TECHNOLOGY MANAGEMENT IN PRODUCT DESIGN PROCESS FOR MICRO AND SMALL-SIZED METAL MECHANIC COMPANIES

Ivo Rodrigues Montanha Junior
UFSC – Universidade Federal de Santa Catarina. NeDIP – Núcleo de Desenvolvimento Integrado de Produtos. Departamento de Engenharia Mecânica. Caixa Postal: 476. C.E.P.: 88040-900. Florianópolis-SC. Brasil. Phone: +55 (48) 331-9719.
ivojr@nedip.ufsc.br

André Ogliari
UFSC – Universidade Federal de Santa Catarina. NeDIP – Núcleo de Desenvolvimento Integrado de Produtos. Departamento de Engenharia Mecânica. Caixa Postal: 476. C.E.P.: 88040-900. Florianópolis-SC. Brasil. Phone: +55 (48) 331-9719.
ogliari@emc.ufsc.br

Nelson Back
UFSC – Universidade Federal de Santa Catarina. NeDIP – Núcleo de Desenvolvimento Integrado de Produtos. Departamento de Engenharia Mecânica. Caixa Postal: 476. C.E.P.: 88040-900. Florianópolis-SC. Brasil. Phone: +55 (48) 331-9719.
back@emc.ufsc.br

Abstract. *Although the technological innovation into products and processes can be considered as an important success factor of the companies on competitive markets, few efforts have been done by the companies and by the research centers (methodologies, methods and tools) to support the Technology Management (TM) in Product Design (PD) process. In this context, it was developed a research studying TM approaches (models and methodologies) dedicated to the PD process for micro and small-sized Brazilian metal-mechanic companies (target-companies). It was also accomplished a field research in twelve target-companies, in two reference-companies that use TM concepts and tools on PD process, and three technology support organizations (universities and research centers) that give technological support to the target-companies also were investigated. Based on these studies, it was proposed a TM methodology applied to the PD process. Its phases are: informational design, conceptual design, embodiment design and detailed design. The methodology had been evaluated considerating nine aspects. These results show that the TM methodology has a generic (robust) structure, that can be applied in many metal-mechanic companies, in a simple and practical form, reaching the smaller companies needs.*

Keywords*: technology management, product design, micro and small-sized companies.*

1. Introduction

In spite of the importance of the technological development for the organizations, a research made by IBGE (2002), between the years 1998 to 2000, it showed us that only 31,5% of the Brazilian industries implemented technological innovations in their products and/or in their manufacturing processes. In a regional research, Marquezi (2000) concluded that most of the small-sized eletro-metal-mechanic companies from the west region of Santa Catarina state invested a little in R&D of new products. Brasil (1997) investigated thirty companies of different sizes and economical sectors in the states of Santa Catarina and Rio Grande do Sul, and he also verified that those companies did not invest with an enough frequency in innovations, where only 27% of them had formal design procedures.

These results want to show that, although the technological innovation into products and processes can be considered as an important success factor of the companies on competitive markets, little effort have been done by the companies and by the research centers (methodologies, methods and tools) to support the Technology Management (TM) in Product Design (PD) process.

In order to study these questions, and to develop the methodology of TM in PD process, it was accomplished a bibliographic review about PD process and TM. It was also made an investigation with twelve micro and small-sized metal-mechanic companies from the mid-west region of the Santa Catarina state (target-companies), and with three organizations that give technological support to these companies (universities and research centers specialized in the technologies of these companies). Two reference-companies of TM on the PD process were also investigated. With this, it was established a group of guidelines for the conception of the referred methodology.

In this article, the main results of a case study realized will be presented, with focus on the TM issues. It also will be presented the structure of the proposed methodology, where are indicated some phases, activities and tools about TM for the PD process. At the article's end, it is presented a critical analysis of this methodology, considering the referred guidelines, the bibliographic review and the case studies in the target companies. It is also shown the evaluation method of the methodology.

2. Bibliografical review

According to OECD (1998, p.9) “A technological product innovation is the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these.”

Cotec (1998) affirms that the technology management, considered here as one of the many processes associated to the project management, consist, in a general way, as the efficient management of the technological change, involving the management of the human resources, materials and financial ones.

Such processes of change, which seek to optimize the organization processes, can happen in the strategic planning level, considering the technological vigilance, by the permanent identification of threats and opportunities related to the technologies of the company's products. Then, the external information are captured, analyzed and transformed in knowledge, to support the strategic decision making process (Palop and Vicente, 1999 *apud* Carvalho, 2002).

In a similar way, TM can be done by the technological roadmapping, which is defined by Carvalho (2002) as a systematic process of search of deficient technologies in the market. This seeks to help the organization in the best understanding of the market, and in the decision making process about technological investments during Product Development Process (PDP).

Besides these approaches, Coates *et al.* (2001) affirms that the technological forecast can be used to estimate the tendencies and proportions of the technological changes about products and processes, to a defined future horizon. Thus, it helps the company in its strategic decision making process, seeking to program the products launching in the market, with technological innovations.

It is also important to consider the technological transfer, which can occur internally in the company and externally, and by these ways: by the internal training of the professionals together with the technological support organization, or by the acquisition of external technologies, in order to optimize the information use in a TM process.

There are approaches that treat TM in the form of models and methodologies. For example, it can be referred to the Oslo Manual (OECD, 1998), which presents TM concepts, but do not show, in a detailed form, its activities. Other model is the Temaguide (Cotec, 1998), which treats TM concepts in an objective, operational and didactic form, detailing its phases and tools. Besides these, there is the model of Jonash and Sommerlatte (2001), which presents TM concepts and is concentrated on the activities related to the technological strategy of the company, and on the technological transfer issues. This model is less operational, because it presents few tools to its implementation.

The model of Moss Kanter, Kao and Wiersema (1998) is also not so operational, because it shows general concepts and macro-activities level, without mentioning the needed activities and tools to its implementation. They also present some aspects relative to the innovation, adopted by companies such as 3M, DuPont and General Electric (GE). Related to the concepts of 3M, it could be highlighted the participation of lead users during the generation of products concepts, where they help the company to reduce the technological uncertainties of the generated concepts, due to their experience, as was commented by Von Hippel, Thomke and Sonnack (2002).

The DuPont company focalizes its strategies about technological development on its own intellectual capability, giving autonomy to the employees and investing in internal resources, in order to develop its technological solutions internally. The company GE motivates the team working, according to the focus of the systemic reasoning, to create the technological solutions internally, giving strong emphasis on the knowledge sharing among the project partners.

Although different proposals exist for technology management usually, in form of models, methods and tools, there are few approaches dedicated to the phases of the product design process. It was found another gap on the studied approaches, because they present themselves in a conceptual level, having a low level of systematization of the companies’ needs, mainly to the micro and small-sized companies, where the resources are limited.

Attempting to overcome these deficiencies, case studies were accomplished, to identify and analyze the actual conditions of the target companies, whose results were showed on Montanha Jr. *et al.* (2003) and in Montanha Jr. (2004). In the present article, are detailed and discuss the results related to the management of the technology in the researched companies.

3. Case studies and guidelines for the proposition of the methodology

In order to identify the characteristics of the target companies about the TM and about the Product Design (PD), semi-structured interviews were accomplished, as suggests Yin (1994). Then, it was elaborated a questionnaire, with these issues: (i) general characteristics of the company (size, market, customers); (ii) product development (PD sector, PD activities, PD knowledge, difficulties found during the PD, and techniques used on PD); (iii) technology management (used technologies, sources of these technologies, technology vigilance and roadmapping, difficulties to the innovation, and knowledge about TM models).

Were investigated twelve target companies, two companies considered as reference in TM on PDP (to identify best practices about TM on PDP), and were also investigated three Technology Support Organizations (TSO), in form of universities and research centers, whose help the target companies with professional training and technological support services.

3.1. Main results of the case studies

The target companies were classified as Agricultural (four companies, they produces agricultural machinery), Refrigeration (two companies, producing parts and machines for other refrigerators industries), and Metal-Mechanic Diverse (six companies, producing mainly spare and repair parts and equipment for different companies). The reference-companies produce products with high quality, of domestic nature. The technological organizations support researches and technological training of professionals.

Relating to the companies` size, they were classified as Micro-Company (MC), Small-Company (SC), Medium-Company (MdC) and Big-Company (BC), according to the number of employees, as a suggested form of classification presented by SEBRAE (2005).

Only one of the target companies had its PDP's activities and knowledge formalized, where the main design activities were systematically realized by a checklist. The reference companies have their activities and PDP knowledge formalized by their own methods. The technology support organizations use design methodology, and the knowledge created during the PDP are formalized in the descriptive memorials of the projects.

The main technologies used by the researched companies to develop their products and the respective sources, are showed on the Table (1), in Montanha Jr. *et al.* (2003) and in Montanha Jr. (2004). In this table, it can be noticed that the target companies use few knowledge about PDP, as design methodologies or project management.

Table 1. Product technologies and their sources, used by the researched companies

Products technologies and their sources, used by the researched companies		Classification of the researched companies				
		Agri-cultural	Refrige-ration	Diverse	Refe-rence	TSO
Products technologies	Technical drawings and mechanical parts sizing, using CAD software	X	X	X	X	X
	Diverse properties of the materials	X	X	X	X	X
	Ergonomics and safety in the operation of products	X	X	X	X	X
	Industrial automation of the machines	O	O	O	X	X
	Movement of mechanical mechanisms	X	X	X	X	X
	Knowledge about mechanical structures	X	X	X	X	X
	Practices to facilitate the manufacture and the assembly (DFM and DFA)	O	X	O	X	X
	Agricultural cultivations and its periods	X				O
	Handling of refrigeration products, norms SIF* and GMP* (see the Legend)		X			O
	Norms of electrical energy consumption (Procel)		O		X	O
	Thermal sciences		X	X	X	X
	Acoustics and vibrations				X	O
	Teaching methodologies					X
Sources of these technologies	Internal development of technology, using laboratories and experiments	X	O	X	X	O
	External specialists' knowledge	X	O	O	O	O
	Commercial agents (sellers)	X	X	X	X	X
	Magazines, books and technical catalogs	X	X	X	X	X
	Participation in technical conferences	X	X	X	X	X
	Technical visits to similar companies	X	X	X	X	
	Technical visits to fairs and expositions	X	X	X	X	X
	Suppliers: raw materials and equipment	X	X	X	X	
	Interaction between companies and support organizations	X	O	X	X	X
	Study of products from competitors (acquisition)	X	X	O	X	
	Internet	X	X	X	X	X
	Students' apprenticeship in the companies					X

Legend:
X: Frequent utilization; O: Less frequent utilization; TSO: Technology Support Organizations;
SIF: Service of Federal Inspection, to evaluate the commercialization of refrigerating products;
GMP: Good Manufacturing Practices (norms for food manufacturers and handlers).

Adapted from Montanha Jr. (2004)

Besides the sources of used technologies (presented in the Table 1), the target companies usually accompany the technologies of their products by the contacts with the commercial dealers and with their suppliers, comparing their products characteristics with the competitors'. They do not use formal methods of technological forecasting. One of the companies analyzes the patents of similar products to keep up with the technologies of its products, using systems of technological vigilance, in a similar way of Competitive Intelligence systems, done by internal teams specialized in the practices of obtaining, treating and sharing information.

Some of the main technical innovations of the products, appointed by the companies of the Agricultural and Diverse segments were: the dimensional aspects, efficiency, mechanical resistance, and about material improvements. Aspects of aesthetic differentiation, as colors and product finishing, were also appointed. Some diverse companies mentioned innovations of functional nature. It were identified few innovations in products of Refrigeration companies, because many of the technologies of their products are dominated, then they act on the aesthetic differentiation as differential.

The reference companies accomplish innovations of technical nature, improving the efficiency and the mechanical resistance of their products, minimizing the electrical energy consumption, the product noise and mechanical vibration. They also seek to input more functions and value to their products.

The main difficulties cited by the target companies during their innovation process were: (i) fear of being copied by the competitors; (ii) customers request for defined products; (iii) high cost to build prototypes; (iv) find adequate information, in order to be transformed into innovative concepts. The reference companies mentioned: (i) products have significant technological complexity; (ii) lack of technical resources, needed to the PDP; (iii) reduced time to product design process; and (iv) high technical effort to validate the innovated concept.

The target companies affirmed that they have, during the PD process interactions between the PD section and other sections, by informal talkings or specific meetings. Professionals from the PD sector seek design information, and employees from other sectors also consult the PD sector to obtain design information. The interaction process between the target companies and TSO happens with low frequency, because most of these companies prefer to be self-sufficient. Then, the usual interaction form is given by professional training, with few research activities.

At the reference companies the design is accomplished by teams, where employees from all sectors of the company participate during the PDP, according to the needs. These companies interact frequently with technology support organizations, but they prefer to develop their technologies internally in their own laboratories, in order to preserve the industrial property. They also interact with these organizations to qualify their employees.

3.2. Guidelines for the technology management methodology definition

Based on the analysis of the companies, review research, and on the study of Montanha Jr. (2004), were suggested guidelines to the conception of a methodology of TM in PD. Such guidelines were divided as General (general characteristics of the company) and Specific. They are:

General: (i) to guide the entrepreneurs of the target companies to elaborate the technological strategies about their products and their market definition; (ii) to suggest the main sources of technologies appropriate to the needs of the target companies in their PDP, according with their sector (agricultural, refrigeration and diverse); (iii) to propose communication ways to motivate partnerships between the target companies and the technology support organizations, in order to improve the technological transfer.

Specific, to the methodology conception: (iv) to consider the participation of lead users during the generation of innovative concepts of the product (concept used by company 3M); (v) to adopt methods that help the designers to realize impact analysis of the products innovative technologies on the market, during the PD; (vi) to consider concepts and practical tools to register the technological knowledge generated during the PDP, in order to insure that this knowledge will be kept at the company and it can be explored in future projects; (vii) to use, during the PD, the main tools and auxiliary techniques, as market analysis, QFD, FMEA, Benchmarking, technical norms, and others; (viii) to take into account practical mechanisms of accompaniment of product technologies and manufacturing processes of the target companies in their markets; (ix) to use a simple language, explaining the concepts involved in the activities; (x) to be objective in the elaboration of the referred methodology, as well as in the form of use of tools and techniques of TM, in order to motivate its use by the target companies professionals, because usually most of users invest little time and other resources to obtain more information.

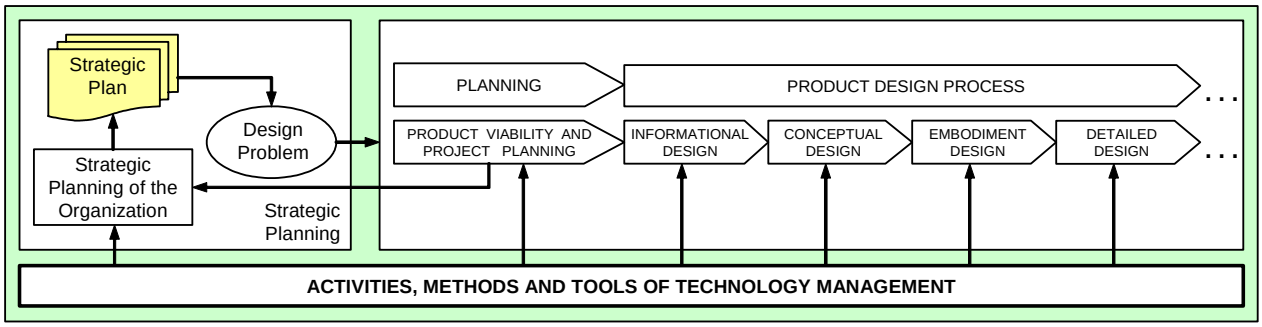
4. Technology management in product design methodology

The methodology proposed by the research of Montanha Jr. (2004), approaches Technology Management (TM) in the Product Design (PD), making possible the development of products in an integrated way. It also uses some concepts of Knowledge Management (KM), seeking to improve the maturity of the organizations for continuous innovation of their products. The proposition was based on a product development model, suggested by Romano (2003). This model was appropriate to the characteristics of the companies studied by Montanha Jr. (2004), integrating and simplifying activities, proposing simple and practical tools to help the TM process.

There were also considered the phases of the planning and design process of the product, but the other phases of the product development process (as manufacturing preparation, product launching and product validation) were not considered. Activities with principles and practices of TM were proposed at the phases of product planning and product design, seeking to help the designers in technological decisions during the propositions of product solutions.

In a general way, the concepts about KM proposed on this methodology seeks to: map the organizational competences, in order to select the members of the design teams, according to the abilities needed to each design activity; and register the experiences of the designers during their activities, permitting that those experiences can be used in similar activities, in future projects.

In this context, Fig. 1 shows a general view of the proposed TM methodology.



Adapted from Montanha Jr. (2004, p.71)

Figure 1. Conceptual view of the technology management in product design methodology

As can be seen on the Fig. 1, the proposed methodology consists of auxiliary activities to help the strategic planning, the projects planning and activities of product design (including informational design, conceptual design, embodiment design and detailed design).

The strategic planning seeks to help the organization during the elaboration of the strategic plan of the project, that is, to elaborate and revise the strategies and objectives of the organization about the product, but in a macro view, where most of the studied TM models act. In the design's planning phase, activities to elaborate the project plan are made, including all of the aspects related to the project scope, time and budget.

The product design phases proposed are from the problem formulation, design specifications definition, development of the product conception, configuration of the selected solution and to develop the technical documentation needed for the product manufacturing.

On the model developed by Romano (2003), each one of these phases is detailed in form of activities, tasks, mechanisms and controls, where they indicate what to do, how to do, and with what to do, in order to lead the Product Development Process (PDP). However, the structure of representing the methodology here proposed is composed only by three items. They are: (i) activity identification; (ii) mechanisms proposed for each activity; and (iii) knowledge domains suggested for each activity (based on the proposal of Romano, 2003).

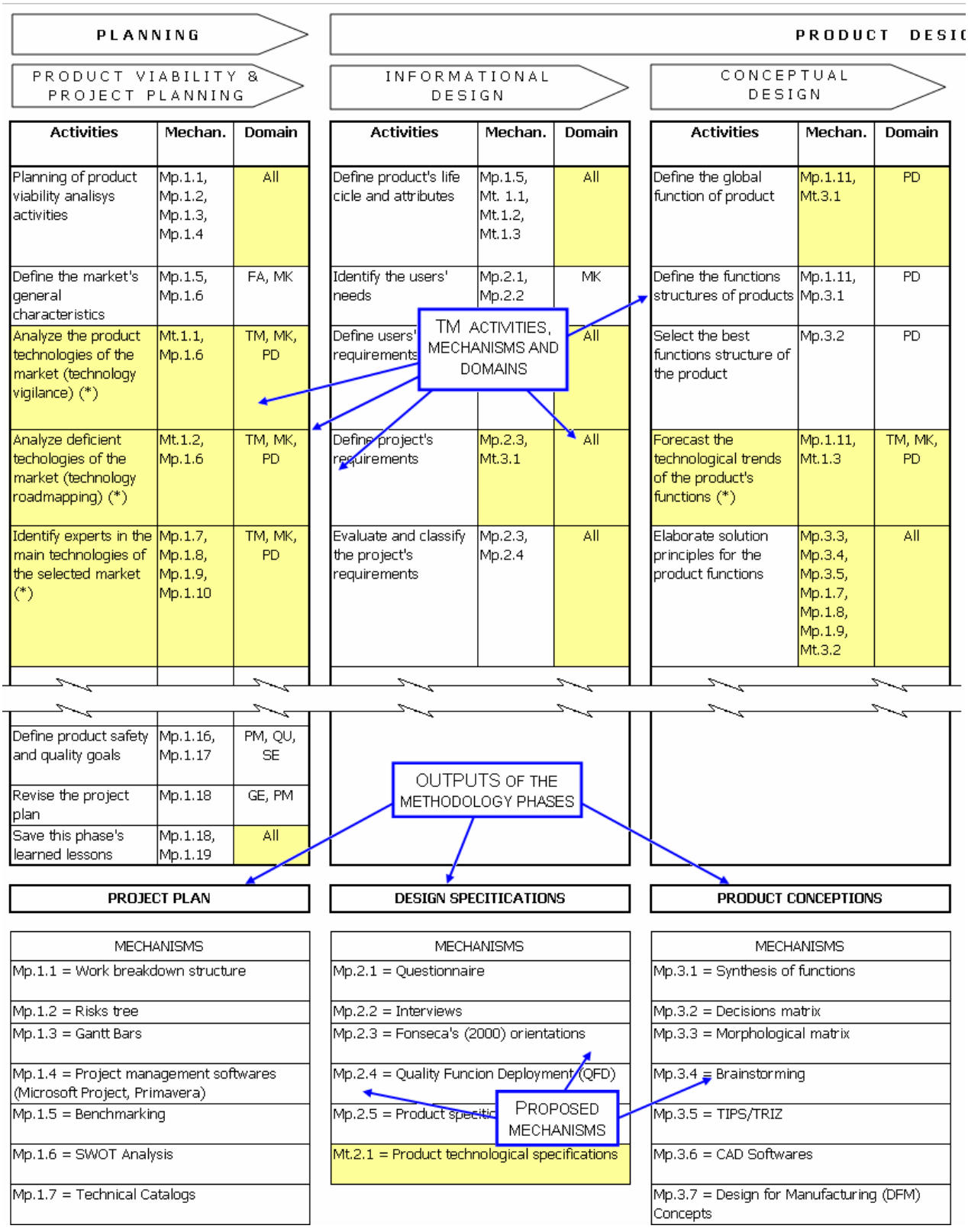
The activities with contributions from the technology management are highlighted in yellow, and they have a symbol (asterisk - *) after the activities' name. Such structure of representing is showed in Fig. 2. This figure also presents the activities and mechanisms (methods, tools, etc., where Dm means Design Mechanisms) of the design methodology (box with white background), and also the activities and mechanisms with TM principles (box with yellow background). It can be noticed that the TM contributions in this design methodology are in form of activities of TM, and/or in form of mechanisms with technological nature (Tn) in the PDP activities.

The design team can use the technologies obtained from forecasting to suggest principles of solution, and then satisfy the product needs and specifications. Besides that, the characteristics of each technology of them can be inserted in the morphological matrix, where are described their availability and domain level (maturity of technology), possible sources, risks, and other comments about each principle of solution using these technologies. For this reason, the selection process related to the adequate principles of solution is facilitated, during the proposition of design conceptions (by the integration of these principles). Such structure can be seen in Montanha Jr. (2004).

Considering the showed propositions, it can be noticed that the proposed Technology Management in Product Design methodology presents itself as practical, objective and simple, so the authors expect that this methodology can be easily implemented in the target-companies. This methodology also indicates methods to guide the professionals of product design, to do the activities related to the technology planning, mainly those innovative ones.

In order to evaluate the referred methodology in the target companies, were adopted the following procedures: (i) three target companies were selected, where the methodology were presented to each company and, at the end, the participants filled an evaluation questionnaire; and (ii) the methodology was evaluated by some experts in TM and PDP, where they also filled the same questionnaire.

Based on these results, the proposed methodology was improved, in order to have an adequate use in the target companies, reaching its main objective.



Adapted from Montanha Jr. (2004)

Figure 2. Partial view of the technology management in product design methodology

5. Final considerations

The proposed methodology reached the objectives and guidelines established by the research of Montanha Jr. (2004), because it presents itself in a simple and practical form, for its application in the target companies. Many of its mechanisms are known from PD models, and it also presents other ones, elaborated to support the TM process.

In a general way, it is hoped that this methodology aids the target companies professionals to manage their technologies in the product design process, in order to support the technological change in their products and manufacturing processes. It is also hoped that this methodology aids in the systematization of the PD activities in those companies, and in the use of concepts of integrated product development.

However, in order to facilitate the implementation of the proposed TM methodology, the target companies should consider the following organizational aspects:

- attribute to PD the same or larger importance given to the other processes, since systematized design practices almost do not exist in the target companies;
- motivate the formalization of PDP activities, in order to optimize the use of resources allocated to the design;
- use in an adequate form the TM concepts of the proposed methodology, during the projects execution;
- adopt organizational structures that facilitate the integrated product development;
- have more interaction with their suppliers and dealers, in form of partnerships into PD;
- strong emphasis on training of professionals in areas such as project management and systematized process of PD, since the proposed methodology is orientated to the managers and professionals of design teams.

Due to the referred methodology is oriented to the managers and to the design team, it presents relationships with the project management processes. Then, the organizations that will use it should give emphasis on the professional capabilities on systematized processes of PDP and project management.

6. References

Brasil, A.D.,1997, “Conhecimento e Uso de Metodologias de Desenvolvimento de Produtos: Uma Pesquisa Envolvendo 30 Empresas Situadas nos Estados de Santa Catarina e Rio Grande do Sul”, Dissertation (Master of Production Engineering), Graduation Program in Production Engineering of UFSC, Florianópolis, Brazil.

Coates, V. *et al.*,2001, “On the Future of Technological Forecasting”, Journal of Technological Forecasting and Social Change, New York, Elsevier Science Inc., Ed. 67, P.1-17, http://www.sciencedirect.com/science/journal/00401625.

Cotec,1998, “Temaguide: a Guide to Technology Management and Innovation for Companies”, Barcelona, Cotec, http://www.cotec.es.

Carvalho, M.A.,2002, “Previsão Tecnológica”, Internal Publication of the Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

Instituto Brasileiro de Geografia e Estatística – IBGE,2002, “Pintec: Pesquisa Industrial Inovação Tecnológica 2000”, Rio de Janeiro, Brazil.

Jonash, R.S. and Sommerlatte, T.,2001, “O Valor da Inovação: Como as Empresas Mais progredir Atingem Alto Desempenho e Lucratividade”, Rio de Janeiro, Brazil, Editora Campus.

Marquezi, S.L,2000, “Uma Estratégia Para Apoiar Tecnicamente Empresas da Região Oeste de Santa Catarina no Desenvolvimento de Produtos”, Dissertation (Master of Production Engineering), Graduation Program in Production Engineering of UFSC, Florianópolis, Brazil.

Montanha Jr., I.R. and Ogliari, A. and Back, N. and Patussi, V.C.,2003, “Diretrizes Para a Concepção de Um Modelo de Gerenciamento de Tecnologia no Processo de Desenvolvimento de Produtos”, Gramado-RS, Brazil, IV Congresso Brasileiro de Gestão do Desenvolvimento de Produtos.

Montanha Jr., I.R.,2004, “Sistemática de Gestão da Tecnologia Aplicada no Projeto de Produtos: um Estudo Para as Empresas Metal-Mecânicas de Micro e Pequeno Porte”, Dissertation (Master of Mechanical Engineering), Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

Moss Kanter, R. and Kao, J. and Wiersema, F.,1998, “Inovação: Pensamento Inovador na 3M, DuPont, GE, Pfizer e Rubbermaid”, S.Paulo, Brazil, Negócio Editora.

Organisation for Economic Co-operation and Development – OECD,1998, “Oslo Manual: The Measurement of Scientific and Technological Activities – Proposed Guidelines for Collecting and Interpreting Technological Innovation Data”, 2nd.ed., European Comission – Eurostat: OECD, http://www.oecd.org.

Romano, L.N.,2003, “Modelo de Referência Para o Processo de Desenvolvimento de Máquinas Agrícolas”, Thesis (Doctorate of Mechanical Engineering), Graduation Program in Mechanical Engineering of UFSC, Florianópolis, Brazil.

Serviço Brasileiro de Apoio às Micro e Pequenas Empresas – SEBRAE,2005, “A Micro e Pequena Empresa no Brasil”, http://www.sebrae.com.br.

Von Hippel, E. and Thomke, S. and Sonnack, M.,2002, Criando Inovações Tecnológicas na 3M, in: “Inovação na Prática: Identificando Novos Mercados”, pp37-58, Harvard Business Review, Rio de Janeiro, Brazil, Ed. Campus.

Yin, R.K.,1997, “Case Study Research: Design and Methods”, 2nd. ed., SAGE, London, U.K.

7. Responsibility notice

The authors are the only responsible for the printed material included in this paper.