Critical success factors in the management of product development process in medium and small technology-based companies within the process control automation sector

Daniel Jugend
Federal University of São Carlos
jugend@dep.ufscar.br

José Carlos de Toledo
Federal University of São Carlos
toledo@dep.ufscar.br

Sérgio Luis da Silva
Federal University of São Carlos
sergiol@power.ufscar.br

Glauco Henrique Souza Mendes
Federal University of São Carlos
ghsm@uol.com.br

Abstract: Excellence in the management of product development process (PDP) is a source of business competitive advantages, mainly for those technology-based companies, which benefit from the important competitiveness factor of launching products with a diverse technological content. The capacity of managing this process affects factors such as a new product time to launch, cost and quality of the product developed. The objective of this paper is to describe and analyze the main practices and success factors related to PDP management in medium and small technology-based companies within the Process Control Automation sector. Therefore, the following subjects were analyzed: perceived product performance, product innovation degree, skills to develop products observed by both the company and the project leader and the quality of how the PDP was carried out. A survey was used gathering data from a sample of 32 companies in the State of São Paulo. Results emphasize that the management of new product projects by the surveyed TBCs should consider actions that enhance the pre-development activities: new product projects, integration with the company strategy, technical and economic characteristics those products have and the development of the project manager managerial skills and relationship. Companies should also resort to their small size as a facilitating factor to integrate functional areas.
Keywords: product development process, success factors, small and medium size technology-based companies, process control automation sector

1. Introduction

The smaller size technology-based companies benefit from the important competitiveness factor of launching products with a differentiated technological content. The capacity to maintain a flow of products, both innovative and competitive, depends on the research and development capacity of those companies as well as their capacity to manage new product development process. The capacity to manage that process influences factors such as new product time to lunch, cost and quality of the product developed.

In the developing countries small and medium technology-based companies essentially operate within market niches, not occupied by the bigger companies, and normally to substitute imports. Nevertheless, their economic potential should not be neglected. Although technology-based companies (TBCs) may mostly be small sized, they frequently develop innovative products, and thus are likely to boost the economic growth in their operations regions (YAP & SOUDER, 1994; SOUDER et al. 1997; KEIZER et al., 2002), influencing with their technological innovation culture both their partners, customers, suppliers and competitors.

Most field researches involving small and medium size TBCs in Brazil, according to CARVALHO et al. (2000), focus primarily the development of technological poles and business incubators. Thus, according to those authors, a lack exists of empirical studies which reveal management factors critical for the success of those organizations. Furthermore, Product Development is a process critical for those companies and barely known from the academic point of view.

The study of management of product development process (PDP) in small and medium size TBCs is yet in a beginning phase in Brazil. As attested by MACULAN (2003), those companies face significant managerial difficulties, influencing the success rate of the products they develop.

Even in developed countries, a lack exists of empirical studies which reveal the critical success factors in the management of product development process in minor sized TBCs, report MARCH-CHORDÀ et al. (2002) and SOUDER et al., (1997).

According to LEONE (1999), best practices for small and medium companies can only be recommended upon consideration given to their peculiarities. Therefore, it is relevant to identify the management practice type, taking into account companies of a specific industrial sector, their size and peculiarities of their organizational structure.

Taking into consideration the context pointed at, the objective of this paper is to describe and analyze the main practices and success factors relative to PDP management in small and medium size TBCs operating in the Process Control Automation (PCA) sector. Therefore, following issues were analyzed: perceived performance of the product, product innovation degree, skills of both company and project leader for product development as well as quality of the PDP activities execution.

Survey was the research method adopted, collecting data by applying a questionnaire in 32 small and medium size TBCs, in the PCA sector, located in the State of São Paulo. The reason to carry out this research in that region was its significant TBCs concentration and according to FERNANDES et al. (2000), that sector is one of the most representative within the smaller-sized TBCs in this state.

Companies in the PCA sector can be deemed as innovators because they are classified as performing medium-high intensity technological innovation (product and process included) within 33 sectors researched by IBGE (2005), thru the National Technological Innovation Research (PINTEC). The report produced by PINTEC defines the PCA sector as generator and promoter of technical progress, with potential to influence their customers and suppliers.

Beyond that, PCA companies bear certain characteristics which result in additional challenges for the PDP management, for example: need of full command and integration of different technologies (optics, electronics, mechatronics, software, telemetry, amongst others) applied into their products; need of strong integration with customers to adequately customize the product so as to meet the customer's industrial production process requirements.

This paper initially discusses concepts on TBCs, presenting next a bibliographic review on critical success factor in PDP management. Following are the research method, results and conclusions.

2. The small and medium size technology-based companies

FERNANDES et al. (2000), attest TBCs are organizations whose knowledge is a component strategically significant for their competitiveness and carry out important technological efforts, since they concentrate mostly on new products development and production.

The productive and organizational characteristics found in smaller size TBCs differentiate them from the bigger size ones, also technology-based, and even from those small and medium companies operating in other conventional economy sectors.

That differentiation can be better understood based on the definition formulated by SEBRAE/IPT (2001) of smaller size TBCs: organizations engaged in project, development and production of new products/processes, characterized by the systematic application of technical-scientific knowledge, use innovating technologies, devote a high proportion of expenses to Research and Development (R&D), hire a high proportion of technical-scientific and engineering staff and meet small specific markets' requirements.

Other aspects distinguishing minor size TBCs from those of the traditional sectors, according to PINHO et al. (2002), are the following: they operate in reduced scale, they undertake the risk of innovating activities beginning with the development of technologies not previously tested in the market, in most cases their products are not final and in general capital goods, components and industrial systems.

FONSECA & KRUGLIANSKAS (2002) emphasize the small size TBCs have an innovation dynamics of their own, rely on technical-scientific staff as well as researchers who keep close links with research environments. Differently, those authors state the scenario of the traditional small companies shows stronger difficulties to manage the modernization and innovating technology costs, do not have an innovation culture and have relationship problems to deal with research centers.

Studying small and medium size TBCs in more economically developed countries as compared with Brazil, YAP & SOUDER (1994) and SOUDER et al. (1997) define them as companies which develop, produce and trade sophisticated technology products and.

In this paper, small and medium TBCs are considered to be those:

- whose basic characteristic is the application of technological knowledge turned to the new products systematic development; and
- that meet specific market segments (*niches*) and/or imports substitution.

3. Critical success factors in the management of the product development process

A research line in the area of PDP management is finding success factors, namely, differentiating practices (tactics, methods, tools and techniques) that, provided they are thoroughly and well executed, contribute to increase the probabilities for success in launching new products (COOPER et al., 2004a; KAHN et al., 2006). Many authors (SILVA et al. 2006; ERNEST, 2002; SOUDER et al., 1997; YAP & SOUDER, 1994) point out a set of factors associated to the success of new products.

According to GRIFFIN (1997), the first study in this field was carried out by the consulting company Bozz, Allen and Hamilton in 1968, which verified that almost 1/3 of the products launched, ended up in failure. For ERNEST (2002), this type of study became popular within the last four decades as a result of its practical relevance and interest inherent to the researches.

The vast amount of literature in the area produced a collection of factors associated to the success of new products (SOUDER et al., 1997; ERNEST, 2002; COOPER et al., 2004a,). The success of a new product depends on the configuration and dynamics of controllable variables (inherent to the company) and non-controllable variables (company's insertion environment).

For the purpose of this paper the following factors were investigated: new product innovation degree, characteristics of the target markets, product characteristics, technology sources, company skills/ability, project leader skills, integration of PDP, PDP organization and execution quality of PDP activities. These factors are to be briefly discussed below.

SILVA et al (2006) point out the existence of a strong relation among companies with innovation and prosperity tendencies in the market. Despite this fact, there is no consensus regarding the innovation degree of the project, the product and its success (GARCIA & CALANTONE, 2002).

SOUDER et al. (1997) attest market orientation as critical to the success. This factor approaches aspects such as company capacity to evaluate market potential for a new product, understanding the needs of the target market and translating such information into PDP language (ROZENFELD et al., 2006).

There are numerous products characteristics that propel them to success: low cost, high quality, superior performance and unique attributes (TOLEDO et al., 2002). The need to integrate the strategy of product development with company strategies at program and project levels is also recognized (CLARK & WHEELWRIGHT, 1993; COOPER et al, 2004b).

Technology sources can also contribute for the success or failure of a new project, because they demand acquisition, adaptation and managing skills (KAPPEL, 2001).

The main organization aspects of PDP mentioned in the literature include the company organization for product development, the degree of integration between the functional areas, level of PDP structuring and characteristics of key-individuals involved in the project execution (ROZENFELD et al., 2006). ERNEST (2002) indicates five important factors linked to organizational characteristics of PDP: setting up multifunctional teams, authority and responsibility of the project leader, the scope of responsibility over the project by the development team, commitment of the team members and high degree of communication during the entire project.

Regarding to carrying out PDP activities, ROZENFELD et al. (2006) recommend paying attention to the pre-development phase, above all, handling of technical and market studies, and feasibility analysis. GRIFFIN (1997) emphasizes the need for quality in activities concerning generating and analyzing ideas, technical development and market introduction.

As regards PDP management in TBCs, VERGANTE et al. (2001) indicate that many studies of product development are carried out in companies located in relatively stable vicinities, a quite different reality from the areas or markets where TBCs are usually established. According to these authors, there has been recent evidence that in places where TBCs are inserted (whether they are small, medium or large), where technology and consumer needs change rapidly, a more adaptable product development approach becomes necessary, which will permit such companies to explore and respond to changes even in more advanced stages of product development projects.

Furthermore, according to VERGANTE et al. (2001) and MARCH-CHORDÀ et al. (2002), because they are in an environment where their competitors constantly incorporate technological innovations in the products they develop, the smaller TBCs tend to face two main difficulties when executing tasks related to product developments: the need for continuous learning during the development process and the need to incorporate new project information up to the moment of conclusion and launching of the project.

4. Research method

Aiming at understanding the factors with influence on the success or failure of products developed by TBCs in the PCA sector, the approach chosen was the quantitative exploratory survey. The choice was grounded on the fact that, besides demanding the research in various companies, the study of product development management in TBCs in the PCA sector is a phenomenon not yet studied in Brazil.

As research procedure the survey method was utilized, since it is recommended whenever it is interesting to produce quantitative descriptions of a given population, by using a pre defined research instrument, normally a questionnaire.

According to criteria defined by both SEBRAE (Brazilian Agency for the support of Micro and Small companies) and IBGE (Brazilian Geography and Statistics Institute) small companies were considered to be those with 20 thru 99 employees, and medium companies those with 100 thru 499 employees.

Despite the intense research carried out, no document was found listing TBCs small and medium size in the PCA sector in the State of São Paulo. Therefore, to begin with, 350 questionnaires were emailed to all the industrial automation companies in the State of São Paulo and registered in the International Automation Congress and Fair (CONAI), the most important meeting of this sector companies. During this first contact, the intention was to identify how many and which ones could be considered as small and medium size TBCs. The scope of the first questionnaire was also to identify the company size, confirm it could be classified as a TBC and prove the company carried out routine new product development activities.

This first approach yielded 52 answers, within which 26 companies matched the profile intended by the research. To widen the sampling, internet sites of all the industrial automation companies in the State of São Paulo, as registered in the Brazilian Association of Electro-Electronic Industry (ABINEE), were visited; other companies, as recommended by industrial automation professionals, were visited as well. Those which appeared to be potential candidates for this research were contacted by telephone. Out of this second contact trial, 20 companies matched the intended profile.

Thus, a 46 companies group was identified, characterized as TBCs which perform small and medium size in the PCA sector located in the State of São Paulo. All of them were initially contacted by telephone to participate in this research, 32 accepted to be visited for the application of the questionnaire. The sample thus obtained represented around 70% of the population previously identified.

Since these companies have similar characteristics, mainly as regards families of products developed, technologies utilized and customers served, as well as operating in the same economy sector, the sample can be considered representative of the TBCs population that perform small and medium size in the PCA sector.

Table 1 shows the professionals profile of the visited companies who were interviewed.

The managing directors are also entrepreneurs of those companies, working directly in the product development activities same as managers and engineers do.

Table 1. Interviewed professionals profile.

Position	%
Managing director	53
Manager	31
Engineer	16
Total	100

To allow the data collection, 2 questionnaires were utilized, which were pre-tested in two companies previously selected, prior to the definitive shaping.

The first questionnaire, semi-structured, was meant to gather general data and characteristics of the subject companies, and also a general view of the PDP structure.

The second questionnaire, structured, was applied twice in each company. The scope of the first application was a successful project so that the company described a product development experience considered as successful; the scope of the second application was a project that the company would describe as an unsuccessful product development experience. Those projects should have been carried out in the last five years and the application of this questionnaire focused identifying success critical factors in PDP, by pointing out practices associated to project management.

In this structured questionnaire, a 1 thru 5 scale was utilized, the answer content depending on the factor to be answered. Chart 1 shows those factors, variables and scales.

The dependent factor is the result of the new project (product) and the independent factors are all the other factors, chart 1, influencing the new product result. Figure 1 shows these factors.

5. Product development management: general characteristics and critical success factors

5.1. Sample profile

Table 2 indicates cities and/or regions and the respective number of companies participating in the research.

It can be observed that around half the companies researched are located in the great São Paulo (São Paulo and ABCD), as long as the remainder is distributed in the interior of this State.

As regards size, Table 3 shows that 84% are small size companies. That significant number of small companies can be attributed to the common spin-off practice among entrepreneurs operating in that sector. During the research it was also observed those entrepreneurs acquired experience and knowledge in big sector companies; thus they perceived the business opportunity to start a small entrepreneurship in a given market niche, often not taken care of by the big companies.

Chart 1. Factors, variables and scale utilized to measure factors influencing PDP success and failures.

Section 1: Project results		
Factor	**Variables**	**Scale**
New Product Result	- In general, how do you rate the overall new product result - How do you rate the new product result as compared with the performance criteria below: • Benefit. • Market share. • Strengthening of brand name / company image. • Customer satisfaction. • New skills generation for the company.	Much below expectations (1) thru much above expectations (5).
New Product Innovation Degree	- The project resulted in a new product for the market. - The project resulted in a new product for the company. - The project resulted in a new platform. - The project resulted in a new derivative product.	I fully disagree (1) thru I fully agree (5).
Section 2: Characteristics of both Product/Market/Technology sources		
Factor	**Variables**	**Scale**
Target Market Characteristics	- There was strong synergy among the already explored markets and the target market for this new product. - The market for this product type was growing, thus justifying a new product launch. - The assessment of potential market for this project was well carried out by the company. - Customers/clients strongly desired this product type. - Users' requirements were clearly understood and properly translated into new product specifications.	I fully disagree (1) thru I fully agree (5).
Product Characteristics	- The product performance is above competitors. - The product offers same solutions as the competitors although with lower price advantage. - The product has nearly the same characteristics as the competitors' products. - The product was well in agreement with the company's competitive and product strategies.	I fully disagree (1) thru I fully agree (5).
Technology Sources	- Hire outside professionals to make up non existing skills in the company. - Use of licencing strategy - Alliances and partnerships with clients. - Alliances and partnerships with suppliers. - Alliances and partnerships with research centers and universities. - Alliances and partnerships with other institutions. - Own/internal development.	Very weak (1) thru very strong (5).
Section 3: Skills Levels – Organization/Company and Project Leader		
Factor	**Variables**	**Scale**
Company's skills	- In general, the company had the technical skills necessary to carry out the project. - The R&D/Product Development area had the technical skills necessary to the project. - The Commercial area had the technical skills necessary to the project. - The manufacturing area had the technical skills necessary to the project. - The Service area had the technical skills necessary to the project.	I fully disagree (1) thru I fully agree (5).
Project Leader Skills	- The project leader had the technical skills necessary to run the project. - The project leader had the interpersonal/relationship skills necessary to run the project. - The project leader managed to motivate the people involved in the project. - The project leader had full authority to make decisions on project issues. - The leadership style adopted by the project leader was adequate for its execution, thus stimulating communication and conflicts management. - The leadership style adopted by the project leader allowed the participation of the product development group members in the project decision making. - The product development group members were motivated to carry out this project.	I fully disagree (1) thru I fully agree (5).

Chart 1. Factors, variables and scale utilized to measure factors influencing PDP success and failures (continuation).

Section 4: PDP Organizational characteristics		
Factor	**Variables**	**Scale**
Integration	- Upper administration commitment and support were decisive to carry out this project. - The project was managed linked to the other running projects in the company. - During the project there was adequate integration degree between the Commercial and R&D/ Product Development areas. - During the project there was adequate integration degree between the Manufacturing and R&D/ Product Development areas. - The project had the participation of various areas/departments in carrying out the ideas generation and selection activities. - The project had the participation of various areas/departments in carrying out the viability analysis activities. - The project had the participation of various areas/departments in carrying out the technical development activities (product project). - The project had the participation of various areas/departments in carrying out the prototypes build activities. - The project had the participation of various areas/departments in carrying out the product/market tests activities. - The project had the participation of various areas/departments in carrying out the commercial launch activities.	I fully disagree (1) thru I fully agree (5).
Organization	- The project activities were executed separately in different areas/departments and people involved only reported to the manager/supervisor of said areas/departments (functional structure). - To carry out the project, a team was formed with people from different areas/ departments who participated on a full or partial time basis. - A project leader/manager was appointed and people involved reported both to the manager/supervisor of those areas/departments as well as to the project manager/ leader (matrix structure). - To carry out this project a team was formed with people from different areas/ departments who worked full time in the project. - A project leader/manager was appointed and people involved reported only to him (pure project structure).	I fully disagree (1) thru I fully agree (5).
Section 5: PDP ativities execution quality		
Factor	**Variables**	**Scale**
PDP Ativities Execution Quality	- Ideas generation and selection activities. - Viability analysis activities (technical and economic)). - Technical development activities (product project). - Prototypes build activities. - Product/market tests activities. - New product commercial launch activities. - Document preparation, follow-up and reporting activities necessary for product validation.	Very bad (1) thru excelent (5).
Other Activities Execution Quality	- Project goals establishment and performance objectives. - Establishment of toll gates and go-no go points for the PDP stages, namely, each following stage may only be initiated upon assessment and approval of results/ activities of the preceding stage. - Documents emission (briefings, drawings, tests results etc) pertaining to project execution. - Fulfillment of product regulatory requirements. - Simultaneity degree in carrying out PDP activities. - Finally, a general evaluation was carried out to identify the “rights” and “wrongs” throughout the project.	Very bad (1) thru excelent (5).

Those companies were perceived to develop a wide range of products, whether catalog or customized to specific client industries. Table 4 shows the main product families developed by the companies under study.

The main sectors served by those companies are industries: food; automotive; power generation, transmission and distribution; electro-electronic; chemical and petrochemical; beyond other industrial automation companies.

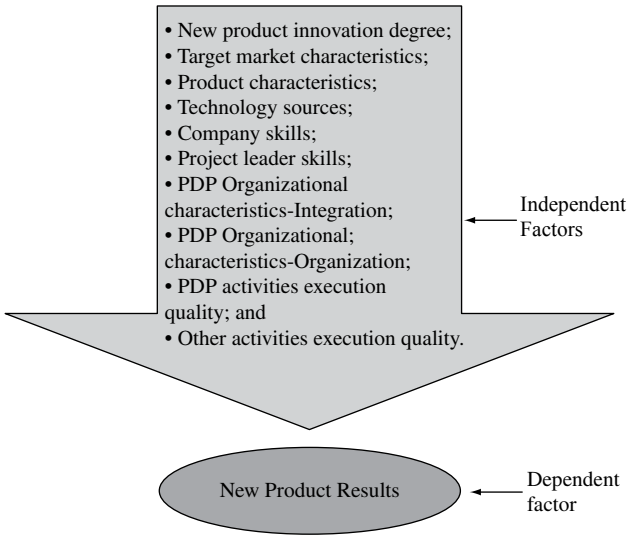

Figure 1. Dependent and independent variables.

Table 2. Geographic distribution of the companies studied.

City or region	Companies Qty	%
São Paulo	15	47
São Carlos	5	18
Campinas Region	4	12
Marília Region	3	9
Sertãozinho	3	9
ABCD*	2	6
Total	32	100

*Applies to Santo André, São Bernardo do Campo, São Caetano do Sul and Diadema cities, all of which are part of the "great" São Paulo.

Table 3. Companies distribution per size.

Company size	Companies Qty	Companies %
Small Size	27	84
Medium Size	5	16
Total	32	100

5.2. Product development general characteristics

As regards product developments strategy, 44% of the companies were perceived to develop catalog products only, namely, they are companies that detect a market niche for a given product, develop it and try to sell it their potential clients. Normally, as observed by JUGEND (2006), the catalog products for PCA companies suffer a fitting job to allow installation in the production line of those customers. Consequently, even the catalog products call for an adaptation job, though software or calibration to allow its functioning in the client industries' production line.

Other 28% of companies' strategy is just customized products development, namely, the product development begins once the client requests a specific product. The remaining 28% of companies develop both catalog and made-to-order products.

Around 60% of the companies studied have formalized procedures to carry out PDP activities. In 41% of those companies, that formalization is associated to the certification of conformance with ISO 9001:2000. The importance of such certification is linked, mainly, to the main clients' requirements, normally represented by big industries which demand certification evidence from their suppliers of process control automation equipments.

As regards the innovation of the products they develop, it was observed that 81% of companies resort to platform type projects, that is, develop a base product and reutilize its information and solutions in adapted, improved or extended versions of new products. Due to that predominant characteristic, platform or derivative projects, it can be attested that those companies mostly concentrate on incremental innovations rather than radical changes.

As regards innovation sources for products development, it was observed that 61% of companies do not establish partnerships to acquire technology, rather they develop it by them. Among those which develop partnerships (39%), the most common link is with other companies (31% of the sample companies resort to that mechanism for the technology joint development). Regarding other organizations, just 6% of companies resort to universities and 3% to research institutions.

After this brief characterization of PDP management in the researched companies, the next section will discuss critical success factors in already developed projects.

5.3. Critical success factors

The purpose of this section is to examine managing factors and practices that influenced past product development projects in a 5 years' period, in the 32 Technology Based Companies (TBCs) investigated.

The sample identified 32 cases of successful product development projects and 23 unsuccessful ones. Nine companies did not produce/submit the unsuccessful specific cases, 7 just justified themselves saying that since they only develop customized products projects, there is no possibility of unsuccessful cases.

It is also worth wise observing that by following an acclaimed international research model with this method (YAP & SOUDER, 1994; SOUDER et al., 1997), each company defined success and non-success from their own perception (such aspect was not standardized). Success was considered to occur when project results turned out to be within or beyond expectations; results below expectations were considered unsuccessful.

A descriptive analysis was made of each individual variable in the structured questionnaire relative to the factors investigated, with the purpose of identifying the

Table 4. Main groups of products developed.

Product families	Companies that develop products (%)*
Control systems (temperature, proximity, humidity, pressure, among others)	25
Software for automation applications	22
Indicators (temperature, velocity, pressure, power, output, among others)	16
Automation panels	16
Sensors	12
Programmable logic controls	9
Converters	6
Gauges (temperature, energy, voltage, etc)	6
Temperature monitors	6

*all of the companies investigated develop more than one group of products.

association of such variables with the aspects of successful and unsuccessful products developed. All of the variables applied in the questionnaire were identified as important for PDP management, as previously discussed in Section 3.

The quantification of the degree of association between two variables was made by means of the so-called factor loading. Such measures describe, through a single number, the association (or dependence) between two variables (BUSSAD & MORETTIN, 2002).

For the purposes of this research, the objective of factor loading is to verify if it exists and how strong the association between that variable is with the success and non-success of the products developed, expressed by means of a 1 to 5 scale. For the present research, the highest value the factor loading can assume is 0.7. Such value would demonstrate that for this variable all of the success cases would have maximum scores and all of the unsuccessful cases would have minimum scores, thus revealing a critical success variable for the product development project.

Therefore, the factor loading (association) with values close to or higher than 0.5, was adopted as strong, because these values indicate that in cases of non-success, the responses would be concentrated on the minimum values; and for the success cases, on the maximum values. That, indicates this is a critical variable for PDP management, namely, a variable strongly associated with the developed product's success or unsuccess.

Out of the 64 variables investigated, Table 5 illustrates the factor loading of the 10 variables that showed the strongest associations with the developed products' success or unsuccess of the companies investigated, always taking into consideration only the variables that had their respective p-values (t-test) below the significance level of 5% ($p \leq 0.05$).

It was also intended to identify the critical success factors, thru their mean values, for successful and unsuccessful projects. Those revealing wider mean amplitudes are factors which should receive more managerial attention, because a variable high scored for the success cases and low scored for the unsuccess case is deemed as critical for the product success or failure.

Table 6 shows the variables with widest response variability (difference between mean values) evidenced in the success and unsuccess cases.

When examining Tables 5 and 6, it is perceived that the most success-critical variables, namely, the most representative as regards association with both successful or unsuccessful developed products (contingency coefficient above or close to 0.5 and p-value ≤ 0.05) and the response mean values (wider amplitude between mean values of successful and unsuccessful results) are those related to the pre-development stage, as proposed by ROZENFELD et al. (2006).

According to those authors, critical decisions are made in that stage and prior to the project development itself. Therefore, the company should review and articulate with its strategy the portfolio of product projects to be developed, as well as define the team responsible for the development. Furthermore, in that very moment the company intends to consolidate information on technology and market for the future products.

Grounded on this support information, the development team should define the new product projects to be carried out and, there on, initiate economic-financial viability analyses as well as product cost and final price of individual projects. Upon definition and approval of those requirements by the development team, the development stage will follow, involving detailed aspects of attributes (systems, subsystems and components) the developed products will have.

The adequate integration of the product to be developed with the competitive strategies of the company and the synergy between the new products and the markets these companies have already explored, have also been verified as critical success elements, which should be present since the initial elaboration of the product concept, as well as in the pre-development stage. That fact becomes evident when Tables 5 and 6 are examined: "the product was well articulated with the company strategies and products", from

which it can be inferred that pre-development quality is an actual critical success factor for those companies.

The alignment among the strategic planning and the future products, assigning priorities according to capital limitations, technologies, skills and markets the company operates in, becomes an unavoidable step to be solved by the researched TBCs. Once more, depending on the execution quality, the critical success factors evaluation will assure future products an increased success probability. These results reinforce the findings by CLARK & WHEELWRIGHT (1993) and COOPER et al. (2004b), attesting that failure in the products development activities often occur due to the fact that companies do not link their development projects to their respective company strategies.

Tables 5 and 6 show that variables related to product cost and technical advantages, as compared with competitors, are also related to the success of the product being developed. Maintaining these advantages throughout the entire project depends, above all, on defined product characteristics that will be developed (technically and economically) in the detailed stages of the product project and fabrication

Table 5. Main variables associated to the developed product success or unsuccess.

Variables	t-Test	Factor loadings
Product characteristics		
The product offers superior technical performance as compared to the competitors.	0.001*	0.509
The product was well articulated with the competitive strategies and products of the company.	0.002**	0.502
The product offers the same solutions as the competitors, but with cost advantages.	0.004*	0.482
PDP activities quality		
Preparation and follow-up activities involving documents and reports necessary for product validation.	0.024**	0.502
Activities of viability analysis (technical and economical).	0.003**	0.479
Project leader skills		
Leadership style enabled team participation in project decisions.	0.009**	0.444
The project leader motivated individuals involved in the project.	0.013**	0.432
The leadership style adopted by the project leader was adequately exercised, encouraging communication and conflict management.	0.013**	0.432
Individuals of the development team were motivated to execute the project.	0.020**	0.419
PDP organizational characteristics – integration		
There was adequate proportion of integration along the project between commercial and R&D/PD (development team).	0.010**	0.440

* significant at $p \leq 0.001$; ** significant at $p \leq 0.05$.

Table 6. Variables which showed wider differences between mean response values evaluating success and unsuccess.

Variables	Response mean values	
	Success cases	Unsuccess cases
Degree of innovation of the product		
The project resulted in a derivative product	3.41	2.13
Product characteristics		
The product was well articulated with company's competitive and product strategies.	4.17	2.64
The product offers same solutions as the competitors', but with cost advantages.	4.20	2.95
The product offers technical performance above competitors'.	4.06	2.90
Target market characteristics		
There was strong synergy among the markets already explored by the company and the target market for the new product.	4.00	2.25
The evaluation of the market potential for this project was well accomplished by the company.	3.77	2.61
PDP activities execution quality		
Preparation and follow-up activities involving documents and reports necessary for product validation.	4.35	3.00

process, which also call for a sound pre-development management.

In addition, the development of a superior performance product, with cost advantages above competitors, unavoidably will not only depend in an efficient development of both product and process projects, but also on the components acquired from outside sources, which suggests the need to involve suppliers in PDP activities.

As a complement to Table 5, Table 6 shows the importance of those companies being engaged in the innovation degree of their products, given the importance of derivative products developments (improved, derivative or adapted) stemming from the existing platforms, an important trend the TBCs in the PCA sector benefit from, as discussed in item 5.2.

As regards functional integration, the present study verified and shows in Table 5, the importance of closeness between the Product Development and Commercial areas for the project and the development of products launched by TBCs, thus endorsing the research by SOUDER et al. (1997) and ERNEST (2002)

The integration of the Commercial and Product development areas is especially important for the PCA companies, due to the strong need to interact with clients, as long as they request adequate product customization and/or calibration to match their production line singularities.

Therefore, for those companies, a well succeeded new product development demands the presence of the Commercial area representatives, technically supported or composed by people with deep knowledge on the technical attributes of the products to be developed or alike.

The preparation and follow-up activities of documents and reports necessary for product validation was another variable indicated as important by the companies. This can be justified in the automation sector of process controls on account of stringent demands by their clients, what often requires the use of formal procedures like ISO 9001:2000 standard, for example, to systemize activities of product development in order to assure quality.

Malfunction of process control automation equipment may cause serious problems to the client's production site, and consequent losses like total interruption of the industrial process. Such potential risk justifies the clients' concern when purchasing PCA equipment whose product development process be standardized and duly certified upon quality system audits, as would be the case of conformance to ISO 9001:2000.

The effective conduction of product validation activities proved to be relevant for the success of products developed by the PCA companies.

With reference to levels of company competency, mainly as regards motivating and enabling personnel participation in the project, it was verified that managing capacity of the leader is a critical success factor for these companies' product development. Additionally, it was observed that both successful and unsuccessful developed products, as well as the respective project leader evidenced enough technological knowledge on product and process. Nevertheless, the differential factor was the managerial skill demonstrated by the leader of the development product project.

Those leaders' management skills, as characterized in this research, involved the skills to generate the effective participation of the functional areas, motivate people involved, exercising the necessary authority throughout the product project development. This significant fact proves companies depend on their leaders, to an extent in like entrepreneurships.

No correlation was verified between successful or unsuccessful developed products and technology sources; in either case, the variables related to that factor scored low ranked.

That low interaction to obtain outside technology or to develop it jointly leads to questioning considerations about small and medium size TBCs, attesting they keep intense partnership relations with universities and research centers. As shown by the results above in the present research, to develop technologies to be applied in their products, most companies do not depend or do not resort to relationships with universities and research centers.

6. Conclusions

This paper analyzed management practices and critical success factors during the realization of new product development projects.

Product development is a complex process and any research in this area shows limitations. The main restriction of this paper is related to the option made to examine critical success factors in the new product development projects, although just within an specific sector of the Brazilian small and medium size TBCs. Future research may lead to investigate the core subject within other sectors, software and biotechnology, for example. Despite the limitations, some considerations can be made in view of the results obtained.

By interpreting the results obtained, it can be understood that such companies assign priority and be concerned with the characteristics of the products and their articulation with the company strategy. By so doing, they should pay much attention to the pre-development stage, when technical and economic requisites of the products to be developed are being structured (detail stage of the product project and manufacture process), and keep this in mind and attitude so that future products have a characteristic that pursues convergence with strategy and the company's target market.

The pre-development stage tends to be effective when right decisions are made to properly articulate product project and company strategies, capture desired technology and market information, and to analyze in early stages cost and prices of the product to be produced. Good decision making in this phase can be facilitated by creating a "multifunctional development team" right at the beginning of PDP steps, as suggested by CLAUSING (1994) and ROZENFELD et al. (2006).

Thus, from the PDP beginning, analyses and screenings within the areas of Production, Engineering, R&D (develops technology to be incorporated into the product) and Commercial, will be intensified and concentrated on the product to be developed. That integration can be deemed as an important management mechanism, since the multifunctional team boosts the accumulated knowledge exchange, by and amongst each company's function. Integration also diminishes uncertainties and consequently increases decisions quality as made during the beginning of the development; this is likely to lower project cost due to the probable reduction of problems occurrence throughout the PDP.

That type of organizational arrangements for product developments can be implemented more easily in small and medium companies, as those object of this research; due to their size, integration and inter-functional communication, the organizational arrangement tends to occur more naturally. It is a management mechanism to be better explored by the small and medium size TBCs in the PCA sector.

As regards these companies, it was observed there is an obvious tendency in adopting quality assurance systems to help meet client demands, who look for reliable automation equipment of process controls with assured technical performance.

However, for the development of a new product, the efficient systematization of such activities will greatly depend on how these companies organize themselves regarding the managerial capacity of the project leader and the functional integration, especially among the Product and Commercial areas, as the results suggest.

Thus, among all the existing factors in managing the process of product development in small and medium size Technology Based Companies within the Process Control Automation sector, the critical success factors above should deserve full attention in order to plan and implement company wide managerial training plus additional specific training of the product development leaders.

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