

LEAN THINKING PRINCIPLES APPLIED TO DESIGN METHODOLOGY: A CASE STUDY IN THE RESEARCH PRODUCT DEVELOPMENT CYCLE

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Abstract: *This work presents a proposal of the methodology design where were applied lean thinking principles considering a case study developed in association with the design activities of research group of CTI (Renato Archer Center of Information Technology). Nowadays, the mechanical design engineering demand the set of knowledge from different areas of the electrical, computational and material engineering's as well as customer requirements. The product's time to market is increasingly slightest being necessary that individual and teamwork experiences will be considered in the improvement and development of products. The lean thinking is based on five principles: specification of objective value; identified of sequentially of value; definition of the workflow and its stages; forestall production and continuous improvement. The application of lean thinking concepts into design development process can generate products that fulfill the customer requirements and at the same time remove the wastage associated to time, cost, materials and human resources allowing improvement that aggregate values to design development process.*

Key-words: *lean-thinking; design methodology; case study; product development.*

1. INTRODUCTION

The project management applied to product development has been even necessary due constant innovations that promote high competitive scenery between industries and research centers. Considering the demand of new and consolidate knowledge necessities to developed multidisciplinary design it is mandatory to have techniques and tools systematic to control these technical information's flux as well as sequential activities involved in the product and design development. This approach includes a quite control of risk management inherent to new products and can increase the success change. The "lean thinking" term was used for first time in the manufacturing engineering in the 90's Womack and Jones (2004) when there was an industrial agreement that the integration between the design, manufacturing and servicing and after-sale it was necessary to reduce costs and times. This new configuration of the industries allows that project management techniques could be used and the lean thinking can be applied to design activities. According to Macho e Toledo (2008) the adaptation of lean thinking to the design engineering is a recent approach. The use of lean thinking principles as well design methodology techniques during design process development contribute to the times reduce with higher aggregate value as knowledge fluidly and to improve the communication with production and commercial areas. Within this focus the individual technical experiences and the intuition of the product and design engineer can be transferred and improvement in the design development teamwork. The development of a procedure based on principles of lean thinking in association of methodology techniques applied to project management it is expected that the information's of a product as design, manufacturing, maintenance and costs involved will have a linear flux with better distribution of the costs and/or reduced them as well an integration of design activities with other areas of the product development cycle. The Figure 1 presents the intersection between the three lines of an updated design.

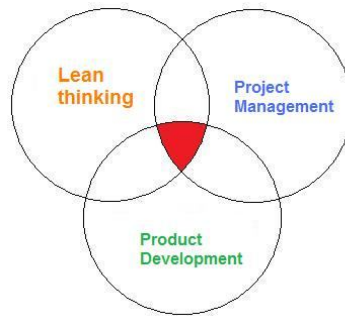


Figure 1: Intersection of: lean thinking, project management and product development.

The applications of lean thinking and the project management support the design development eliminating of potential wastes as time, materials, human resources and investments improving for example, design and manufacturing qualities, documentation with fundamental information's directed to specific workgroup. According to Womack and Jones (2004) the focus of lean thinking is the elimination of waste during some process, activities that do not generate value perceived by customer. The proposed of this work are review and discuss principles of lean thinking and project management applied in design activities where it is developed a case study in a research group.

2. REVIEW

The different types of informations must be known as well as the channels where are transmitted. There are two types of channels: informal and formal. There are many ways to these informations. Informal channels are used in the start of research and the conveyed information is recent and the ways of informal channels include: e-mails, meetings, phone conversation. The formal channels include database scientific with access to journals, conferences and congress proceedings, patents and technical literature as book, dissertations and thesis. As this work has a theoretical-deduce approach the theoretical review from structures, techniques and methods from PMBoK® Guide (*Project Management Body of Knowledge*), do *Project Management Institute* (PMI), lean manufacturing and thinking as well case studies allowed a critical analysis of value sequence inside of design methodology. In this way is presented a brief theory from which was extracted concepts to a proposal of sequence value in the design engineering process.

2.1. Management Evolution

The industrial ages can be divided on three phases: Traditional Industrial (1900-1950), Neo-Traditional Industrial (1950-1990) and Information age (1990-today). The figure 2 presents the ages associated with concepts. In the final of nineteenth century the management was applied systematically with focus on production mode. To the Scientific Management proposed by Taylor and Fayol the high focus on operational tasks of production are the unique and the best way to produce. According to (Bateman and Snell, 1998) there were four principles to guide the scientific management: planning, selection, training, control and execution. The efficiency of these management and productive system is given by full use of the resources (human and materials). The "Ford system" or "Fordism" was the first example of application of these principles where "T" models was manufactured through of high standardization of parts. Max Weber proposed the Theory of Bureaucracy around 1940 based on formal and structured network where it is necessary to have a clear role of each relationship inside of the system, through of the systematization represented by rules and standardization of the behavior. This procedure aimed to eliminate the variability of the results (Bateman and Snell, 1998). The negative points observed in this theory are: organizational structure slowly and response time to modifications delayed mainly against the periods that it necessary major changes. The main contributions are: the determination allocations in the organizational structure and formal documentation. Some years later Mayo and Maslow were the representative of the Theory of Human Relationship where are considered of psychological and social process influenced in the productive performance. In this period appear the term "Human Resources" where the human role in the productive system is emphasized. Maslow defined hierarchy of necessities of human necessities where necessities as creativity, problem solving and acceptance of facts (self-actualization level) only manifested if the inferior necessities are satisfied as food, water (physiological level) Silva (1998).

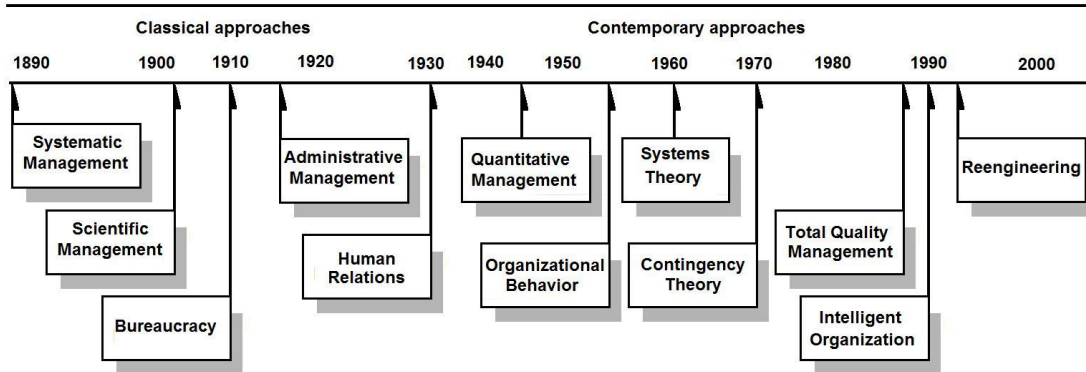


Figure 2: Evolution of management thinking (Bateman and Snell, 1998)

In this way, Bateman and Snell (1998) classify the evolution of administrative along of time:

- Scientific Management (Taylor and Fayol): the single best way to produce, focus on operational;
- Theory of Bureaucracy (Max Weber): standardization eliminating variability;
- Theory of Human Relations:
 - Mayo: psychological and social aspects x production
 - Maslow: Levels of human needs;
- Quantitative Management: use of measurable parameters to quantitative analysis - based on accumulated experience;
- Organizational Behavior: Motivation to meet the needs, self-development and pro-activity;
- Systems Theory: How the company interacts with the environment;
- Contingency Theory: to have alternative solutions, plan B;
- Total Quality Management: increased competition; produce more and better;
- Toyota Production System represents the Japanese model of management: minimization of inventories; planning production (demand response); what creates value is not eliminated from the process.
- Intelligent organizations: flexibility, alternative solutions, collaboration.
- Reengineering: the elimination process, to reevaluate the work.

Nowadays, the management and the management production have presented an approach systemic. There is a transition between “Machine/Industrial Age” to “Knowledge Age” which demands of the “products” requires innovations associated to design and productivity activities. The high quantity of Chinese products present in the international market with low costs creates a problematic view on the tendencies of the production organization and the quality aspects in the next years. The Figure 3 presents the evolutionary history of production systems where it is possible to associate the school administration and its key concepts.

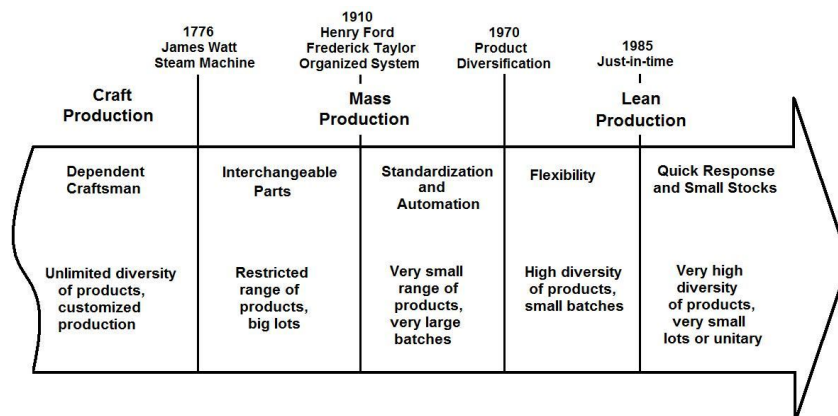


Figure 3: Evolutionary history of production (Doro, 2009)

In the Figure 4 it is possible to observe the concomitant between the management schools, the evolution of quality concept, project management and design methodology. This correlation allows highlight the importance these concepts applied together to an organization.

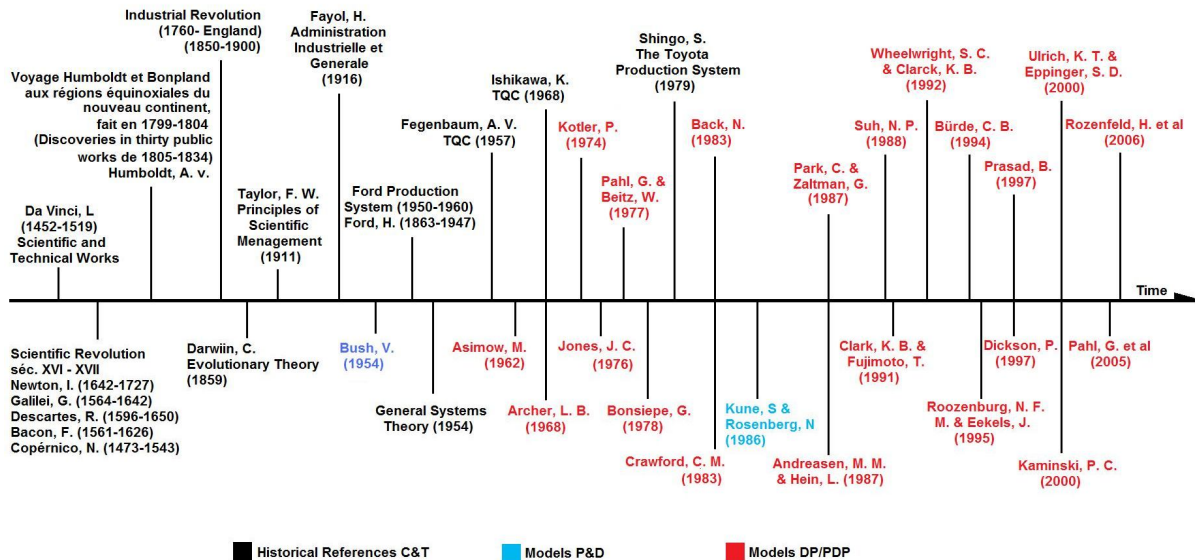


Figure 4: Model diachronic methods of product development contextualized by historical marks of science and technology (Suarez *et al*, 2009)

2.2. Product Development and Management Project

According to Laidens (2007) the product development is a multidisciplinary process, composed not only by functional areas as engineering, marketing, production and development and research, but too human resources, logistics, financial and quality control as well as the external activities of the design and manufacturing areas as market and suppliers. Laidens (2007) suggests that product development is seen as a process, and as such needs to manage and control their steps. The focus should be given to the ongoing management of the business process, incorporated into product strategy, market and technology. The products can be ranked according to the value that adds to the client. Kotler and Keller (2006) are five levels of product: central benefit, basic product, expected product, expanded product and product potential. The life cycle begins with the product launch and lasts the entire time it is in use until the time of disposal. The product life cycle is part of the process of product development in its implementation phase and introduction in the the market. Development product process is a task that involves research, planning and control consistently. Leite *et al* (2007) divide the activities of product development into two fronts: the product planning and product engineering, as showed by Figure 5.

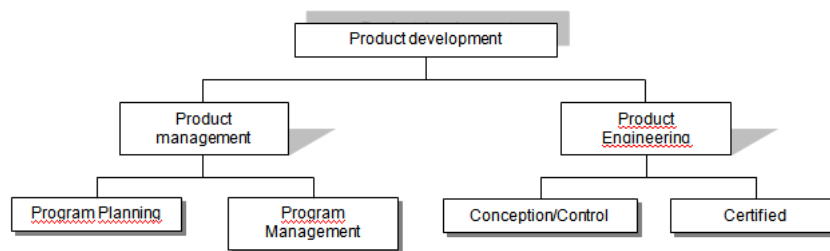


Figure 5: Generic organization of the activity of product development (Leite *et al*, 2007).

The Product Planning is constituted by Program Planning and Program Management. The Planning Program is includes the integration of the activities involved in product development. At this stage, there is the centralization of information and communication with all project activities and teamwork involved in product development, in order to obtain a transparent and coordinated. Management Programs is an activity that promotes programs and orchestration of its control. The Product Engineering includes the Design / Verification and Certification. According to Leite *et al* (2007) in the Design are defined the list of technical requirements, conceptual design as well as numerical and analytics results together the systems, sub-systems and parts. During the verification phase are made optimization processes

being concluded with the certification phase. The order of product development process occurs allow that design methodologies can be applied to support the technical decision, many times lead by market. According to Delgado Neto (2009), product development involves the following design phases: Feasibility Study, Preliminary Design and Detailed Design, as shown in Figure 5. Attention is necessary that each phase occurs independently of the other so that the end of the activities of a phase she will not be resumed. The objective of the application of lean thinking in the area of product development is the improvement the aggregate value with less time and cost. This condition is more criticizes due to increase of competitively in terms of innovations and costs as well the reducing of product life cycle. The use and application of lean principles during the product development process makes the information flux more uniform without losses of important data of the product mainly when there are a high level of the computational resources. According to Machado and Toledo (2008), the lean thinking applied to product development process can be provide management and coordination of the complex process with high intrinsic value, resulting in better control and use of available resources.

2.3 Management Design

A project can be defined as set of activities whose have an initial point and a final state defined with set purpose using a finite set of the resources. According to (PMI, 2004), the project is a temporary effort used to create a “product”, service or a specific result. Projects can be classified in four phases: conceptual, planning, execution and finalization. According to PMI (2004) the project management is a integrated process. The interactions between the process demand compensation with requirements costumer and design objectives. Processes are set of activities co-ordinate whose goal is to produce a “product” or a service to specific costumer. In order that there will be a homogeneous flux, the processes must be synergy. According to Houaiss Dictionary the term “synergy” is a “group actions (...) to obtain a better performance against actions isolated. The analysis of lean thinking in the process of product development wants to demonstrate that it can lead to achieve better productivity and efficiency in organizations. The efficient of process management, such as lean thinking, requires involvement of all levels. Conjugating the diverse talents, adding to the skills, styles, cultures and different backgrounds it generates a competitive edge that has the goal of success and achievement of the goal established by the collaborative work. The Figure 6 shows a maturity model processes, divided into five levels, with attention to the level of the optimized process, which is part of the analysis of lean thinking. The engineering design is a systematic process where the design engineers generate, evaluate and specify components and structures to assembly of the machines, equipments and process inserting the requirements costumer fitted to technical constraints. Considering the management design, Kerzner (2006) defined project as to planning, programming and control of a set of tasks integrated to reach the initial goal, considering the success of the teamwork.

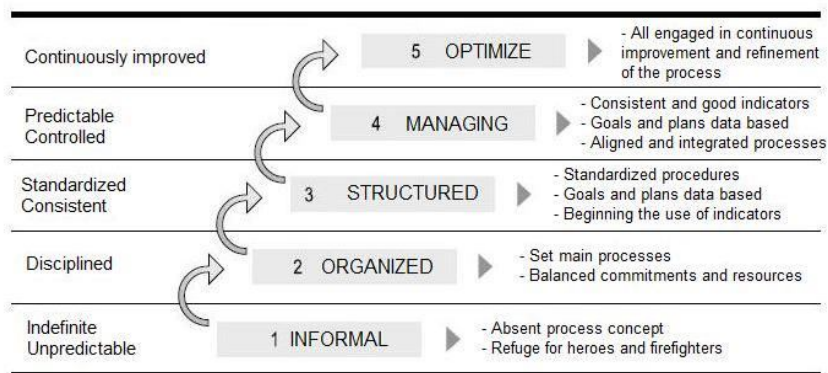


Figure 6: Maturity process model (Siqueira, 2005)

2.4 The “Toyota system” and the lean thinking in the product project management

The two goals of the Toyota Production System are: to reduce costs by eliminating of all kind of the waste and build of a system at work so that production can immediately respond to periodic changes of the market, according to the Sustainability Report 2009, Toyota of Brazil (2009). Womack and Jones (2004) define the lean thinking as, "(...) it is Lean because it is a way of doing more with less - less human effort, less equipment, less time and space - and While approaching more to offer customers what they want." Lean thinking is an organizational philosophy, the area of process management, whose main target is to fight and prevent waste and this causes no increase competitiveness. Morgan and Liker (2008) report that the lean product development is founded on three systems: skilled personnel, tools

and technology and processes, and these three systems are deployed in the 13 principles of the Lean Product Development. In the process, one can cite the definition of value, exploitation of alternative solutions, continuous flow of information relating to product development and standardization. The obtained of the qualified personnel or teamwork involves the follow characteristics: to determine the chief engineer, organizing skills and functional integration, develop skills, integrate suppliers into the system, learning and continuous improvement and continuous improvement culture. The last point of the tripod is tools and technology that involve the following principles: adapting technology to people and processes, aligning the organization through effective communication and use of tools for standardization and organizational learning. Lean thinking has five principles, which are accurately specifying value; identify value chain, the flow - to make the remaining steps that create value, flow, pull production and perfection. Also according to Womack and Jones (2004), "lean thinking is a way to specify value, line up on the best sequence of the actions that create value, perform these activities without interruption whenever someone requests and to perform them optimally increasingly effective." Waste indicates system problems and they add time and cost to the manufacturing process. You can find wasteful overproduction, producing too much or too early, can be the intellectual, when an activity that adds values not just consuming time, or the talent of a person. Also found in waste transport systems, inventory above the minimum, wait, are for parts or finish of a stage to continue the production, repairs, recalls, among others. It must be remembered that in the analysis of each of the five steps listed above need to try to eliminate as many as possible of waste, whether in manufacturing, logistics, in short, in all stages by passing the product from the definition to the finished product, ready to be delivered to the customer. The definition of value is defined by the customer up to the team. It is necessary that this definition is very well specified so that we can get to customer satisfaction. This applies so that what appears to be of interest to a group of customers may not appeal to another. From then identify the value chain of the product. Womack and Jones (2004) affirm that the value chain is the set of all specific actions required to bring a specific product to pass through three critical management tasks in any business: problem solving, information management and physical transformation.

2.5 Proposed methodology: lean thinking and the process of product development

The purpose of this work is to involve project management, design methodology and lean thinking concepts so that obtain an information flux lean with aggregate value sequence. Many authors have been worked on this proposal by individual methods or tools approached by project management and product design. These tools or techniques that can be applied in one of the stages or phases of the design were very confused with the product design in all, most of the proposals of several authors are presented with tools steps mixed partially applied, neglecting the presentation of sequence logic, or even a graphic form that facilitates the understanding by the reader. Following are the steps for integration to occur between the three areas, resulting in the proposed methodology:

1 – To know the sequence of project management: PMBOK Guide as a reference - to identify the presentation of the stages of management control and documentation, but cannot find the stages of AS will be held the stage of product development.

2 – To use methodologies to product design that presents the steps explaining how to perform product development: identify where to apply the steps in documentation management. How, for example, the application of the PMBOK Scope statements applied to the early phase of the Feasibility Study methodology chosen (Delgado Neto, 2009).

3 – To apply the principles of lean thinking.

4 – To rearrange the stages of product design methodology according to lean principles: a clearer view of the stages of product design methodology along the lines of lean thinking.

5 – Focuses on the tools being used at each stage lean and apply them.

From this sequence is expected to be shown the feasible options for the design within the proposal for a technology known by the company or who exists and present applicability.

2.6 Case Study

Based on product development, project management and concepts on lean thinking is proposed the value flux considering the design methodology.

Lean thinking can be seen as a different use for the product design. The focus is given on how to contribute to what to do. It also provides a closer approximation of the customer, which ultimately generates a better quality product. In lean thinking the performance of teams from different areas has occurred since the beginning of the project, bringing a decrease of time, from its inception until the release of the final product, since they act simultaneously along the cycles of the project. It should be noted that the use of lean thinking done in conjunction with the methodology of product design and assisted by project management can result in products developed with a focus on customer needs, saving time and waste of resources, both financial as human and material. The beginning of the study aims for a methodology that encompasses the three areas (project management, product design and lean) proves to be possible to improve the

process of product design, demonstrating the steps that really add value to the final product, thus being able way, have benefits in their implementation, in line with the strategic objectives of each organization. Each of the areas addressed by the proposed methodology by itself does not achieve the objective of defining and adding value to a product. The use of techniques for each area provides an option for the optimization and evaluation of the correct definition of customer value as well as the actual increase in value to the product needed to be developed. The objective of this work is propose a model based on project management, lean thinking and design methodology to describe the activities of the information flux inside of the CTI. The analysis of this information flow, as shown in Figure 8 shows the possible improvement of product design, demonstrating the steps that really add value to the end and can thus bring benefits to its implementation, According to the organization's strategic objectives. An important point to note is that before, without mapping the flow of information, people were not involved in this flow and the perception that their area contributes to it. The Figure 8 presents the implemented methodology to manage the flux of information technical of the Division of the Rapid Prototyping- DRP of CTI- Campinas.

Figure 7 presents the starting point of the current flow of activities that will be applied lean. This makes it possible to visualize in a general way the whole process flow and identify various points where the lean methodology can be applied.

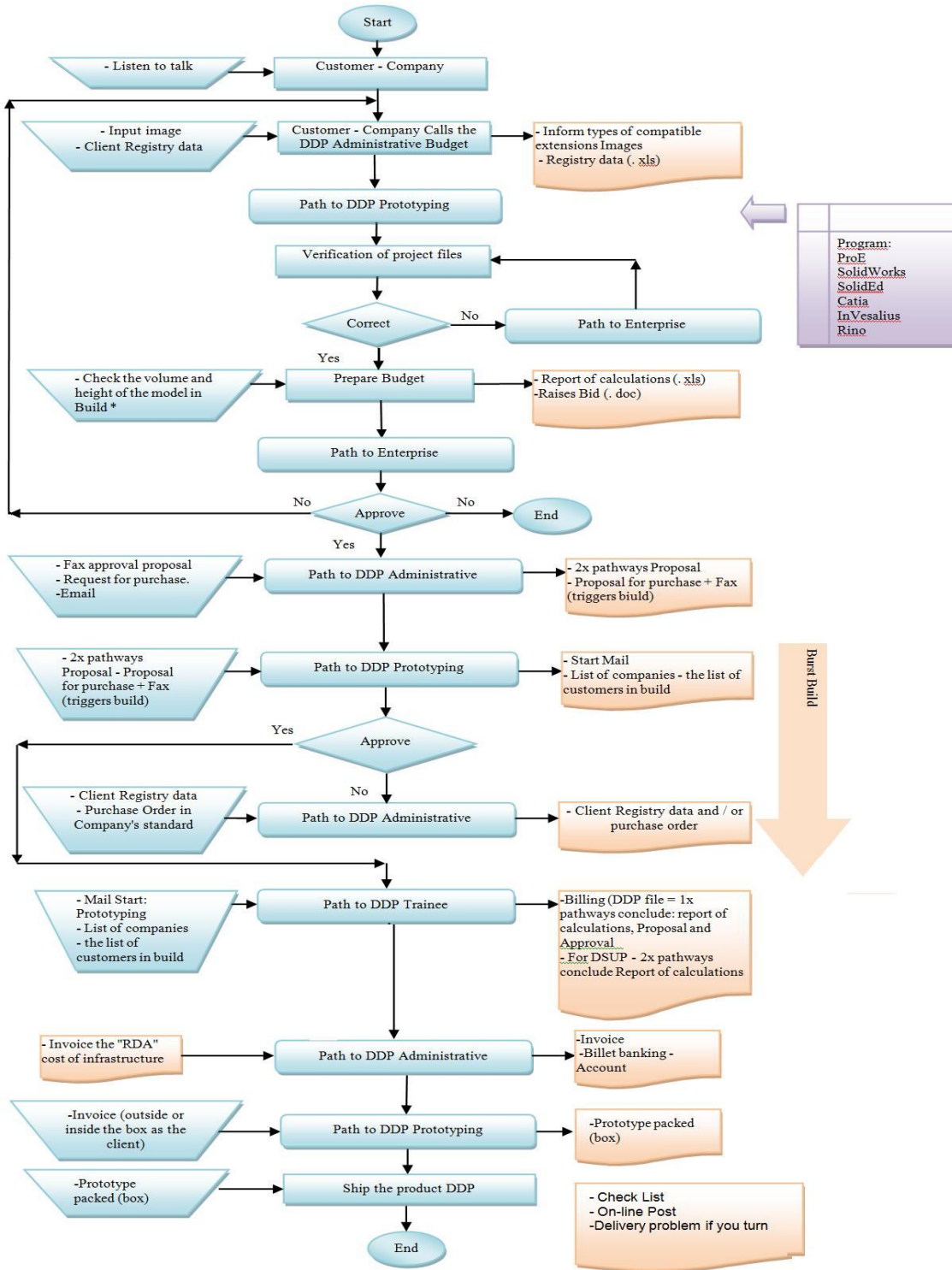


Figure 7 – Proposed work flux to the development of the products obtained from additive manufacturing - CTI (adapted from Delgado Neto, 2005)

2.7 Conclusions

This work presented a theoretical study about production and design concepts where the objective was to obtain a value flux clear related to flux of the organization. For this study were compared administration of production models and concepts of lean thinking and evaluate the common points considering the design engineering through of the design methodology area. The value concept permeates the main theories related to design and production activities in an organization being this an industry or service. The complexities of the product and process with the insertion of new and fast technologies change all types of flux of communication that have different types of informations, where there is only a specification of a dimension of component set in activities in a business organization. This condition drives strongly new products, process and services and reinforcing the teamwork. The production administration, project management and lean thinking concepts are interconnected due to value sequence fundamental to design engineering. Considering the lean thinking concepts from Toyota system applied in association to design methodology methods as: QFD (Quality Function Deployment, Value Analysis, Morphological analysis is possible to obtain a significantly reduction of development product time and simultaneously to improve the design quality. A case study was development to exemplify the value sequence to the product development.

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4. REFERENCES

- Bateman, T. S., Snell, S. A. 1998. "Administração: construindo vantagem competitiva". Ed. Atlas, São Paulo.
- Delgado Neto, G. G. 2005. "Uma Contribuição à Metodologia de Projeto para o Desenvolvimento de Jogos e Brinquedos Infantis". 2005. 166 f. Dissertação (Mestrado) - Curso de Engenharia Mecânica, Departamento de Projeto Mecânico, Universidade Estadual de Campinas, Campinas.
- Delgado Neto, G. G. 2009. "Desenvolvimento e aplicação de um programa computacional, para abordagem sistemática de desenvolvimento de produtos e serviços". 165 f. Tese (Doutorado) - Curso de Engenharia Mecânica, Departamento de Projeto Mecânico, Universidade Estadual de Campinas, Campinas.
- Delgado Neto, G. G., Dedini, F. G. A. (2010) *Aplicação de um Programa Computacional, para Abordagem Sistemática de Desenvolvimento de Produtos no Ensino de Engenharia*. In: Anais do Second Ibero-American Symposium on Project Approaches in Engineering Education – PAEE2010, Barcelona, Espanha. Guimarães: Research Centre in Education (CiEd) University of Minho and Department of Production and Systems School of Engineering of University of Minho.
- Doro, M. M. 2009. "Solução integrada para auxiliar na garantia da qualidade na produção em pequenos lotes." 127f. Tese (Doutorado) – Curso de Engenharia Mecânica, Universidade Federal de Santa Catarina, Florianópolis.
- Hammer, M., Champy, J. 1994. "Reengenharia: revolucionando a empresa em função dos clientes, da concorrência e das grandes mudanças da gerência." Ed. Campus, Rio de Janeiro.
- Kerzner, H. (2006) "Gestão de Projetos: as melhores práticas." Ed. Bookman, Porto Alegre.
- Leite, Heymann A. R. (org.). (2007) "Gestão de Projeto do Produto: a excelência da indústria automotiva." Ed. Atlas. São Paulo.
- Laidens, G. , 2007. "Modelo conceitual de integração de ferramentas no processo de desenvolvimento de produtos alimentícios utilizando os princípios da gestão do conhecimento". 2007. 132f. Dissertação (Mestrado) – Curso de Engenharia de Produção, Universidade Federal do Rio Grande do Sul, Porto Alegre.
- Liker, J. K. 2005. "O Modelo Toyota." Ed. Bookman, Porto Alegre.
- Kotler, P., Keller, K. L. (2006) "Administração de Marketing." 12^o ed. São Paulo: Pearson Prentice Hall.
- Machado, Marcio C., TOLEDO. (2008). *Nilton N. Gestão do Processo de Desenvolvimento de Produtos: uma abordagem baseada na criação de valor*. São Paulo: Atlas.
- Morgan, James M., Liker, Jeffrey K. , 2008. *Sistema Toyota de Desenvolvimento de Produto: integrando pessoas, processo e tecnologia*. Porto Alegre: Bookman.
- PMI. 2004. *Um Guia do Conjunto de Conhecimentos em Gerenciamento de Projetos (Guia PMBok®)* 3.ed. Newton Square, Pennsylvania, EUA: PMI.
- Silva, M. T. 1998. *Correntes do pensamento administrativo*. In: *CONTADOR, J. C. (Org.). Gestão de operações*. 2 ed. São Paulo: Blucher,
- Siqueira, X. (2005) "O Modelo de Maturidade de Processos", Nucleando Qualidade, número 45, Ano XI.
- Suarez, T.; Jung, C. F.; Caten, C. S. (2009). "Adaptação e aplicação de um método de desenvolvimento de produtos em uma microempresa de manufatura de produtos decorativos." *Revista P&D em Engenharia de Produção*. Vol. 7, N. 01, pp. 37-63.

Toyota do Brasil. 2009. Relatório de Sustentabilidade 2009. São Paulo.

Womack, James P., Jones, D. 2004. "A mentalidade enxuta nas empresas: elimine o desperdício e crie riqueza." Ed. Campus, Rio de Janeiro.

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