Incorporating Life Cycle Cost Management in Product Development Process

Osvaldo Magno Freixo
Federal University of São Carlos
freixo@terra.com.br

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

Abstract: Decisions taken during the development phase of a product affect its Life Cycle Cost as a whole, or in other words, the choice of a certain alternative project has an influence on costs of manufacturing, operation, maintenance and even of the disposal of this product. Moreover, decisions taken in the initial stage of the product development can be difficult to revert at later stages of its life cycle, or rather, such decisions can jeopardize competitiveness of the product in an irremediable way. Therefore, to adopt an alternative project or to take a decision related to a product one should have the best possible notion of the impact that such an alternative or decision will have on its Life Cycle Cost – LCC. The purpose of this article is to discuss the management of these Life Cycle Costs during the Product Development Process - PDP and to identify the minimum requirements necessary, so that such a management can be included in this process, apart from presenting a set of proposals aimed at elaborating a LCC Management Model. Initially, the importance of 'the cost' stands out as a competitive differential and how it is affected by the decisions made during the development of the product. Reasons are discussed considering cost management as one of the integrant aspects of models referred to regarding the development of the product and the different definitions addressing this question. An attempt is made to differentiate costing systems or methods, cost estimation models and cost management, emphasising the Quality of Information, the Processes of Management clearly established and people's abilities as essential factors, so that the cost management concerning the life cycle of the product actually happens in an adequate and expected way.
Key words: Product Life Cycle, Life Cycle Costs, Cost Management, Product Development.

1. Introduction

The price paid by consumers when buying a product should cover all its development and manufacturing costs, apart from other necessary financial efforts related to the carrying out of sales incomes. The difference between income obtained and all costs or expenses made by the company represent its profit, which should match the expectations of the investors, whether associates, shareholders, partners etc.

Concerning costs it is also important to discuss the "pricing" of the product, which is, the establishment of its price on the market. KOTLER and ARMSTRONG (1995) divide the strategies of defining prices into three categories: Price-definition based on costs, price-definition based on the value (of the product) and price-definition based on the competitors/the competition. The Table 1 summarises these strategies. With relation to them COGAN (1999) affirms that with the exception of contracts based on cost or anachronic alternatives of commercialisation like cartel or monopoly, it is after all the market that determines the prices of products. Concerning this, it is not the cost, which generally determines the price but, in reverse order, a maximum price is established by the market and a profit margin is given to the company. The result is a maximum possible cost to be put into practice known as "Target Cost – TC".

Much work in the literature claims that most product costs are defined in the initial phases of their development. For instance, CROW (1997a) and WEUSTINK *et* al. (2000) can be cited. Due to this, CLARK and FUJIMOTO (1991) affirm that changes to products should be made in these initial phases because as the later the alterations are

Table 1 – Strategies to set prices (KOTLER and ARMSTRONG, 1995).

Price-definition based on costs	This definition of price is done while being added to a standard margin related to the product cost.
Price-definition based on value	It uses the perception of consumers in relation to the value of the product. Value and price orientate the decisions about the project of the product.
Price-definition based on competitors	Consumers base their judgement of the value of the product on price the competitors charge for similar products. The price can be set at the levels of those from the competition or with the intention of substituting it.

introduced, the more expensive they will become. In fact, making changes while the product is still a concept, an idea is much less laborious and involves far less resources to actually make the alterations as if the projects and processes have already been defined, or as if the tools have already been projected and manufactured, and mainly, if production and distribution have already been initiated (see the 'recall' cases of the mobile industry). TOLEDO (1994) presents an idea of how huge the costs of these alterations are, affirming that if the product is still being developed a certain alteration costs **C**, the same alteration would cost **10xC** if the product already was in the production phase, and it would even cost **100xC** if the distribution of the product had already started.

It is important to mention that when you talk about costs of a product you should not only think about the manufacturing costs, which are usually the first that come to mind. But the concept of "costs" should also be expanded to other phases of the product life cycle. Thus, if a development team adopts a certain solution, they should be conscious that the solution will have positive and negative impacts on the whole production process, i.e., not only on the manufacturing costs but also on the costs of operation, maintenance and even on those of disposal, once the product has become useless.

Recent improvements in legislation in relation to protecting the environment should also be remembered. Battery companies, for example, are obliged to re-collect the disposed products and to recycle them or, at least, they have to guarantee the batteries do not contaminate the environment. Specially concerning car batteries, dealers who change batteries should collect old ones and take them to the factory where they are almost completely recycled.

At first it appeared to be an additional cost, because of the re-collection and recycling, but in the end it proved to be a saving on raw material. Obviously, it is necessary, when developing a product, that such a demand is anticipated in the way that the manufacturing characteristics, the product assembly etc. allow this kind of re-utilisation at the least possible cost. These decisions concerning the product configuration affect not only the costs incurred in the manufacturing phases, but also the disposal ones.

There are many different initiatives to adopt similar measures in relation to other products like tyres, for instance. Sooner or later manufacturers of these kinds of products will be responsible for collecting and disposing of the old carcasses adequately, which nowadays rubbish dumps, brooks and rivers are crammed up with. This new responsibility will certainly imply greater care in the development of new products in a way to minimise the impacts of these additional costs and, perhaps, reverting them in favour of the individual company.

Another example, maybe even more cutting, regarding the concern of decisions taken during the PDP, but which affects the whole product life cycle, is found when buying a car. Not considering very individual cases, which the buyer of a car does not care about the vehicle's fuel, the prices of car parts, maintenance services and the availability of an licensed dealer? and who doesn't even care whether it is easy to re-sell the car or the value of it after a certain time of use, in other words, the depreciation costs?

It can clearly be observed that the cost of buying a car is only one of many components of what is known as the product "Life Cycle Costs", that, as well as the rest, is mainly defined by decisions taken during its development. The importance of an efficient cost management takes place when the product is still being conceived, planned and projected, when, in fact, big and small decisions can determine the degree of the project's profitability.

In terms of understanding these questions better, the purposes of this article are to establish a connection between

the management of the Life Cycle Cost (LCC) and the Product Development Process (PDP), to identify basic requirements of a management model concerning the Life Cycle Product Costs, as well as to put forward a strategy to develop this model.

2. The importance of incorporating Life Cycle Cost Management into the Product Development Process

Although there is concern in companies regarding the impact of decisions relating costs in the PDP, some questions still remain unanswered: Not forgeting other restrictions concerning the project and market, such as Quality, Time-to-market, Logistics, etc. (so-called 'trade-offs'), how can one guarantee that a specific solution to a project represents the lowest possible product Life Cycle Cost? what are the necessary conditions for people who are responsible for taking decisions not to be insecure?

Of course, these issues can be addressed in another context which does not relate to costs, and perhaps the solution could even be the same: the improvement of the decision process should result in a better PDP.

This question has results from research carried out at the Department of Production Engineering at UFSCar and will now be illustrated. The company which was investigated is well known for developing high-tech products, for being an up-to-date company in terms of development practice and for investing in research. Even though it has all these favourable characteristics, the people who were interviewed from various areas of the company involved in PDP saw many opportunities in improving the decision making process concerning costs. Most of them were related to the PDP itself.

To sum up, the interviewees' observations focus on three aspects: a) the PDP does not foresee any activities explicitly related to the management costs. In other words, how do the requirements concerning product costs (established in the company's Business Plan) should reach the engineers and in how much detail and in which way are they detailed to systems and components and by whom? b) where can one look for information (past data or not) concerning costs, how to make available and at the same time make it confidential? c) what the necessary requirements of people who deal with these kinds of administrative and financial questions that are less technical in an engineer's point of view?

According to the interviewees, in this company there is no clear definition as to the responsibilities and activities concerning the control of Life Cycle Costs, at each stage of developing new products in relation to the product target cost. Thus, the product target cost is also not detailed in a convenient way and this raises doubts as far as the cost limits of each system, subsystem or component of the product is concerned. Information about costs of parts and components are not readily available to the project teams and the team leaders and generally they are not adequately trained to deal with management cost questions. Concerning more developed projects (if they have more detailed and precise information) changes are made only after a more critical analysis regarding the implications of such alterations to the product cost has been carried out.

How then has the company achieved such success? Answer: it is due to decisions having been made by a few very experienced people who know about the product and who are business minded, yet act intensely in the initial stages of the project and the planning of the product. The outcome of this is that the engineering project, in its other stages, lacks support with regards to the management costs. Nevertheless there are perspectives that activities concerning management costs (the responsibilities and conditions of the tollgates of the next stage in the PDP having been defined) will be incorporated into the PDP of the researched company.

In one way this case study reinforces what many authors claim, in other words that the majority of product Life Cycle Costs are defined in the first stages of its development. According to HANSEN *et al. Apud* COMPTON and ELIAS (2003), 90% of these costs have been committed after the project of the product (Figure 1). According to CROW (1997a) 70 to 80% of the product Life Cycle Costs are defined in the initial stages of its development. RUSH and ROY (2000) share this view (Figure 2). Despite this, according to CROW (1997b), the emphasis of the traditional method is on technical issues, time, aesthetics or technology and in many organisations the cost is used to define the price, instead of the opposite (contrary to the market) or, in other words, importance is given when the product is at an advanced stage of development and not much can be done about reverting the undesirable situation.

According to CROW (1997a), effective cost management concerning product life cycle requires DESIGN TO COST (DTC), which consists of the following:

◆ An understanding of customer affordability or competitive pricing requirements by the key participants in the development process;

◆ Establishment and allocation of target costs down to a level of the hardware where costs can be effectively managed;

◆ Commitment by development personal to development budgets and target costs;

◆ Stability and management of requirements to balance requirements with affordability and to avoid creeping elegance;

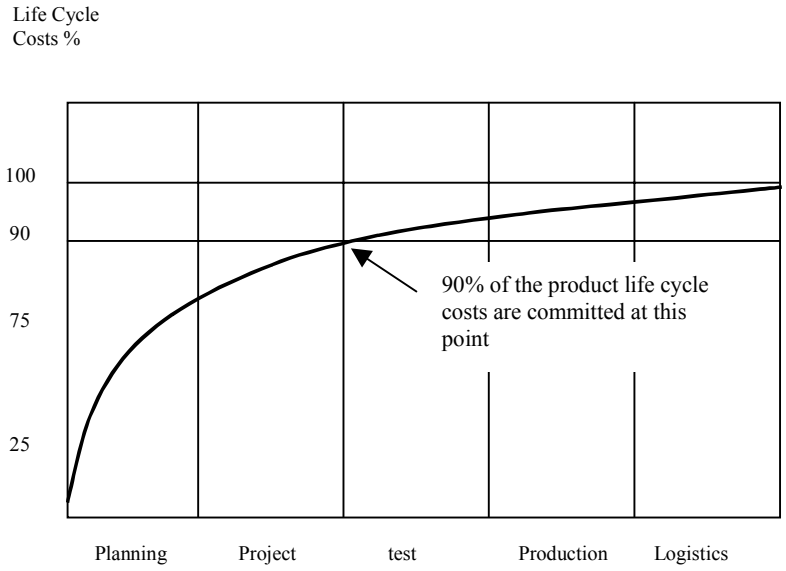

Figure 1: Commitment of product LCC (Hansen *et al. Apud* Compton and Elias, 2003)

◆ An undestanding of the product's cost drivers and consideration of cost drivers in establishing product specifications and in focusing attention on cost reduction;

◆ Product cost models and life cycle cost models to project costs early in the development cycle to support decision-making;

◆ Active consideration of costs during development as an important design parameter appropriately weighted with other decision parameters;

◆ Creative exploration of concept and design alternatives as a basis for development lower cost design approaches;

◆ Access to cost data to support this process and empower development team members;

◆ Use of *value analysis*/function analysis and its derivatives (e.g. *function analysis system technique*) to understand essencial product functions and to identify functions with a high cost function ratio for further cost reduction;

◆ Application of *design for manufacturability* principles as a key cost reduction tactic;

◆ Meaningful cost accounting systems using cost techniques such as activity-based costing (ABC) to provide improved cost data;

◆ Consistency of accounting methods betwen cost systems and product cost models as well as periodic validation of product cost models; and

◆ Continuous improvement through value engineering to improve value over the longer term.

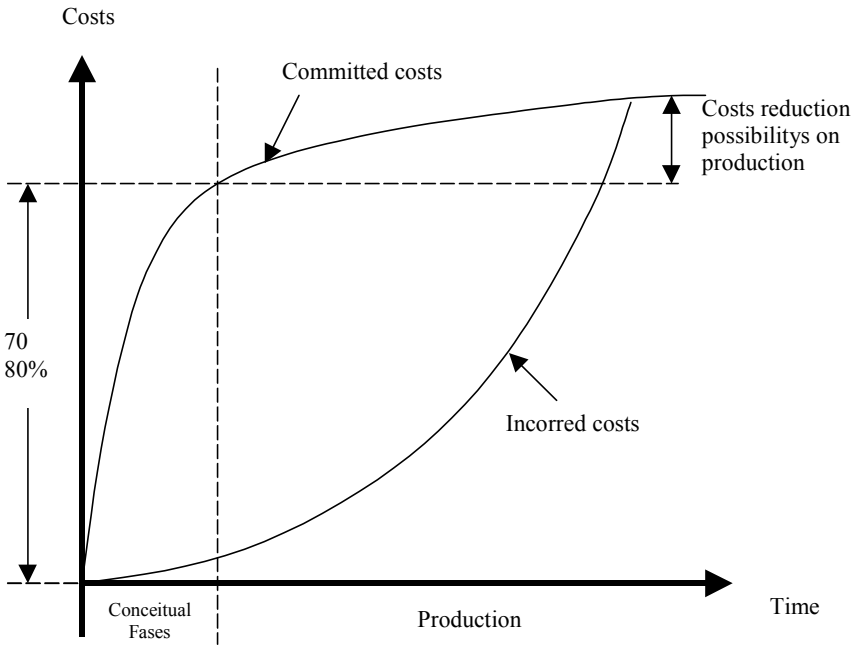

Figure 2: Commitment of the product costs curve (RUSH and ROY, 2000)

In the recommendations above one can observe a concern that transcends a simple adoption of a costing model of the product life cycle. Calculating this cost is only part of a much bigger management process. Apart from this, being part of a process called "Design – to – Life Cycle Cost" by STERLING (2001), the estimative or costing models of products, according to him, are not always efficient in the first phases of their development. An important observation made by the author is that the existing LCC models are all managers of data banks with a larger or smaller capacity to import, modify, analyse, integrate and manage a huge quantity of data that will be made up of reports with information to be used during the product development and the decision taking.

RUSH and ROY (2001) further observe that the necessary knowledge to develop a costing model is complex and its sources vary immensely within the Simultaneous Engineering environment. The authors claim that people constantly use a combination of logic, commonsense, education and experience and judgement to produce an estimate of relevant costs keeping precision and time in mind. It is a question of applying a series of tacit knowledge, difficult to be understood by non-specialists.

All this reinforces the idea that a cost management process should be incorporated in the respective PDP, with defined activities and responsibilities, through which (while a project is in progress) all the utilised alternatives would be a result of a critical analysis of its impacts on the Life Cycle Costs of the final product.

3. Differences between Cost Estimation, Cost Accounting and Cost Management

There is an important distinction between "Cost Estimation", " Cost Accounting" and "Cost Management". For clarification, here is a parallel to an every-day-life situation: The planning of a trip. Presumably, R$ 2000,00 were spent on a 1000 km trip last year for four people. This year a 2000 km trip is planned for five people and it would be of interest to know what the costs would be. In the first stages of their "holiday project" the exact itinerary and further details of the trip are not yet known. Therefore a cost estimation could roughly be made while the trip is being planned using proportionality, for instance. If the distance doubled and the quantity of people is raised by 25%, then expenses will approximately reach R$ 5000,00 (125% more than the expenses made on the first trip). According to how the idea proceeds, details of the trip get more defined and there is more information available about the itinerary and better estimations can be made. Accommodation expenses probably will not double just because the distance did. Costs related to fuel, tolls etc. should not increase 125% only because there is one more person on the trip, and like these expenses, there are other things to be considered. A more realistic estimation could be made that might be between R$ 4000,00 to R$ 4500,00, for example. The more and the better the information about the new trip is, the higher the precision of evaluating its costs. This is a typical process of "Cost Estimation".

As far as Cost Accounting is concerned, there is not much to it. Just sum up all the incurred costs during the whole trip and the new value is set. There might be doubts about the shares for each person. Imagining that there are five friends, some might have extra costs concerning accommodation and food, for instance. Therefore, the way they agreed on the distribution of the costs (criteria of share) is what is going to determine the amount each person will be charged individually. Finally, from the investigation you can draw conclusions if the previously established cost estimation was good or bad. Cost investigation is basically the accounting of the trip.

As to Cost Management, what is the difference in relation to the previously described processes of estimation and accounting? Before estimating the costs of the new trip some other questions should be answered, such as:

a) If it is possible to go on a trip with a travel agency, would it include accommodation? and how much would this lower or increase the costs? Would time be saved? And regarding comfort, safety and absence of unforeseen casualties, would these factors compensate for a possible expense to major (trade-offs)?

b) Would it also be possible to change the travel route or use cheaper accommodation to reduce costs in relation to the year before?

c) If the trip were made in a different period of time, would prices of travel and accommodation be different too? would it prolong the trip, would it allow the journey to be further away or would the price be reduced?

The difference of defining cost management from cost estimation and cost investigation is that there are procedures

and previously adopted solutions questioning, and thus being perfected, which can lead to better results than in the previous project. If the last trip was expensive, and one has not recognised it as such, why should the same steps be repeated? Why not look for new alternatives and information? It certainly could result in financial benefits.

The exercise which has just been carried out is not very different from what a travel agency does whose offered service is nothing more than a product. The product process is the same in industry. Cost management of its new projects not only considers the knowledge of what has happened in the past with other products, but also the new alternatives searched for, evaluating the impact of each one of them in the product Life Cycle Costs and by control, in the PDP, estimated costs up to every stage in relation to what has been stipulated. It can be confirmed that cost management is present in the whole PDCA cycle (Plan, Do, Control and Act) and involves people from the most diverse departments of the company like Marketing, Finance, Production, Commerce and Engineering. On the other hand, cost estimation and cost accounting are part of cost management, which involve a much smaller number of departments (maybe some of them being Engineering and Accountancy), and they are not always present in all the stages of the PDCA cycle (Figure 3).

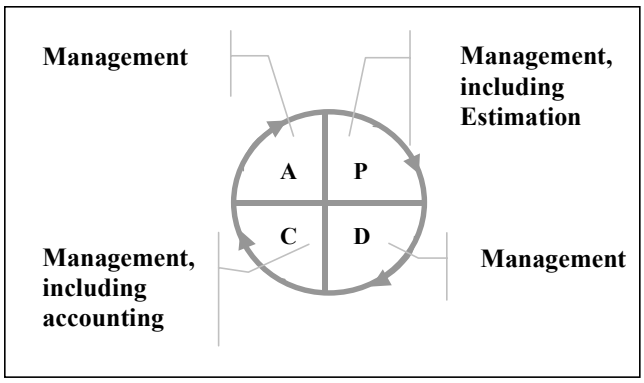

Figure 3: Cost Management and the PDCA cycle.

4. Cost Management and Reference Models for PDP

PDP activities and tasks can be defined, structured and organised in many ways with minor or major efficiency. A unique way of developing a product does not exist and every company can define its own process, with its own special characteristics considering its organisational culture, economic segment, development strategies etc.

There are many researches dealing with improving product development models. Many of these researches emphasis one of the aspects that composes the PDP. Some models focus their attention on more administrative questions, of project control. Others detain themselves more in operational tasks of engineering development and manufacture. Various companies end up adapting some of these models to their local conditions. These development models serve, therefore, as a starting point of new "ways" to develop a product and are known as reference models.

According to ROZENFELD (1997) by a business process model it is possible to make policies and management strategies visible, rationalises the flux of information and documents throughout the development of the product integrating the company around a unique and focused vision in a type of business directed to a market or client with well defined suppliers. PDP is one of this business process of the company.

BUSS and CUNHA (2002) despict that "some reference models are offered to areas which have studying PDP as their objective: The Administration, having support from Production and Marketing is concerned about the merchandising aspects and about organisation and production control; the Engineering using its connection to Production Engineering which basically focuses on the aspects referring to the engineering of the product and to the development of the technical project of products; and the Design that is mainly concerned with characterising the problem and with the investigation of possible alternatives." For KRISHNAN and ULRICH (2001) the apparent disconnection between various models found in the literature arises from these differences of definitions and points of view.

According to MAXIMIANO and RABECHINI JR. (2002) the concern of companies about their development models and management models has been growing, apart from the individual evaluation of the maturity level of these management models. According to the authors, a movement of systemisation of principles accompanied a recent emphasis on the project management from this knowledge, which has transformed it into a discipline. Since 1987 these principles have been registered in the PMBOK guide (Project Management Body of Knowledge, the Body of Knowledge concerning Project Management), which is periodically updated (PMI, 2003), and parallel publications on this topic

have multiplied, spreading and updating the techniques and concepts available.

KRISHNAN and ULRICH (2001) mapped the necessary principle decisions to the product development, after having done an extensive bibliographic revision. The authors link these decisions to five stages of the process: Concept development, Project of supply-chains, Product development, Test and validity of performance and launching the product (Table 2).

The "Price" (and therefore the "Cost") appears as one of the characteristics whose target values should already be defined during the concept development, or better, during the first phases of the product development. This definition of target value for "price" has implications on the target value for "cost", also called "Target Cost". For COGAN (1999) the cost of a product is one of the elements that support decisions of going into or staying in the market, to launch or withdraw a product. In his opinion "costs" seem to be an important tool for the decisions of merchandising, economic and financial character making it a competitive differential for organisations.

Therefore, it is observed that an integrated development model of products aggregates activities that functionally belong to various departments of organisational knowledge (Marketing, Finances, Engineering, Commerce etc.) but even though, depend on each other and they cannot be carried out separately because its interaction influences the results of this huge entrepreneur process, that is the Product Development. The development models should preview the impact of each decision, related to each functional area, in all characteristics of the product: performance, cost, acceptance in the market etc. Thus the cost management should integrate the product' development process and, therefore, the activities related to it should also compose the development model adopted.

Consequently, a reference model emphasises questions of management or operation or both. No matter what the focus, the model should necessarily recognise the cost management. It means to say that as there are tasks related to calculating the dimensions of a certain part or subsystem, or to the configuration control of a product (in which phase each component is found, if there are changes, if the design is concluded etc.), there should also be activities aimed at responding if that subsystem has an estimated cost in the limits of what was defined as the maximum cost allowed. It is necessary to know if the product, in each of its development stages, enables the company to reach its business objectives (the desired profits).

Table 2 – Decisions concerning product development in a project (Krishnan and Ulrich, 2001)

PDP STAGES	DECISIONS TO BE MADE
Concept development	What are the target values of the characteristics of the product, including price? What is the central concept of the product? What is the architecture of the product? Which variants of the product will be offered? Which components will be shared by the different variants of the product? What will be the shape and the industrial design principles of the product?
Project of supply-chain	Which components will be planned and which selected? Who will plan these components? Who will produce the components and assemble the product? What will the configuration of the physical supply-chain be? What type of process will be used to assemble the project? Who will develop and supply the technology and equipment for the process?
Product development	What are the key parameter values of the development? What is the relation confi ion between components and precedence of assembly? What is the detailed project of the components, including material and the selection process?
Test and evaluation of performance	What is the prototyping plan? Which technology should be used for prototyping?
Launching the product	What is the plan to test the product on the market and launch it? What is the plan to boost the production?

In the same way that the project cannot proceed if a certain system or component has not been sufficiently developed yet, to the extent of reaching the performance which is expected, one cannot progress while the impacts of each decision in the product Life Cycle Costs are not yet known to certainly guarantee at each development stage, that the estimated costs until that instance would be within what was defined as Target Cost in the business plan. If this does not happen, one runs the risk of developing a product that might have the expected technical performance, that would be offered in the stipulated time limit, that possesses good distribution logistics and maintenance but which would be too expensive for the market to which it is proposed or that it would not give the expected outcome to the company.

Obviously, the decisions made in PDP not always fit exclusively into Engineering and generally it should not be like this. A lot of choices involve commercial, structural or marketing questions. Therefore, it is necessary, no matter what the basis of the decision is, that one will know the consequences in terms of the product Life Cycle Costs as well as paying attention to quality, time to launch the product, etc.

5. Basic requirements for LCC Management in the PDP

The management of Life Cycle Costs of a product throughout its development requires basic conditions. All through our research, questions, which arose when we dealt with this subject, can be summarized as follows:

a) In the current PDP, which activities are related to the management costs? Are they sufficient?

b) Which information is needed in order to carry out these activities? Is it available?

c) Where does this information come from? Which difficulties are encountered in obtaining it?

d) What are the main difficulties when using or processing such information for those who take decisions in the PDP?

Such questions are related to processes (activities, tasks, responsibilities), to information (sources, information medium, format) and to the capabilities of the people who deal with management costs. Figure 4 represents the relationship between these factors to provide the necessary conditions for the management of product Life Cycle Costs in the PDP.

The formal processes of managing LCC are important in so far as which activities and tasks to be carried out are concerned. For example, the management process defines who is responsible for determining the product target cost, who should detail the cost to the systems, subsystems and components, who the people in charge of maintaining information databases concerning costs data (historical, from the market, from partners, etc.), that are necessary to take decisions and make sure trade-offs are made considering the whole product life cycle. The processes certainly define activities and tasks not only in terms of product development teams, but also in terms of their interaction with other sectors of the company such as Manufacturing, Supplies, Customer Services, the Finance Department, etc., without whom it would not be possible to take decisions confidently (especially engineering ones) concerning the implications of product life cycle costs.

With regards to information, it is worth remembering an important aspect: it should be available to the user in the quickest, most relevant and intelligible way possible. Besides, the way in which information about costs is available should meet the needs of those who use it at each stage of the PDP. As the project develops, information should be detailed. Furthermore, it is not just a question of IT (Information Technology) application. IT alone does not guarantee that the necessary information is available in an adequate way. According to GOLDMAN (2002), while almost 100% of IT investments are intended for structuring the management of information only 20% of the decisions are taken based on this information. Most of the decisions do not have a structured grounding: articles in journals and on the Internet, exchange of information with suppliers and clients, evaluation of consultations and published work, processes of reading documents, brainstorming and planning studies, to sum up, never-ending sources of circulating information.

This fact certainly makes the decision process more complicated and uncertain. Perhaps this explains the enormous growth of a research area called 'KNOWLEDGE MANAGEMENT'. Emphasizing this point, ARRINGTON (2002) affirms that companies look for Information Directors that are not only knowledgeable about technology, but also business, the company and what affects the final results.

Finally, the management processes concerning the LCC which are formally defined and incorporated into the PDP

or that have quick and precise information about the most varying product costs are no use without having trained people to carry out such processes efficiently and make good use of the available information. In order for this to happen, a 'culture' related to costs needs to be created or improved. This means not just preparing an engineer to confront issues regarding the dimensions of a component, the choice of a material or simulation of a system in operation. In the face of different alternatives to a project, he should also be capable of being able to take a position in relation to product Life Cycle Costs. In other words, choosing a specific supplier of a component is not something that only concerns the function of this component in operation or at least its price. This choice requires an analysis that transcends the more immediate aspects concerning a project, those that are more exposed.

This analysis should consider if there is economy or rationalization of the productive processes, if operating the product is cheaper, if the maintenance costs are not affected in terms of the choice of this or that material, component or supplier, if there are other requirements concerning the market, clients, legal issues, etc. affected by this choice and also if such an alternative meets the economic objectives of the company. In short, there should be training, awareness and involvement of the people responsible for the decisions of the project regarding the role of the PDP as one of the most capable business processes to provide the company with expected results and not a process of just developing a product.

6. How to develop a LCC Management Model

A Cost Management Model cannot be something separate from the PDP. Many management activities are closely linked to the PDP itself. Actually, the Cost Management Model activities are a subprocess of PDP. Therefore, the activities related to the management costs should be incorporated into the existing PDP model. The PDP model of the company should actually be improved so that one of its aims can be met (among others equally important) which is to guarantee that the product life cycle cost complies with the limits stipulated in the Business Plan, without committing other aspects such as quality, time, logistics, the environment, etc.

How should this be done? Developing or adapting a PDP model is not an easy task. Moreover, improving it also requires preparation and planning. According to ROZENFELD (2000) one of the biggest difficulties of administering the PDP is the existence of partial visions of this process or, in other words, similar to an engineer who has a specific vision concerning the PDP regarding calculations, drawings, etc., other professionals also see things in their own way, business, finance, marketing, etc. Therefore, the ideal would be to capture all these visions when defining the Management Cost Model.

As was already confirmed, the main questions related to the preparation of this model refer to three main aspects: processes, information and capacity. Therefore, an effort to extract impressions related to these questions from these partial visions should be made. However, how can this be done? Firstly, it is considered that the involvement of the people directly related to costs management and the PDP is of fundamental importance for this work to be carried out. In other words, who better than the person who deals with day-to-day administrative questions can say what is missing, what is difficult and what is not working. This does not mean that the participation of people outside the company in terms of consultancy is not welcomed. On the contrary, such participation could be fundamental, but it should be limited to planning and conducting the research work inside the organization with people from the organization and not be either determined or told what should be changed or how it should be done. Therefore the work is very linked to Action Research (see THIOLENT, 1997). Secondly, to get the best impressions related to the questions,

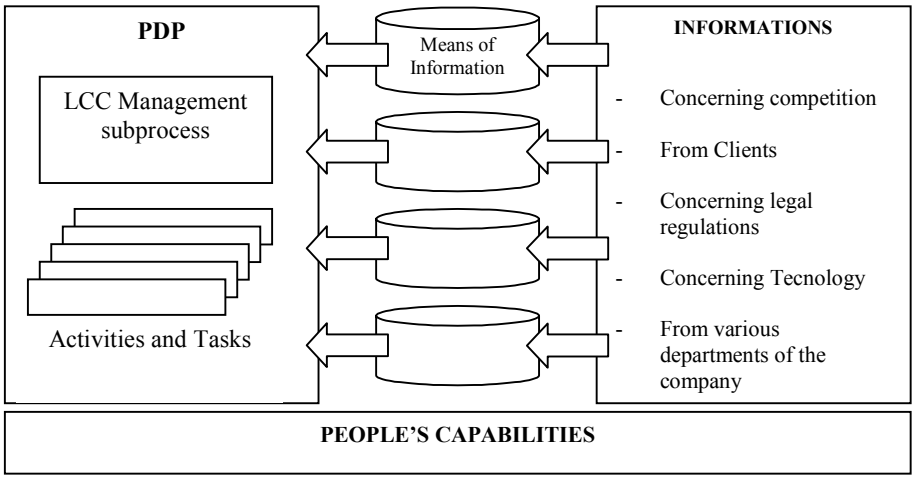

Figure 4: Key factors to LCC management.

which have arisen, are dealt with, people to be interviewed should be chosen carefully, as well as defining the answers diagnostic and analysing methods. Preferably, the interviewees should have management experience inside the company. Therefore, there will be a better chance of the collected impressions and statements contributing to the improvement of the management cost process which briefly is an eminent management process and which at certain stages is carried out by top professionals.

Obviously there are many other strategic concerns in a participative research process such as this. For example, how to make people notice the importance of being engaged in their work, to report about the process or to see results.

There are also operational concerns such as how to choose the research team, to draw up questionnaires, etc. These details related to Action Research are looked at more closely in the bibliography.

It is important to mention that in such work many different options are suggested. Most of the time, it is not worth tackling them all at the same time, however it is important to establish priorities. By analyzing the interviews, it should be possible to identify what the main concerns are of those involved in cost management of the product in terms of establishing the first stages in the construction of the model. Finally, an answer to the questions which have already arisen should be sought: which activities should there be concerning cost management at each stage of the PDP, for whom should they be and how, and which information is needed.

Figure 5 represents the incorporation to the PDP of the management cost subprocess. With regards to the management subprocess of the LCC at each stage of the PDP, the target costs, which defined the last stage, should be detailed. Thus at each new stage, when taking a decision, the established cost limit for each system, subsystem or component (in terms of the target life cycle cost of the product) should be known. In order to evaluate the impact of each decision concerning the LCC, models of estimated costs suitable for each stage of the development should exist, whether or not more detailed information related to the project is available. In situations in which, at a certain stage, the estimated cost extrapolates the target cost of the product or system, new alternatives should be analyzed. Furthermore, it is possible to redistribute target costs between systems as far as the total LCC of the product being maintained within the set limits is concerned. The comparison of the estimated LCC to the target costs of the systems and components works as a 'check', which facilitates going from one step to another in the PDP.

As previously seen, it is worth remembering that the more advanced the development of the product is, or in other words, near the end of the PDP, the more implications of changes to costs and time limits there are. On the other hand, the earlier an alteration is made, the quicker, easier and cheaper it will be.

7. Conclusions

Defining a Life Cycle Cost management process is no different to defining a process of calculating the dimensions of each component of the product. Concerning the dimension calculation, the following should be defined: who the responsible people for the calculations and drawings are, what the calculation methods to be used are, what activities and corresponding tasks and which information is needed to obtain a result. We are completely certain that the parts will resist the efforts in terms of what would be possible to manufacture and assemble, or in other words, that the best option was chosen.

However, the product costs are not limited to the development costs, manufacturing and assembly, initially extended to the company and afterwards passed on to the client. There are other costs involved when obtaining the product, such as operation and maintenance costs, as well as others which extend to the society, such as costs concerning the degradation of the environment related to the operation of the product and its disposal (air pollution, water, soil, etc).

It was shown that all of these costs, called product Life Cycle Costs – LCC are directly related to the PDP as far as the decisions taken when the product is being developed are concerned. In other words, what is going to determine whether or not the product will be attractive to the client in terms of cost are the decisions taken when the product is being developed. This also happens to other characteristics such as performance and reliability, etc. Therefore, it is clear that in the same way that a development model has activities, information and responsibilities concerning the choice of material of a certain product component, it should also determine who the people responsible for the evaluation of

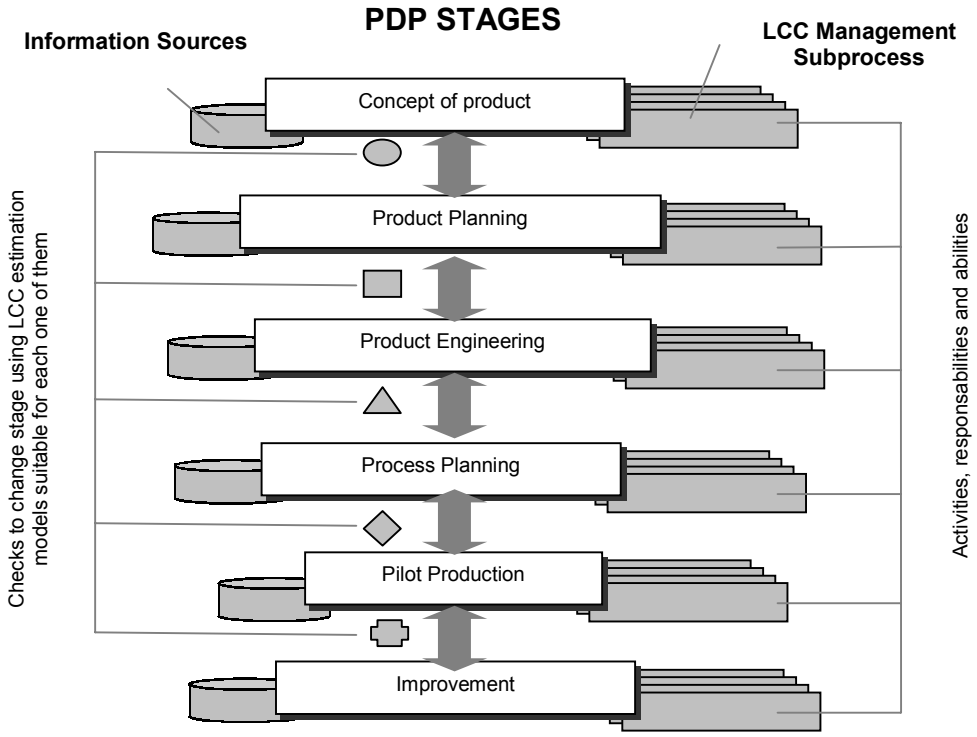

Figure 5: LCC management subprocess, Information sources and Stages in the PDP

product Life Cycle Costs are, according to this definition. Moreover, it should also determine which cost estimation methods should be used, which corresponding activities and which information is necessary for this process (with as much certainty as possible) in order to make sure the chosen alternative suggests a lower LCC considering what was defined in the Business Plan and without committing other aspects such as quality, for instance.

In the same way that a decision concerning the choice of material (it could be inspected in terms of resistance, performance, etc), the project should also be inspected in case the cost resulting in such a decision implies a higher value than the target cost set for a component, subsystem, system or product. The process is iteractive, to be repeated as many times as necessary so that, apart from the costs, other attributes concerning the product can be reached, such as Quality, Design, Logistics, the Environment, etc.

Thus, one can admit that the Cost management of the product life cycle presuppose a set of organized activities and information that consists of a product development subprocess, in the same way that quality management, requirements management, time management, etc during the development of a product can also be considered as subprocesses of the PDP.

How to arrange an efficient structure, which allows appropriate cost management in the PDP is another challenge. There are many factors, which can facilitate or hinder this composition, such as the level of development and complexity in the existing PDP, the organization culture and the level of staff training in the company, among others.

It is known that at least two ways of intervening in an organization exist: the first is consultancy, in the case where people outside the company diagnose a problem, propose measures and finally are informed of what is happening until the end and when results can be seen; the second way of intervention is whereby people from the company are involved both in the organization of a project as well as the implementation or improvement of a process concerning its evaluation.

This second way of intervention was suggested because the involvement of people who participate in the processes to be evaluated is fundamental in terms of the fact that they are the most knowledgeable about the processes. Many people can accompany them maybe since the beginning of the company's activities. Who better than these people to witness and to point out defects and opportunities to improve, as they are well informed and prepared to take part in participative research? How long would an external consultant

need to acquire only a small part of the company's philosophy which these people identify with, in which every tool and training they can have counts? The Action Research can be presented as an effective method to identify opportunities of improving the product development process and to propose practices of the product cost management of its life cycle. The influence of a company's characteristics during the development of a management model of LCC can be empowered or diminished if the development of this model is the result of a joint effort between a group of people with the capacity to conduct this process, external or internal to the company to clarify the importance of the project to the rest and giving evidence to actions and results, and a working group, from inside the organisation, preparing to carry out all the operational tasks to encourage interviews and to support diagnostic and analytical actions of the collected impressions.

The cost management model of the product's life cycle, as a subprocess of PDP, will only have credibility and the chance to be implemented successfully if it was the result of the composition of the most varied opinions, evaluations and suggestions of improvements from people that know the organisation and the business.

References

ARRINGTON, R. **Executivos de TI conquistam espaço**. www.investews.com.br, 2002.

BUSS, C. O., CUNHA G. D. **Modelo Referencial para o Processo de Desenvolvimento de Novos Produtos**. XXII Simpósio de Gestão da Inovação Tecnológica, Salvador, 2002

COGAN, S. **Custos e Preços – Formação e Análise**. Editora Pioneira, São Paulo, 1999.

CLARK, B.C. and FIJIMOTO, T. **Product Development Performance: Strategy, Organization, and Management in the World Auto Industry**. Harvard Business School Press, Boston, 1991.

CROW, K. **Product Cost Management Through Integrated Product Development**. DRM Associates, 1997a. Product Development Forum Home Page, 31/01/2000.

CROW, K. **Target Costing**. DRM Associates, 1997b. www.npd-solutions.com, 31/01/2000.

GOLDMAM, I. **De olho no Mercado da Informação Estruturada**. www.aliceramos.com, coluna Softworld, 09/12/2002.

COMPTON, T.D. and ELIAS, N. **Activity-Based Management**. www.atkinson.yorku.ca/~garys/abky15, 26/12/2003.

KOTLER, P. e ARMSTRONG, G. **Princípios de Marketing**. Livros Técnicos e Científicos Editora S A. Rio de Janeiro, 1995.

KRISHNAN V. and ULRICH, K.T. **Product Development Decisions: A review of the Literature**. Management Science, Vol. 47 N.º 1, 2001.

MAXIMIANO, A.C.A. and RABECHINI R.Jr. **Maturidade em Gestão de Projetos – Análise de um Caso e Proposição de um Modelo**. XXII Simpósio de Gestão Tecnológica. Salvador. 2002.

PMI – PROJECT MANAGEMENT INSTITUTE. **Compendium of Project Manegement Practices**, 2003. www.pmi.org., 26/01/2004.

ROZENFELD, Henrique. **Modelo de Referência para o Desenvolvimento Integrado de Produtos**. In: ENCONTRO NACIONAL DE ENGENHARIA DE ENGENHARIA DE PRODUÇÃO (17. :1997 :Gramado, RS). Anais... Gramado: UFRGS, 1997.

ROZENFELD, H. Núcleo de Manufatura Avançada Home Page. www.numa.org.br, 2000.

RUSH, C. and ROY R. **Analysis of cost estimation process used within a concurrent engineering enviroment throughout a product life cicle**. Proceedings of CE 2000 Conference, Lyon (France).

RUSH, C. and ROY R. **Capturing Quantitative & Qualitative Knowledge for Cost Modelling within a CE enviroment**. ISPE International Conference on Concurrent Engineering: Research and Application. Los Angeles (USA), 2001.

STERLING, J.C. Analysis of Life Cycle Cost Models for DOD & Industry USE in 'Design-to LCC'. http://nissd.com/sdes, 20/08/2001.

THIOLENT, M. **Pesquisa-Ação nas Organizações**. Atlas, São Paulo, 1997.

TOLEDO, J.C. **Gestão da Mudança da Qualidade do Produto**. Revista Gestão & Produção, UFSCar, v.1, n.º 2, p.104-124, 1994.

WEUSTINK, I. F., BRINKE E., STREPPEL A. H. and KALS H. J. J. **A generic framework for cost estimation and cost control in product design**. Jornal of Materials Processing Tecnology. Elsevier Science S A, 2000.