design requirements
		Identify the design specifications established that relate the requirements of form, materials, safety, ergonomics and manufacturability		
		Matching the characteristics of the initial layout with specifications laid down by regulation	Compare the initial layout with specifications established by regulation	
		Plot outline of the layouts in development demonstrating its features	Detailed drawings	Preliminary cost manufacturing
		Estimating costs of the layouts generated	Methodology of cost estimation	Preliminary cost manufacturing
		Evaluate layouts generated (in view	Meeting of the team of	Final layout

Table Continuation

		of technical and economic criteria)	product development	
		Select Layouts		
		Establish the key dimensions of the components, materials, manufacturing processes, tolerances, etc.	Components catalog components existing standardized components	Design specifications
		Establish the final shape and arrangement of the components	Drawings	
		Prepare drawings of the components		
		Prepare list of components	Parts List	Names and quantities of components
		Determine the number of components (in case there is need for making more thanone)		
		Writing technical specifications	Technical Specifications	Technical Specifications
		Fix final layout	Drawing	Final layout Drawings of the final layout

From the analysis of design specifications established by regulation, identify those that define the requirements that determine the shape and dimensions of the Minibaja, as well as other requirements to be considered in developing the layout, such as materials, security, ergonomics, manufacturing, etc.

Considering this information is drawn up a schematic diagram of the constructive elements of BajaSAE, ie the parts of the product represented by the principles of solution chosen, by the existing components and/or functions have not yet determined.

The next task is the grouping of the constructive elements in modules, considering to the limits defined by the requirements of the regulation. Must be defined the shape and layout of the constructive elements of each module, establishing its main dimensions. About sketches drawn of the layout identify the interactions and interfaces among the building elements and/or modules, to provide appropriate solutions for them. Following are selected and grouped the best principles of solutions which define the final layout of the BajaSAE.

Once reviewed, the final layout is fixed and the definitions of form and style are improved, while that drawings completed. Established the final layout, begins the development of design for manufacturing (Table 2) and simultaneously, the preparation of the primary structure of BajaSAE (Table 3).

Table 2. Development of the manufacturing plan

Input	Activities	Tasks	Mechanisms	Outputs
Final layout Components List	Develop the manufacturing plan of the BajaSAE	Check the need for making laboratory testing in laboratory	Meeting the team of product development	Manufacturing plan from BajaSAE
		Establish the types of tests to be performed		
		Prepare schedule of fabrication and assembly of BajaSAE	Schedule prototype	
		Issue requisition to manufacturing of BajaSAE	Prototype request	Prototype Request
		Attach manufacture plan to system of project documentation	System design documentation	Manufacturing plan and Request for prototype

In this activity are also prepared, the schedules of manufacturing and assembly of BajaSAE. With the development of the plan of manufacturing and testing of BajaSAE your request is issued. The construction occurs only in the sequence, after the cost analysis done and the project is approved by the team.

At the same time is prepared preliminary structure of the prototype (Table 3), which includes all components and modules that make up the BajaSAE, and that should be attached to manufacturing plan. As has already been released the preliminary cost of components, it is estimated the total cost. This estimate will be compared later with the true cost of Minibaja mounted.

Table 3. Preparation of the primary structure of BajaSAE

Input	Activities	Tasks	Mechanisms	Outputs
Final list Components List	Develop the primary structure of BajaSAE	Review the components list of BajaSAE	Primary structure of BajaSAE	Primary structure of BajaSAE
		Preliminary cost estimate of BajaSAE	Methodology of cost estimation	Preliminary cost of BajaSAE
		Attach primary structure and cost estimative to system design documentation	System design documentation	Primary structure and cost of BajaSAE

From this point on, various activities are carried out simultaneously by a team of product development, including definition of requirements for manufacturing, capability internal and external production of components, and security analysis. The requirements for the manufacture of prototype are defined, ie the resources needed to manufacture the components and assembly of the prototype (Table 4).

Table 4. Definition of preliminary requirements for the manufacture of prototype

Input	Activities	Tasks	Mechanisms	Outputs
Factors influencing the plan for manufacturing Prototype Request	Define the preliminary requirements of the manufacturing of BajaSAE	First set the devices and tools necessary for manufacture and assembly of BajaSAE	Team meeting	Preliminary requirements for manufacturing
		Preliminary cost estimate of manufacturing of BajaSAE	Methodology of cost estimation	Preliminary cost manufacturing
		Prepare and issue construction investment request of BajaSAE	Solicitação de investimento para construção do BajaSAE	Solicitation of investment for construction of BajaSAE
		Attach requirements of manufacturing, manufacturing costs and solicitation of investment in the system design documentation	System design documentation	Attached

About these requirements is made a preliminary estimate of cost of manufacture, for which it is drawn up and issued the solicitation of investment for the BajaSAE construction, which is reviewed during examination of cost.

Assessed the capability to manufacture internal components (Table 5), ie the ability of a given manufacturing process items within the specification range, with the purpose of providing training to meet future demand.

Table 5. Capability internal manufacturing of the components

Input	Activities	Tasks	Mechanisms	Outputs
Influencing factors on the plan manufacturing	Assess the internal capability of manufacturing of components	Check current capacity, resources, time, equipment and personnel	Team meeting	Internal manufacturing capability
		Identify likely areas of manufacturing and assembly for internal manufacture		
		Attach study of manufacturing capability within the system of project documentation	System design documentation	

Similarly, one must assess the capability of manufacturing with suppliers and/or sponsors, while that carries out a preliminary review of the structure of the prototype with respect to evaluation "make or buy" (Table 6).

Table 6. Manufacturing capability evaluation of external components

Input	Activities	Tasks	Mechanisms	Outputs
List of components purchased Factors influencing the plan for manufacturing	Assess the external capability of manufacturing components	Check current capacity, resources, time, equipment and personnel	Team meeting	External manufacturing capability
		Review evaluation "make or buy " (considering the cost of material, labor, transportation and equipment availability)	Meeting of team for the cost-benefit analysis	
		Attach the study of external manufacturing capability on the system of project documentation	System design documentation	

Continuing the activities, carried out analysis on the final layout for checking compliance with requirements established by regulation.

As already available preliminary cost of BajaSAE, the preliminary cost of manufacture, the solicitation of investment for construction of BajaSAE, performs the analysis and evaluation costs (Table 7).

Table 7. Analysis and evaluation of costs

Input	Activities	Tasks	Mechanisms	Outputs
Cost analysis Assessment of costs	Analyze and evaluate the costs and design approval	Perform economic analysis	Evaluation of resource in cash and potential sponsorships	Design approval
		Compare the cost preliminary of BajaSAE to its cost goal	Team meeting	
		Approval and release of the amount needed to manufacture and assembly of BajaSAE		

Table Continuation

		Attach the analysis and assessment of costs to the system of project documentation	System design documentation	

If the project is not approved on the basis of analysis and cost evaluation, the team must take the necessary decisions, for review of design and manufacturing plan.

With the approval of the project, taking in hand the final layout, the preliminary plan and requirements to fabrication, structure and preliminary evaluation of the own capability of manufacturing its components or external, it starts to manufacture and assembly of BajaSAE (Table 8).

Table 8. Manufacture and assembly

Input	Activities	Tasks	Mechanisms	Outputs
Construction and assembly of BajaSAE	Building and assemble the BajaSAE	Update schedule for manufacturing and assembly	Prototype Schedule	Schedule of fabrication and assembly
		Review manufacturing plan and assembly of BajaSAE	Manufacturing plan and assembly	Manufacturing plan and assembly
		Define components that will be made by team and constituents to be acquiredexternally	Team meeting	
		Evaluate existing components that can be leveraged from previous designs		
		Prepare for the manufacture and assembly of BajaSAE	Drawings of the component laboratory prototype	Components of BajaSAE
		To manufacture, buy, receive and store components of the project		
		Implement and monitor mounting BajaSAE	Monitoring team	Prototype
		Achievement testing and adjustments		
		Record lessons learned	System design documentation	Project document (report)
		Closure Design BajaSAE	Team meeting	

The assembly should be held according to the primary structure of BajaSAE and monitored by staff. All submissions should be recorded in the records of lessons learned, indicating the corrective actions in case of problems or discrepancies between design and assembly.

During and after mounting the BajaSAE, the same components are identified with the project code and name of the person responsible.

In a team meeting the BajaSAE prototype is presented and evaluated for compliance with the criteria established by regulation. Finally, the project is formally closed through communication to stakeholders.

5. FINAL THOUGHTS

This study involves an experiment with modeling the process of developing of BajaSAE, being the result obtained based on an extensive set of information resulting from a bibliography search about the subject (design method).

The use of modeling as a means to improve the development process of BajaSAE, will facilitate the obtaining a satisfactory outcome with regard to identification and explanation of the inputs that are part of the scenario of the design process, as well as obtaining a structured plan that provides the necessary support for its development.

In conclusion, the contributions of the application of the partial model rely mainly on the vision of all the work that involves the process of developing a BajaSAE. This vision is only possible with the implementation of a structure that makes all activities transparent, ie a structure that presents clearly that each activity should be held when and how. These factors make it easier through the use of the model.

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8. RESPONSIBILITY NOTICE

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