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AND MANAGEMENT IN INDUSTRY
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Doctoral Dissertation
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Title:
IMPLEMENTING AN OBJECT-ORIENTED METHOD
OF INFORMATION SYSTEMS FOR CIM
TO THE MEXICAN INDUSTRY

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Warsaw, Poland - San Luis Potosí, México
May 1997

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## CHAPTER I. INTRODUCTION.

As the process of globalization advances in the world, there is an increasing need for companies to compete and be more efficient to respond fast to the challenges of a global market and international competition. The mexican process of globalization started a few years ago with the creation of NAFTA, and this has increased the pressure to mexican companies to be more efficient and capable to compete with international companies. The use information systems and advanced manufacturing technologies is crucial to achieve an efficient operation to respond fast to the changes that occur in the international manufacturing environment. This thesis presents a method for implementing information systems for CIM in the mexican manufacturing environment, this work provides a framework to build integrated information systems which can help mexican companies to become more efficient in their operation and this increased efficiency could reflect in a faster response to customers, lower operation costs and an increased capacity to adapt to the international competition. Bellow an introduction to each chapter of the thesis is presented.

Chapter 1 presents an introduction to the thesis and to the concepts and fundamentals of the thesis. Starting with an introduction to the process of globalization of manufacturing and then presenting the mexican process of globalization and a general introduction to the mexican manufacturing environment. Then presents a general overview of the international manufacturing environment and the concept of CIM (computer integrated manufacturing). This chapter then explains the role of integrated information systems in the concept of CIM and an introduction to object-oriented technology for developing information systems. Next this chapter presents the benefits of applying information systems in mexican manufacturing companies. Finally this chapter presents the hypothesis and objectives of the thesis.

Chapter 2 which is called CIM In the World, presents an introduction to the concept of CIM, it also explains the models of CIM that have been used, and how they have evolved form an Automated Factory to an Integrated information systems model.

Chapter 3 entitled The Mexican Manufacturing Environment, presents an analysis of the mexican environment. This chapter presents some information about the structure of the mexican manufacturing sector. It also presents the situation of CIM in mexican companies, and the problems related to information systems operation that are present in México.

Chapter 4 entitled Object-Oriented Methods presents four of the most commonly used object-oriented methods, starting with an introduction of the general structure of object-oriented methods, next this chapter presents in alphabetical order the Booch-Method; the Coad, Yourdon and Nicola method, the Objectory Method, and the Rumbaugh object modeling technique. This chapter finishes with some conclusions and a comparison of the methods.

Chapter 5 entitled A Method For Implementing Integrated Information Systems For CIM in México, presents a method for building an information system with object-oriented techniques. Starting with the evaluation and justification phase in which the scope of the information systems is defined. Next the analysis phase is presented, following with the Simplification phase in which the analysis is refined. Then the Design phase is presented in which all the objects of the information systems are designed. Finally the Integration phase is described in which all the information systems will be integrated.

Chapter 6 presents a prototype implementation of the method. In this chapter an example of the application of all phases of the method in a specific company is described, beginning with a description of the company, and then presenting all the detail of the application of the method in this company, finishing with the results obtained in the company after aplying the method.

Finally chapter 7 is the chapter of the conclusions of the thesis. This chapter presents the conclusions and comments from the work, as well as some comments about the future trends in methodologies for developing information systems for integrating companies. This chapter also suggests future lines of investigation which could emerge in the future as technology in information systems evolves.

## I.1. THE GLOBALIZATION OF MANUFACTURING.

The process of globalization is advancing in the world as protecting measures are going down and the need to compete increases. After the second world war, the Japanese started their process of reconstruction and faced the need to import all energy and raw materials and to rebuild their industry [1] , thus orienting their industry to export markets. While in the US and Western Europe their focus mainly remained in the local markets which were big enough and companies did not had to worry about exporting.

Western companies oriented to local markets remained in methods of mass production and adopted more slowly the quality principles as they had a market of consumers [2]. While the Japanese started to work as efficient and simple as possible because of the limited resources they had, and as their attention was mainly focused on the export market they adopted faster the quality principles. So companies in the US and Western Europe began to worry about the export market since their local market share had been reduced and would continue to do so if they did not responded. Around 1970s the Western companies began to react but their focus remained in cutting direct labor and controlling the complexity of their operations and quality inspection, while the Japanese were focusing on continuous flow manufacturing (or JIT) and building quality products from the beginning, so the process of expanding for the Japanese continued and the process of losing local market continued for the west. So this increasing competition lead western companies to look out for new markets, which accelerated the process of globalization, this also implied to look for other places for manufacturing their products where they could have cheap labor thus lowering their costs and increasing their opportunity to compete.

Today free trade, open markets and globalization of manufacturing and businesses have influence in almost every country of the world, the developments in communication, computers and transportation have accelerated the process of globalization and we can really say today that there is almost no place to hide from international competition [3]. This of course has benefits and drawbacks, companies have access to international markets and at the same time face international competition from all over the world.

## I.2. THE MEXICAN PROCESS OF GLOBALIZATION.

The creation of NAFTA has brought a new condition in México creating a manufacturing trade block in North America.

Mexican plan since 1989 had three components [4]:

1. A social consensus called "el pacto" to break the inflationary inertia.
2. Restrictive fiscal and monetary policies to eliminate the original causes of inflation.
3. Trade liberalization, privatization of state-owned enterprises and government deregulation.

All this points were successfully carried out and lead to the creation of NAFTA which started to function in 1994. But since México opened the frontiers it began importing a lot of products which lead to the loss of many domestic companies, this also lead to a negative balance between imports and exports.

México delayed the change in the value of the peso because of the change of presidency which lead to a financial crisis in December 1994. In 1995 the value of the peso is half of the value of 1994, and this is an opportunity to export. Today there is no going back, mexican manufacturing companies have to be oriented to exports.

The creation of the NAFTA agreement, among others, give mexican companies the possibilities to have deep connections with foreign companies. If the companies do not take advantage of that situation they will lose international market opportunities. Mexican companies are now reacting to this process of globalization either because they see market opportunities or because they have lost part of their local market share.

Now mexican companies have to compete with international companies, and international standards of efficiency are the criteria for success. This means that if a mexican company wants to succeed in the global market they must be as efficient as international companies and they must provide cost effective products with the international standards of quality [59].

## I.3. THE MEXICAN MANUFACTURING ENVIRONMENT.

The mexican manufacturing environment is characterized by a lot of small companies (about the 98%) and the rest are medium size and big companies (about 2%). Big companies generate about three quarters of the income of the manufacturing sector and employ almost two thirds of the work force [53].

This creates a mexican manufacturing environment in which very few big manufacturing companies are the most important part of the economy. While there are a lot of small companies that are less efficient and productive than the big companies that generate only about one quarter of the income of the manufacturing sector.

So in general the picture of the manufacturing sector shows that small companies have lower efficiency than big companies, which are of course less prepared to compete in an open economy where competition of foreign companies is increasing. So there is a need to increase the productivity and efficiency of the small companies in order to have the possibility to compete and also to cooperate with international companies [55].

In order to make small companies in mexico more efficient, they need to adopt technological advances in the areas where a small investment makes feasible to apply a technological improvement [52]. One of the technologies that is feasible to apply to small manufacturing companies is the technology of information systems which could help the small companies to take decisions and be more efficient with a moderate investment in information systems [54]. More facts and detail of the mexican manufacturing environment will be given in chapter 3, where the situation of the mexican manufacturing environment will be examined.

## I.4. INTERNATIONAL MANUFACTURING ENVIRONMENT.

Manufacturing companies are immersed in a competitive international environment. Some of the characteristics of this environment are the following [5]:

- increased competition
- customer requires high quality products
- shorter product life-cycle
- pressure to offer lower prices
- more customized products

In the mexican industry these factors have had an increasing impact in the recent years because of the free trade agreement and the need to maintain a good balance between imports and exports. Companies need to respond to these challenges of the international market, these involves several strategies and actions, among some of them are the following [6]:

- improve product and process quality
- better customer support
- reduce costs
- design and manufacture new products in a short time
- faster response to market changes
- flexibility in the production process

These strategies and actions, should not be implemented isolated from each other, rather they should be integrated along the enterprise to achieve a fast respond to the market. As the need to integrate companies was recognized, the concept of CIM (Computer Integrated Manufacturing ) was developed around 1980s in Europe and has extended to America and Asia [7].

## I.5. (CIM) COMPUTER INTEGRATED MANUFACTURING.

The concept of CIM integrates all the functions of a company including product design, production, marketing, and the administrative functions of a business. One of the first approaches to CIM was to create a highly automated factory, in which there were interconnected computer systems to control machinery for production [18]. These approach of course meant a significant reduce of human labor. However this approach did not make automated factories significantly more competitive, efficient or productive. The problem was that computers could not plan for new products, respond to a changing market or take decisions.

A second approach to CIM around 1985 was to focus on the information that the people need to do their work. In these approach an integrated information system, together with some automation of the factory, was the key to the increased competitiveness. Some premises of this approach are the following [8]:

- to have the correct information
- that the information has the quality and format required
- the information needs to be in the precise moment when it is needed
- the information needs to be in the place where it is needed

A third evolution of CIM in the 1990s focuses on the customer, and the forming of teams in the organization to achieve a high response to customer needs and a highly efficient operation of the factory. Of course the information systems in this approach gains further relevance as a means of communication between people around the company. Some of the premises of this new approach are to focus on [9]:

- always be oriented to the customer
- the relevance of people and decision making
- forming teams in the organization
- improve the process of the company

The core element of a CIM system is the information system and the databases associated with it, because that are the elements that integrates the different manufacturing technologies and the administrative systems of the company, so information technology plays a very important role in the manufacturing strategy of a company [10].

## I.6. THE ROLE OF INTEGRATED INFORMATION SYSTEMS IN THE CIM CONCEPT.

From the previous discussion we can observe that a company that needs to respond fast to the competitive environment must be tightly integrated, this integration means linking all the functional areas of a company so that information flows in a continued manner and can be used to respond fast to the market. One of the key concepts in a manufacturing strategy is integration, in the sense that the information generated in one area of the company can flow to other areas were it would be useful, so that all departments of the company can have accurate information on time to do their job faster [57].

The technology of information systems has also a very important role in the chains of activities of a manufacturing company [11], because all activities of value create and use information. Information systems are used in the programming, control, optimization and measuring of other activities of the company, for example internal logistics uses some kind of information system to control materials, send products to customers, etc, in the same way information systems are involved in the processing of orders, administration of suppliers, etc. Also information systems are important in the interconnection of all the activities of the company because each activity requires coordination and to transfer information with other activities, so information systems can help in optimizing the synchronization of activities.

The information system is the infrastructure for implementing CIM and other advance manufacturing technologies, so that the company does not have islands of information or islands of automation. But this integration does not imply that there has to be a real time link between every machine of the company because this would be very complex and expensive for many companies. The integration should mean that the information should flow when it is needed to other parts of the company even if in some parts it would be done manually as the following quote says "users should not feel they have to build a bridge between each island when a daily ferry service might do instead" (Hartland-Swann,1987) [12]. This comment warns us about over-integration because there is a trade-off between integration and flexibility because if a systems is highly integrated it is at the same time more difficult to modify.

Enterprise-wide software projects are complex and difficult to develop because of the size of the projects and the integration of many departments of the company [58]. Object-Oriented technology provides a tool for developing software projects which can be developed with a modular structure reusing software components which are common to several modules.

## I.7. OBJECT ORIENTED TECHNOLOGY FOR DEVELOPING INTEGRATED INFORMATION SYSTEMS.

The term "object-oriented" means that we organize software as a collection of discrete objects (object is a single thing or concept as distinguished from another thing or concept) that incorporate both data structure and behavior [30] .

Object-Oriented technology is based on identifying objects within an enterprise and the ways in which the objects interrelate and also the events that occur among those objects which change the state of the objects in time [13]. This type of analysis is very useful in a manufacturing environment where there are many different types of objects in each different department of the company.

Object oriented development has the characteristic of abstraction in which it is possible to use an object, hiding the implementation details of it. Another key characteristic of object orientation is inheritance, which permits an object to inherit the properties of another object. These two characteristics enable users to develop software as building blocks, reusing existing objects, this provides a development environment suitable for development projects. These characteristics of object orientation and the object-oriented analysis flexibility make object oriented techniques useful for implementing integrated information systems for CIM [14] because they provide the flexibility to model all the functions of an enterprise and provide the possibility to adapt the systems fast as the company evolves.

But just doing an object-oriented analysis of the functions of a company is not enough and we have to be very careful in what parts of the company are we integrating ,we also have to be careful not to automate processes that are inefficient or cumbersome because the automation would just help to do wrong things faster. This suggests that there should be a phase of simplification of the processes of the company before trying to automate or integrate them, this is where the use of reengineering [15] could be very helpful as a tool for simplification of the processes of the company before trying to implement the software systems.

## I.8. THE BENEFITS OF INFORMATION TECHNOLOGY IN MEXICAN MANUFACTURING COMPANIES.

Mexican manufacturing companies have to become more competitive in a open market, but there are many financial limitations and just going directly to an automated factory would be almost impossible and does not guarantee success. So mexican companies have to become more efficient with moderate investments and implementing technologies in time phases that permit the return on the investment [36 ].

Moreover with the actual currency value is very expensive to import robots or automated flexible manufacturing machines. But companies could use their existing machines are workforce more efficiently and reduce costs by simplifying their process of production and using information technology to integrate the companies functions with a moderate investment. As continuous flow manufacturing with Group Technology and fast-change tooling using conventional machines could be equivalent to a flexible manufacturing system [16] . So the use of information technology with simplified manufacturing processes using conventional machines could improve the performance and efficiency of mexican companies requiring a moderate investment.

Actually in México our most cheap resource is labor as advanced manufacturing machines have to be imported. So the development in a company of an information system with mexican engineers is one of the cheapest technological solutions a mexican company can afford to become more competitive (assuming that the processes are simplified). So this thesis defines a method for mexican companies to implement integrated information systems for integrated manufacturing, so that the companies become more efficient and productive to compete in the global market, as an integrated company generally can do more work than the sum of the work of their individual departments.

## I.9. HYPOTHESIS AND OBJECTIVES OF THE THESIS.

Taking into account the international manufacturing environment, the mexican process of globalization and the possibility to use integrated information systems to improve the efficiency of mexican manufacturing companies the following hypothesis and objectives of the thesis are presented below:

Hypothesis:

1. There is a need for a method for developing information systems for CIM in Mexico, because foreign methods do not take into account the characteristics of the mexican environment.

2. Integrated information systems can help manufacturing companies become more efficient and to integrate their functions.

3. Object oriented techniques can be used for implementing information systems for CIM.

Objectives:

1. Analyze the problems of operation related to information that exist in the Mexican small and micro manufacturing companies.
2. Develop a method to implement integrated information systems for CIM in Mexican manufacturing companies.
3. Obtain a strategy for implementing these systems in the Mexican manufacturing industry.
4. Evaluate the performance of the method within an organization.

## CHAPTER II. CIM IN THE WORLD.

### II.1. INTRODUCTION TO CIM.

The term "CIM" appeared in 1973 in Harrington's book "Computer Integrated Manufacturing" [17]. Terms like CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing) and PPC (Production Planning and Control) are also mentioned in this book as part of the concept of CIM. As a result, CIM was understood initially as the addition from CAD and CAM.

CAD has become an important documentation, but not design tool; many people still perceive CAD just as a drafting tool. In a similar way, CAM has been restricted to numeric control machining, in spite of some marketing literature claims. Machine tools are still programmed one at a time, independently one of each other, and without an adaptive feedback.

CAM has been expanded to support a wide range of clerical, traditional, and business-oriented manufacturing management functions. Today shop-floor control applications work with manual inputs, disconnected from the machines and process they are supposed to manage.

The YCIM Model appeared in 1988 [18]. Computer Integrated Manufacturing (CIM) results from effective integration of the information resources in an industrial enterprise. These information resources come from technical and operational tasks. The operational tasks in CIM are frequently referred as the production planning and control system (PPC), and they are represented in the left fork of a Y. The more technical tasks are depicted in the right fork of this Y, as seen in figure 2.1.

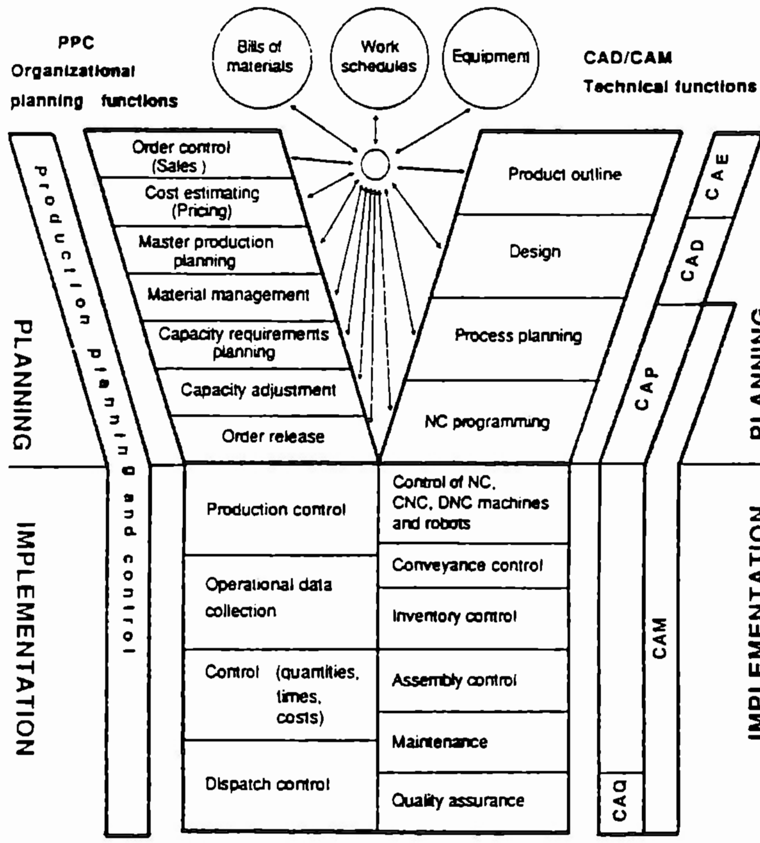



Figure 2.1. The YCIM Model by Sheer [18].

The order handling determines the PPC, while the CA- components support product description and resources. Both systems provide information to other administrative areas, like cost accounting.

An important feature of CIM is the integration of data and operations. During this century Taylorism dominated the management and organizational design of organizations, so the functional structure divided work, responsibility, authority and information in a very efficient way for a typical organization until the last decades [60 ]. There were not effective information systems that could help to manage the complexity arisen from a big factory, so the most effective way to reduce complexity was through work division.

A high throughput was obtained within the sub-processes, but there was a need of better coordination and communication between the production units. In some cases 70% - 90% from administrative order handling and production process time is occupied for communication and lead-in. This wasted time means higher inventories, less consumer-oriented flexibility, and lower responsiveness.

Today's advanced information systems can help to cope with complexity. With a common database a factory can get information updated immediately, so the time traditionally needed for communication is drastically reduced. More and more often information systems are now based on common databases, so if processes are integrated in an information system the complexity is reduced and the need for work division is eliminated. Both data and process integration at the workplace lead to the high rationalization potential of CIM.

In a typical organization there are computers in use, but the information is isolated in each department, and communication between them often takes place on paper. This means a waste of paper, time, and an information degradation. In a CIM process chain both data and process are integrated.

A common and integrated CIM database can mean tremendous benefits, because the information can be used for many purposes. For example, from the geometric data of a part can be extracted useful information to generate the bill of materials. The part designer can query the tool and machine database to verify if there is an available drilling system. Data from the CAD system can be used to program the NC machines. At the same time marketing, design and process planning can be more closely connected.

The introduction of CIM raises the areas of design and product development as a very import decision-making center: material requirements are established, the choice between in-house production and external purchasing is influenced, and the production method is determined. There are a very wide number of possible data links and uses for the information in the database, and there are many which have to be seized yet.

CIM implies changes in organization and the connection of all the information flows within the enterprise in a unified information system. The entire information flow from order receiving to product delivery is a unified task. The benefits from CIM can be reduced costs, fast order processing, less inventory, greater order accuracy, and faster delivery. However, the design and implementation of CIM are very complex and require comprehensive organization, computer-technical and production-technical knowledge.

CIM involves the following:

- an application-independent data organization, so every organization area can have easy access to the unified data base information. This unification would eliminate redundant data; e.g., there would be only one part specification within the enterprise.

- Consistent process chains, so they are closely connected, independently of natural organization structures. This connectivity means, of course, tightly coupled information flows within the organization.

- Small feedback loops, so planned-actual comparison can be made continually so corrections could be realized quickly.

II.2. THE ORIGINAL CIM WHEEL MODEL.

The original CIM wheel model presented in **Figure** was developed in 1985 by the Computer and Automated Systems Association (CASA), a division of the International Society of Manufacturing Engineers (SME) [19].

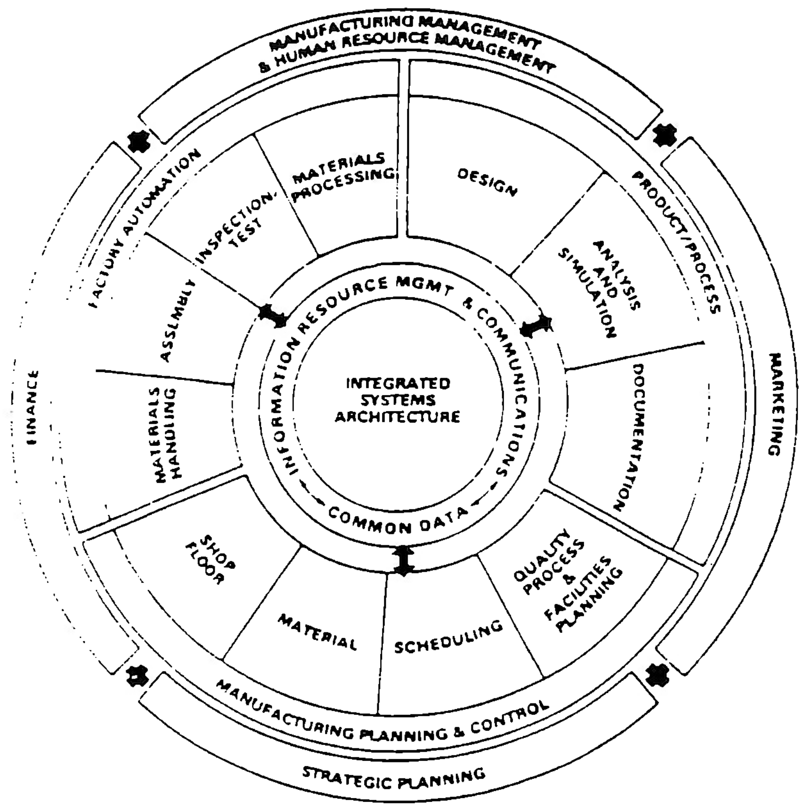



Figure 2.2 The CIM wheel model (CASA/SME) [19].

This wheel was centered on an integrated systems architecture and was recognized as a model of "best practices." This wheel had five mayor components:

a) general business management.

b) product and process definition.

c) manufacturing planning and control,

d) factory automation.

e) information resources management.

The expected benefits from this model were increases in design and product quality, and on overall productivity. On the other side, it was expected to reduce product development times, lead times, inventories, and direct labor costs.

Few years later American enterprises began to suffer the aggressive competence from other international companies, specially Japanese. These companies applied a radically different approach; they mainly focused on the coordinated effort of their people, rather than automation and integration.

There were proposals to address the fierce competence issue, like the Thacker's CIM model [8], but a more comprehensive and integral perspective would be developed by CASA/SME in 1993 [9], with the Manufacturing Enterprise Wheel model. Both, Thacker's model and the Manufacturing Enterprise Wheel will be detailed later in this paper.

II.3. THE THACKER'S CIM MODEL.

The CIM Model or CIM Cone proposed by Thacker in 1989 [8] joins two models: The classical functional management triangle (hierarchycal organizations) [8] and the CIM wheel[19]. The CIM model combines both into a three-dimensional cone, which is shown on fig.2.3.

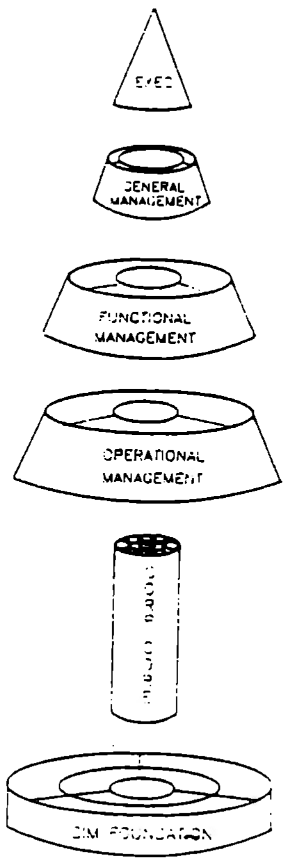



Figure 2.3. The CIM model proposed by Thacker [8].

The need of this combination came from the difficulties to implement the tradition CIM wheel. The problems raised from the lack of communication and integration between the different managerial levels. The main feature of this model is to integrate the efforts from all the managerial levels within the enterprise in an effective way.

The classical managerial triangle shown in figure 2.4. implies a mapping between organizational, planning and responsibility levels, which is shown in third

**Table 2.1.**

| **Organizational Level** | **Plan Level** | **Responsibility Scope** |
| --- | --- | --- |
| Executive<br>General | Conceptual Plan | Mission<br>Goals<br>Direction |
| Functional<br>Operational | Logical Plan | Objectives<br>Strategies |
| Functional Personnel | Physical Plan | Tactics<br>Actions |

There is a functional flow between the organizational levels. Top management, at the executive general level, generates ideas expressed through a mission, goals and other directives. Middle management, at the functional operational level, generates detailed controls to implement these ideas. Those controls are communicated to lower levels through objectives and strategies. At the bottom of the organizational levels is the functional personnel level, who implement the tactics and actions needed to reach the stated goals in upper levels. This is a closed cycle, because top management gets feedback from the bottom level actions.

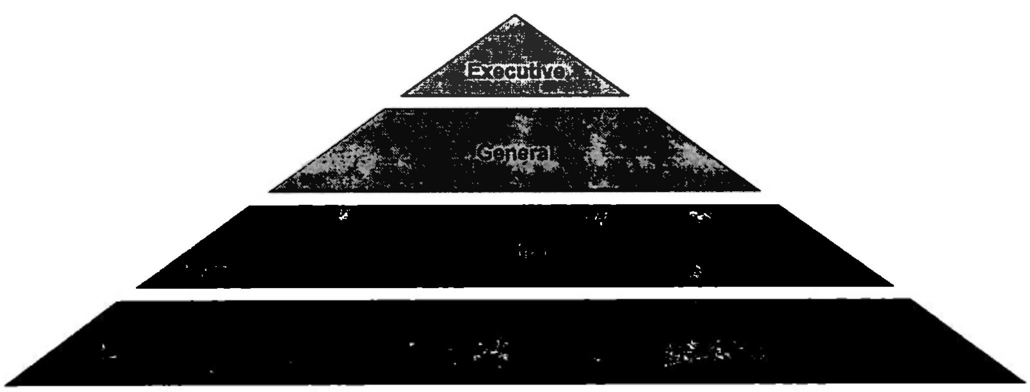



**Figure 2.4. The Managerial Triangle, by Thacker [8].**

The conceptual plan determines holistic requirements and develops conceptual architectures. The conceptual plan supports the synergy that potentially could be obtained from the resources integrated activities.

The logical plan is used to organize the functional elements as developed in the conceptual architectures. Information flows, management chains, decision making processes, support systems, manufacturing processes and systems are the elements needed to organize and implement the conceptual architecture; they must assure the information quality and availability to the other elements. This plan shows how to plan and control the business.

The physical plan specifies detailed requirements, such as hardware, software and database. It becomes the implementation plan for the enterprise.

II.4. THE NEW CIM WHEEL MODEL

The new CIM Wheel Model was developed in 1993, and was named "The Manufacturing Enterprise Wheel" [9].

The new model was centered on the customer and was more environmentally aware.

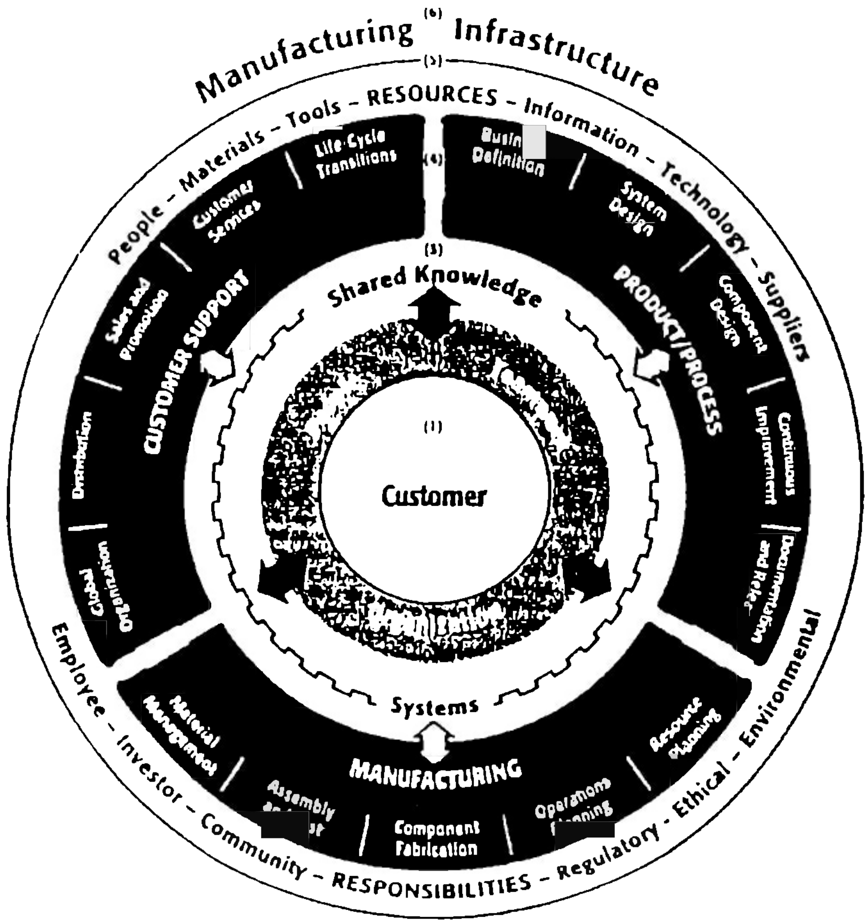



**Figure 2.5. The New Manufacturing Enterprise Wheel (CASA/SME) [9].**

The new wheel established six key areas for competitive manufacturing:

a) the customer,

b) people and teamwork in the organization,

c) shared knowledge

d) processes

e) resources and responsibilities,

f) the manufacturing infrastructure.

Each of these key areas will be explained further in the next paragraphs.

a) Customer

The old wheel (see figure 2.2) was production-oriented, while the new wheel (figure 2.5) is customer-oriented. Customer is the new center in this wheel. Whole enterprise efforts must be aligned on a customer oriented mission, because long term profits and growth can be achieved only when customer needs are met or exceeded.

b) People and Teamwork

People and teamwork importance are honored as the most important enterprise's resource to achieve total customer's satisfaction. This ring includes the following activities to ensure teamwork and cooperation [9]:

- organizing,
- hiring,
- training,
- motivating,
- measuring,
- communicating.

Also, there are new concepts introduced in this ring, such as:

- self-directed teams,
- teams of teams,
- learning organizations,
- leadership,
- metrics,
- rewards,
- quality circles, and
- corporate culture.

c) Shared Knowledge and Systems

In the first CIM wheel "systems integration" appeared at the center. Now shared knowledge still is very important, but it occupies a ring between organization teams and business processes. This ring represents now the interface between people and processes, and a common repository for the information and knowledge of the enterprise.

Included here are manual and computer tools aiding research, analysis, innovation, documentation, decision-making, and control of every process in the enterprise.

d) Processes

The next ring is the largest, and it includes the 15 key processes that complete a product life cycle [9]. These processes are grouped according to their input in three categories: product/process definition, manufacturing, and customer support.

The product/process category defines the product and how to build it. When the definition is complete, ultimate performance, value, and manufacturing expenses must have been determined. The key processes of product/process definition are:

- Business Definition,
- System Design,
- Component Design,
- Continuos Improvement,
- Documentation and Release.

Very often the manufacturing (or service) requires the largest investment of resources for an organization. There are five key processes:

- Resource Planning,
- Operations Planning,
- Component Fabrication,
- Assembly and Test,
- Material Management.

The third process category is customer support. This ring includes the processes needed to deliver products to clients. The five key processes of this ring are:

- Global Organization,
- Distribution,
- Sales and Promotion,
- Customer Services,
- Life-Cycle Transitions.

The enterprise must deliver capabilities to help clients to realize their visions. These capabilities include both products and services. Thus, many concepts applicable to products also can be appropriate to services.

e) Resources and Responsibilities

This ring is very similar to a cell membrane, because it must be thin, resistant, flexible and permeable. This ring serves as an interface between environment and enterprise. It must let in the needed resources as people, materials, tools, information, technology and suppliers, and it must let interact with employees, investors, community, regulations,. ethics and environment concerns. The inputs are the "resources", and the outputs represent the "responsibilities" with the external entities mentioned above.

This ring preferably must be very lean to be more responsive to environmental changes.

f) Manufacturing Infrastructure

Outside the boundaries of the enterprise it is the environment. Competitors, suppliers, customers, workers, natural resources, financial markets, research and education institutions, government and other factors are in the environment. Enterprises have been seen traditionally as local or national entities, but today there is a global competence, so infrastructure evaluation has expanded considerably.

There are two methods [61] [62] to apply the Wheel Model: "Concurrent engineering" and "virtual enterprises". These methods will help enterprises to be competitive in a global market, and they will produce changes both outside and inside the companies.

It is not possible to deliver competitive products if the model is applied in a sequential way. Leaders must change from a traditional lineal model to systems thinking. It means that the key processes cannot be executed one by one, but in a concurrent way. Cross-functional effective teams and effective communication will be needed; both computers and human networking are keys to success.

Enterprises can concentrate on its main competencies and subcontract to other companies. Key processes can be effectively developed by external partners, and these partners can be in very far places, wherever they can be. In this way, "virtual enterprises" can span from small regions to the whole world; the principal difficulty could be the communication, but this problem is being solved through advanced technologies.

Clearly industrial manufacturing is evolving to a multi-disciplinary practice; a broader set of technologies, disciplines and knowledge will be needed for the success of the globally competitive enterprise.

## II.5. THE FACTORY OF THE FUTURE

The factory of the future described by Bray [5], implies to the managers a constantly improving vision of a highly efficient and automated factory. The main features of this vision are integration and automation. Companies around the world are designing and building "factories of the future" with some degree of success, but there is no one that could achieve a complete integration and automation.

The factory of the future is complex and expensive to build, but it has three major benefits: greater flexibility, higher and more consistent quality, and lower labor cost. Since labor costs have been reduced during these years, flexibility and quality are the most important. In a very competitive environment customer satisfaction has come increasingly important, so flexibility to respond to customer needs is key competitive factor.

Flexibility is obtained through more rapid and reliable information systems. New designs can be developed and produced in less time and inventories can be reduced drastically.

Quality is achieved through automated operations with NC machine tools and robots. Quality is not only better, but more consistent. Other benefits are reduced scrap, reworks, and warranty repair costs.

Although both Japanese and American enterprises are striving for the factory of the future, they are driven for different strategies: Japanese manufacturers are focused on quality, while United States is looking for reducing labor costs. The factory of the future has impact over the whole company, because it implies a holistic vision of the enterprise. In this way, marketing, design, manufacturing, accounting, and other organizational areas become involved.

The CIM framework proposed by Gunn[21] for "World-Class Manufacturing" mentions the following components of the factory of the future:

- information technology
- CAD
- group technology
- manufacturing planning and control
- automated material handling
- CAM
- robotics

Later, Gunn[21] proposed an improved framework for world-class manufacturing based on three supporting pillars: CIM, TQC (Total Quality Control), and JIT (Just-in Time). Gunn discusses the first pillar (CIM) based on four functional areas described in second.2: product and process design, manufacturing planning, production processes, and information technology.

**Table 2.2. [21]**

| CIM | |
|---|---|
| Product and process design | • computer-aided design<br>• group technology<br>• configuration management and engineering change control<br>• computer-aided process planning<br>• workcell device programming |
| Manufacturing planning and control | • MRP II<br>• schedule simulation and optimization<br>• preventive maintenance<br>• cost management |
| Production process | • numerical control<br>• group-technology-based workcells<br>• computer-aided testing and vision<br>• quality control and statistical process control<br>• robotics<br>• automated material handling systems<br>• automated guided vehicles |
| Information technology | • database management<br>• network communications<br>• algorithmic applications<br>• artificial intelligence/expert-system-based applications<br>• decision support system tools<br>• application development<br>• software engineering tools<br>• hardware |

The first three functions are important, but few companies are doing more than a handful of functions, and none of these companies have accomplished a full integration and automation. This integration is provided by the information technology, and the additional management and administrative components are provided by the second and third pillars which are TQC and JIT (see tables 2.3 and 2.4).

**Table 2.3.[20]**

| TQC | |
|---|---|
| Product and process design | • design standards<br>• Taguchi analysis method<br>• quality function deployment |
| Manufacturing planning and control | • planning and control of the quality functions, for the factory and suppliers |
| Production process | • employee involvement trough small group activity |

JIT emphasizes concurrence on product and process engineering, and design for manufactureability. JIT efficiency comes from rather setup than long production runs, which build up unneeded inventory.

**Table 2.4.[20]**

| JIT | |
|---|---|
| Product and process design | • product and process engineering<br>• design for manufactureability |
| Manufacturing planning and control | • precise planning<br>• highly visible feedback on operation status<br>• close supplier involvement |
| Production process | • employee involvement}cross-training<br>• workplace reorganization<br>• standardization<br>• minimization of setup times<br>• small batch runs |

The large number of variable inside the factory implies a very complex environment. An effective information management is necessary to achieve the needed level of automation and control. Although there are not two identical factories, it is possible to establish an underlying common information model. A data communications network is necessary to implement this information model in the factory. The network must have an adequate capacity for future needs, compatibility with the different computers and factory equipment, and a high level of fault tolerance.

## CHAPTER III. THE MEXICAN MANUFACTURING ENVIRONMENT.

### III. 1. THE STRUCTURE OF MEXICAN MANUFACTURING.

We would begin by describing the rules of classification of mexican companies. According to SECOFI [63] which is the department of commerce and impulse of the industry, the classification of companies is made by the number of employees according to table 3.1.

Table 3.1. Classification of size of companies (SECOFI).

| CLASSICATION OF SIZE OF COMPANIES | NUMBER OF EMPLOYEES |
|---|---|
| MICRO | 1-15 |
| SMALL | 16-100 |
| MEDIUM | 101-250 |
| BIG | > 250 |

This is the classification of enterprises that follow investigators and researchers, other classifications for credit union loans or bank loans use further criteria based on income, assets, etc.

Comparing this classification with the proposed division of companies for Poland by Grudzewski and Hejduk [64] for constuction and industry, which is presented in table 3.2, shows differences for the micro-companies which in the Polish definition is less than 10 employees and also in the big companies which is considered after 500 employees.

Table 3.2. Classification of companies [64]

| CLASSIFICATION OF SIZE OF COMPANIES | NUMBER OF EMPLOYEES |
|---|---|
| MICRO | 1-9 |
| SMALL | 10-99 |
| MEDIUM | 100-499 |
| BIG | > = 500 |

After mentioning the classification scheme used for mexican companies, the situation of mexican manufacturing is presented in the following paragraphs.

In México 74% of the mexican exports are metallic products, machinery, equipment and basic metal products. The 10% are petroleum and its derivatives, and the rest 16% is food, tabaco, textile, wood, paper, and other products. So there is a strong concentration of the exports in the sector of metallic products, this data can be seen in figure 3.1.

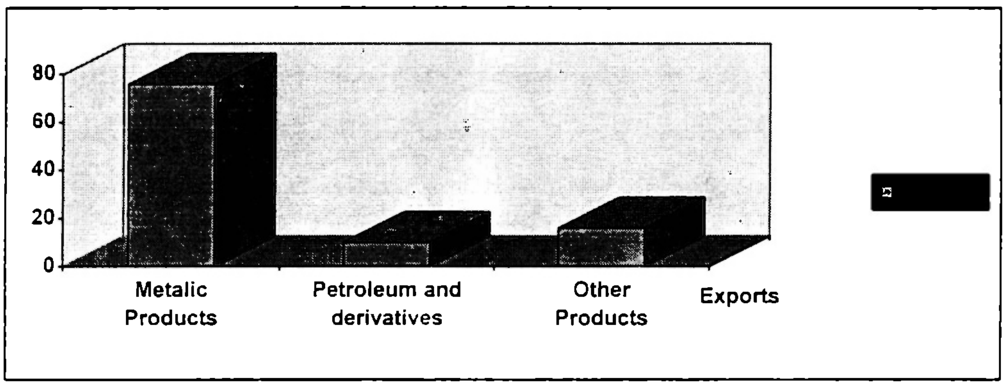



Figure 3.1. Mexican Exports (INEGI) [53].

Also in México 2% of the manufacturing companies are big and medium size companies while the 98% of the manufacturing companies are small and micro companies.

Big and medium size companies generate 74% of the income, while small and micro companies generate only 26% of the income, all this data can be seen graphically in figure 3.2.

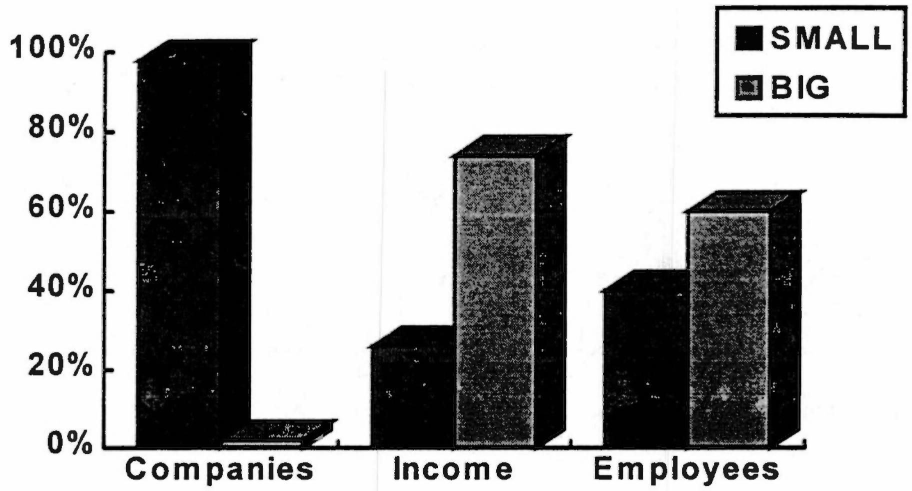



Figure 3.2. The structure of mexican manufacturing. (Source:INEGI) [53].

Big and medium size companies have 60% of the employees and small and micro companies have 40% of the employees as can be seen in figure 3.2.

There are also productivity differences between micro, small, medium and big companies. Micro companies operate in a level of productivity 57% less than the national average of productivity, small companies have a productivity 29.5 less than the national average, medium size companies operate in a level of productivity 10.8 % less than the national average, big companies operate in a level of productivity which is 43% greater than the national average, this information is presented in figure 3.3.

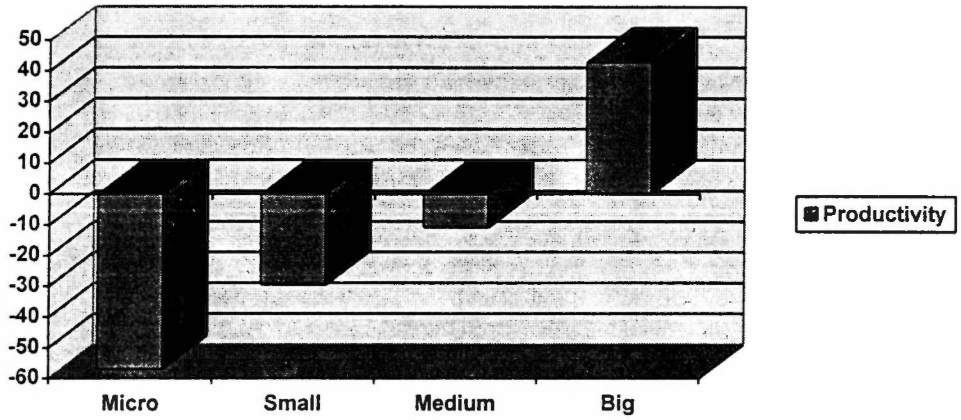



Figure 3.3. Levels of productivity compared to the national average of productivity. (Source :INEGI) [53].

Big manufacturing companies need suppliers of products and services to operate, and due to the financial crisis in México where the value of the peso is very low it is desirable to substitute imports to reduce costs, this could be a role of the small companies but they need to provide products and services of quality for the big companies.

From these points we can see some conclusions as a small group of big manufacturing companies represent the most important part of the manufacturing industry, and there is another group of small companies less efficient and productive than the big ones, so clearly there is a crisis in the small manufacturing companies. Big manufacturing companies are also affected by the crisis in the small companies because they have a weak base of support, that is suppliers with low standards, poor services of maintenance, etc. This situation could be avoided by the big manufacturing companies if they can import goods and materials from international companies, and contract services also from international companies, but this situation is difficult because of the low value of the peso. Also this solution for the big companies would not generate development for mexican companies and would increase the difference in development for the small and the big companies. From this discussion we can see that there exists an uncertain environment of operation for the manufacturing companies because of low quality suppliers and services and because of the uncertain financial situation of México.

III.2. THE SITUATION OF CIM IN MEXICO.

It is important to see the situation of CIM in Mexico, to be able to detect which is the degree of modernization of the mexican manufacturing companies. From a series of questionnaires about CIM in México that were applied to 50 manufacturing companies [21] we can observe some facts about the situation of CIM in México which will be mentioned in the following paragraphs.

Around 40% of the companies do not have any idea of what CIM is. 30% of the companies have heard about CIM and consider it a good option. 26% of the companies have islands of automation in their companies. Only 4% of the companies are making efforts to integrate their islands of automation. This information can be seen graphically in figure 3.4.

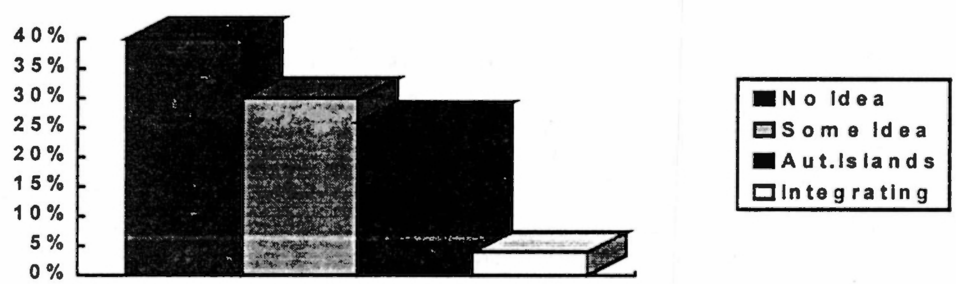



Figure 3.4. Situation of CIM in Mexico (Source: Mendizabal) [21].

In Mexico 90% of the micro and small companies do not know what CIM is. Around 50% of the medium size companies do not know what CIM is. 25% of the big manufacturing companies do not know what CIM is, this data can be seen in figure 3.5.

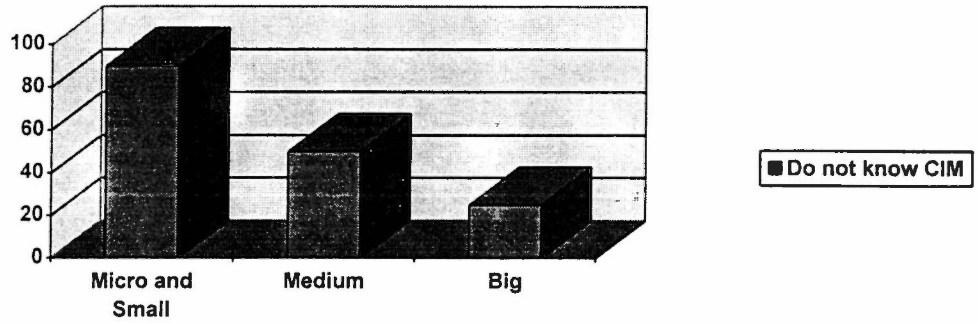



Figure 3.5. Ignorance about CIM (Source: Mendizabal) [21].

As most of the companies are not integrated, if we look only at companies that have their general business management systems complete (general accounting), it can be observed that 5% are small companies, 20% are medium size companies and 75% are big, and 95% of these big companies are using an international software package designed for another country. Figure 3.6. shows the graph of companies that have their administrative systems complete.

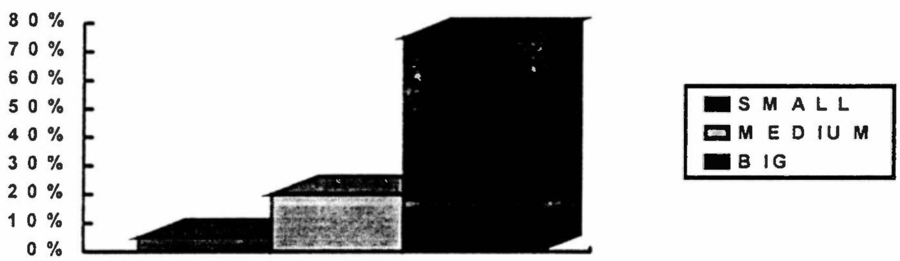



Figure 3.6. Companies that have their business management systems complete (Source: Mendizabal) [21].

Taking about automation, 17% of the companies do not have any automation, the rest 83% have some CAD, NC, or some form of production control. Of these companies that have some form of automation, 34% of the companies use CAD systems, 15% of the companies have numerical control machines, 14% of the companies have some kind of production control, see figure 3.7.

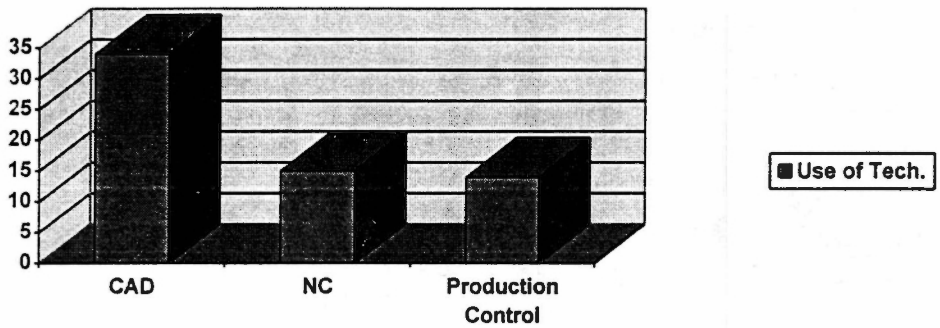



Figure 3.7. The use of advance manufacturing technology (Source: Mendizabal) [21].

As conclusions from the situation of CIM in Mexico we can observe that only a significant percent of big companies have their administrative systems complete and could think of integrating them with the production functions of the company but this would be difficult because the majority of them are using software packages. Small and medium size companies have not yet solve the problem of administrative systems and most of them do not even know what CIM is, so the need for integrated information systems begins in the administrative function.

## III.3. PROBLEMS RELATED TO INFORMATION SYSTEMS IN MEXICO.

To determine the problems of operation related to information systems in México a questionnaire was applied to information system managers of 30 small and micro manufacturing companies. The questionnaire was designed to obtain information about the operation of the information systems and to detect the need of a method for developing information systems. All the information presented in this section and the information in section III.4 are some of the results of applying this questionnaire, to see the model of the questionnaire and how the results were calculated see Appendix A.

These are some of the problems observed related to the operation of information systems in México, especially in times of high inflation and uncertainty:

- The prices of products change very frequently. This causes a constant change of prices in the information system, so users of the system loose control about the prices given to certain customers.

- The salaries change more frequently. This complicates the calculation of payrolls because companies have to take several salaries to calculate taxes and payments to the social security system.

- The exchange rate with the dollar changes almost every day, so to sell products in dollars you have to keep track of the changes every day. Besides suppliers all have a different exchange rates for their products, so the information systems have to register the value of the dollar for every line of products every day.

- Clients do not pay on time when the invoices are due. So the information system has to keep the next payment date, keeping the old payment dates to know how many times you have called to ask for the payment.

- There are many exceptional events. For example: there are many cancellations to purchases to suppliers and of sales to customers. This is sometimes because of defective products or wrong products. So the purchase order or invoice is cancelled, but not everybody notices that. Because there is a lot of information in the system.

More precisely we can see in table 3.3. the problems of operation caused by external factors related to the mexican uncertain environment, these are ordered according to their degree of influence in affecting the operation of information systems. We can see in these table that the factor that affects more the operation of information systems is the change in the exchange rate of the dollar, the second most important factor is the change of prices of suppliers, these two factors indicate that the variation in prices of raw material and services affect the operation of the information systems of mexican companies, and this indicates that the information systems are not designed to accept frequent changes of prices and currency values. Other problems detected in table 3.3 are the modifications to tax laws of the government which are very difficult to prevent because they generally involve changes in data structures and algorithms.

Table 3.3. External factors that affect information systems (Results of Investigation by J.Prieto-Magnus)

| Degree of Influence | Factors of the external environment. |
|---|---|
| 1 | Change in the exchange rate of the dollar. |
| 2 | Change of prices of suppliers. |
| 3 | Modifications to tax laws. |
| 4 | Variation of interest rates. |
| 5 | Customers do not pay on time. |
| 6 | Modifications to labor laws. |
| 7 | Products of suppliers do not arrive on time. |
| 8 | Cancellation of orders by customers. |
| 9 | Suppliers send wrong products. |
| 10 | Scarce raw material. |

Other problem that is mentioned in table 3.3 is the change of interest rates which also affects the change of prices because of the inflation generated. Another problem which is in the fifth place of importance is that customers do not pay on time, this affects information systems because the due dates have to be adjusted several times, so there is a need to maintain a history of the payments status. Other problem that is

related mainly to payroll systems is the modification of labor laws, but this problem is also difficult to prevent because these modifications generally involve new algorithms, files and data structures. Other problems that have a medium impact to information systems are that products do not arrive on time and cancellations of orders by customers. Finally other external factors of less impact related to the suppliers of the companies are that suppliers send wrong products and the scarcity of raw material.

The internal factors that affect the operation of mexican companies were also analyzed in the questionnaire, these factors are mainly factors of efficiency of the internal operation of the company, most of them are human factors that affect the operations of the information system, see table 3.4.

Table 3.4. Internal factors that affect information systems (Results of Investigation by J.Prieto-Magnus)

| Degree of Influence | Internal Factors of operation. |
|---|---|
| 1 | Wrong entry of information by the users. |
| 2 | Departments do not handle information on time. |
| 3 | Processes are not finished on time. |
| 4 | Not inform about cancellations. |
| 5 | Users do not know how to operate the system. |
| 6 | Lack of coordination between departments. |
| 7 | The information is not updated by the responsible departments. |
| 8 | People forget to execute certain options. |
| 9 | The information was changed in the system but not everybody was informed. |
| 10 | There are no standards to entry information. |

The most important internal factor that affects the operation of information systems is the incorrect entry of information by the users of the system. most information systems are validated against wrong formats of data and invalid values. but inspite of this users continue to entry wrong information into the system. this is a human factor that is difficult to address in the software. The next two factors are handling information on time and finishing process on time. these factors are related to information systems that require monthly closing processes and monthly periods. this can be handled by forcing users to verify their information on a daily basis and not waiting until the end of the month where the verification of the whole period of monthly information is a lengthy task, but this requires constant control and verification of peoples work.

The fourth factor of table 3.4 is not informing about cancellations of invoices, purchase orders and other documents to all the people involved or related to those documents, these is because traditional information systems are mainly passive information systems where the information is stored but no one is informed by the system if a change of status of an important document has occurred. The fifth factor is that users do not know how to operate the system, this factor is related of course to training, but it can be addressed also by using friendly user interfaces like graphical user interfaces where the user can explore how the system works without getting lost. The next two factors are the lack of coordination of departments and that the information is not updated by the responsible departments, these are mainly human factors and they have to be addressed in a cooperative manner because the interdepartmental interactions with an information systems are generally increased, and the quality of the information has to be higher and more frequently updated.

Factor number eight is that people forget to execute certain options this is mainly related to systems which are not friendly to the user or that are not well structured in their modules and options, the design of the information system can have a great influence to reduce this factor. The next factor is that the information was changed in the system but not everybody was informed. This factor is also related to the fourth factor and the information system could help if the electronic mail system would be integrated with the information system and the system could send automatic mails to the users involved if some important information was changed. Finally the last factor is that there are no standards to entry information into the system, this can be addressed by providing separate fields to names, addresses and other fields that are groups of information and by providing online examples of how to entry the information.

From the external factors we can conclude that an uncertain environment does affect the operation of information systems to a degree were companies that cannot respond to the changes that occur in the environment might loose control of their information systems, and they have to control prices and payments by hand or by memory. From the internal factors we can conclude that the lack of efficiency of employees can cause big problems in the information system, and this might complicate further if the information system is not designed to help the users to update their work in a daily basis and to know what has happened in other departments. These problems will be addressed in chapter five in the design phase, were concrete proposals of information systems design will be presented.

## III.4. THE NEED OF A METHOD FOR MEXICAN COMPANIES.

There is a need for a method for constructing information systems in Mexico. In the questionnaire mentioned in the previous point, we could detect that 72 percent of the mexican small companies do not use a method, 21 percent of the companies use structured analysis and design [65] and only 7% claim to use object-oriented analysis, this data can be seen in figure 3.8.

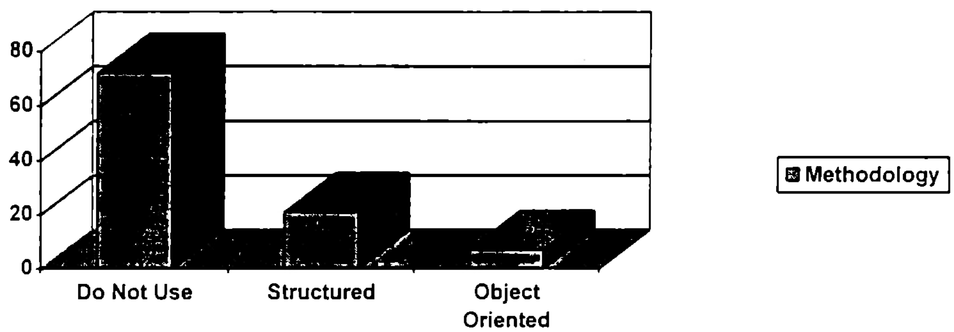



Figure 3.8. Method that small mexican companies use. (Results of investigation by J. Prieto-Magnus)

We could also evaluate from the questionnaire that 79% of the companies have machines use windows, so it is important that they use a method that is object-oriented and includes graphical user interface design, because structured analysis and design [66] are not suitable for developing applications for windows and graphical interfaces [67].

So we can conclude that there are many companies that do not use any method at all to construct software, and the companies that do use a method mainly use structured analysis and design, so there is a need for a method for mexican companies that uses object-oriented techniques and a graphical user interface design that can help small companies to build applications to run on the windows interface.

## CHAPTER IV. OBJECT-ORIENTED METHODS.

### INTRODUCTION.

Object-oriented methods have been developed around the world from the second half of the 1980s and have been refined and extended during the 1990s. These object-oriented methods cover aspects of analysis, design and programming of information systems based in objects. External real world persons, things, machines, forms and concepts are considered to be objects for the object-oriented programming paradigm.

Object-oriented languages first appeared in 1966 with the language Simlula [22], then in the 1970s the Smalltalk system appeared [23], which later evolved to an interactive programming environment Smalltalk-80 in the early1980s [24], then around 1985 C++ appeared making object-oriented programming more widely used among many other programming languages[25].

So the need for object-oriented methods aroused in the second half of the 1980s to respond to the demand of the developers that wanted to use the object-oriented languages available. In the early 1990s a wide number of methods were available [26]. In this chapter we present some of the more widely used methods for the analysis, design and programming of systems with objects, which area the Booch Method [27], the OOA, OOD & OOP (object oriented analysis, object oriented design and object oriented programming method of Coad, Yourdon, and Nicola [28]) , the Objectory method of Jacobson [29] and the OMT (Object modeling technique) by Rumbaugh [30].

The structure of object-oriented methods differs from one method to another, but in general we can distinguish three main phases of these methods which are : Object-Oriented Analysis, Object-Oriented Design, and Object-Oriented Programming, so the general structure of object-oriented methods is presented in figure 4.1. in which the main phases are depicted together with the most common steps of each phase.

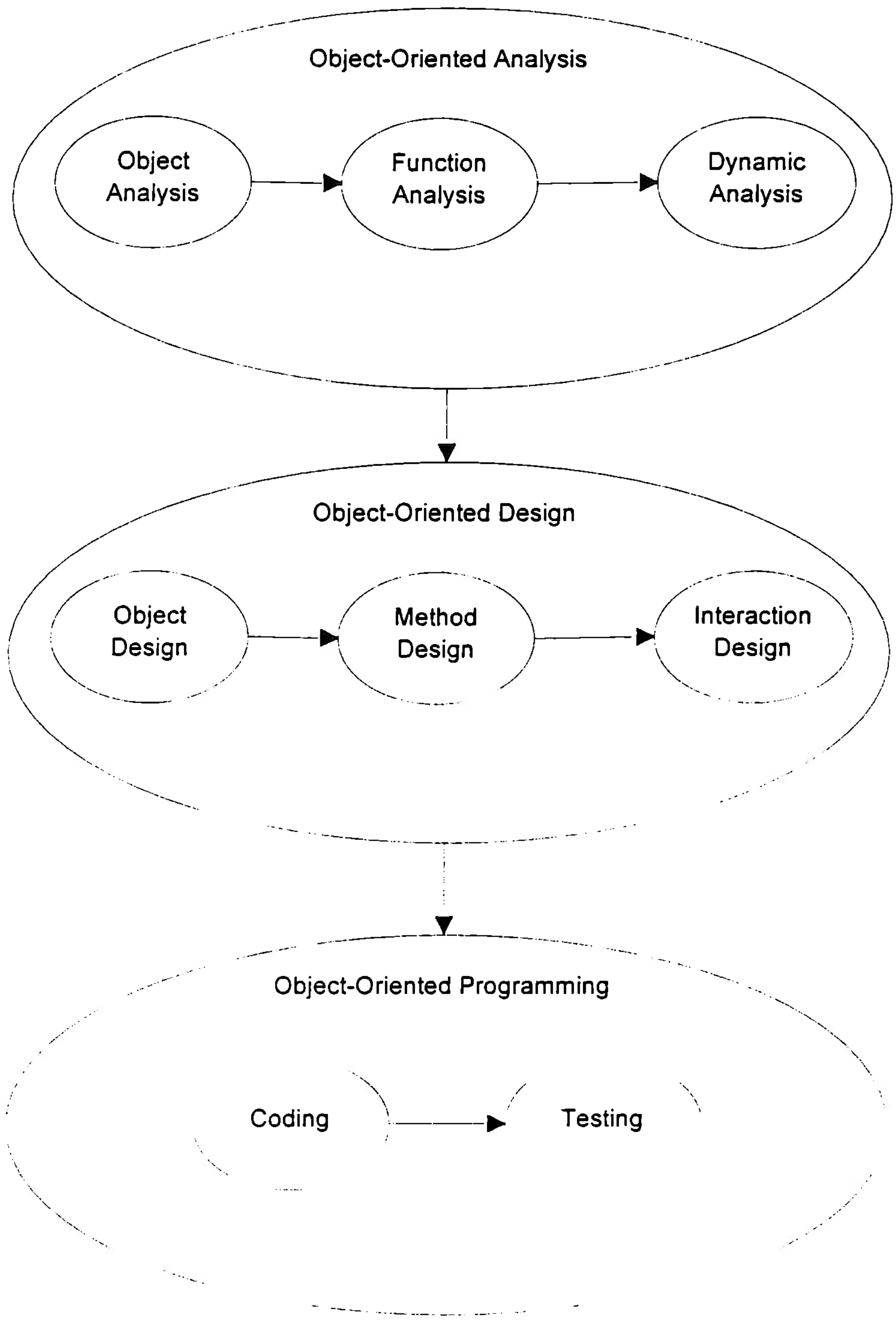



Figure 4.1. General Structure of Object-Oriented Methods (by J.Prieto-Magnus).

In figure 4.1. we can see the general phases which in general are analysis, design and programming, we can also see the steps of each phase. The first phase of object-oriented analysis starts with the Object Analysis in which the objects and their data will be identified, the second step of the analysis phase is the Function Analysis which is the analysis of the processes that are done in a company. The third step is the Dynamic Analysis in which the dynamic interactions between objects are analyzed.

The Design phase starts with the Object Design in which the objects will be designed with all the detail that concerns each object. The second step is the Method Design, in which the functions or processes of the analysis phase will be transformed in to computer procedures (called methods in the object-oriented terminology). The design phase ends with the Interaction Design in which the results of the Dynamic Analysis will be transformed in terms of computer objects for the interaction between them.

The Object-Oriented Programming phase mainly covers the Coding in an specific language and the Testing of the objects of the system. Many methods do not include this phase to make the method more general, because this phase is mainly language specific.

In the next paragraphs we describe the four object-oriented methods mentioned above, to finish the chapter with a comparison of the methods.

## IV.1. THE BOOCH METHOD OF OBJECT-ORIENTED ANALYSIS AND DESIGN.

The Booch method [27] addresses most aspects of the object-oriented analysis and design technical framework, including object modeling, analysis modeling, application design, implementation design, and lifecycle process and issues. The Booch method comprises three main phases: Requirement Analysis, Domain Analysis, and Design (see Figure 4.2).

The requirement analysis is the process of discussion of the system's final purpose. The product of this process must meet the customer's needs. This process does not have formal steps because it must be structured according to the specific characteristics of each project, depending on the newness of the system, existing documentation, and the customer itself.

The domain analysis is focused on that part of the real-world relevant to the system, as it was stated in the requirement analysis. Domain analysis should produce a very concise, but detailed, semantic definition of the system. This semantic definition is concerned with "objects" (e.g., people, machines, categories) and their relationships.

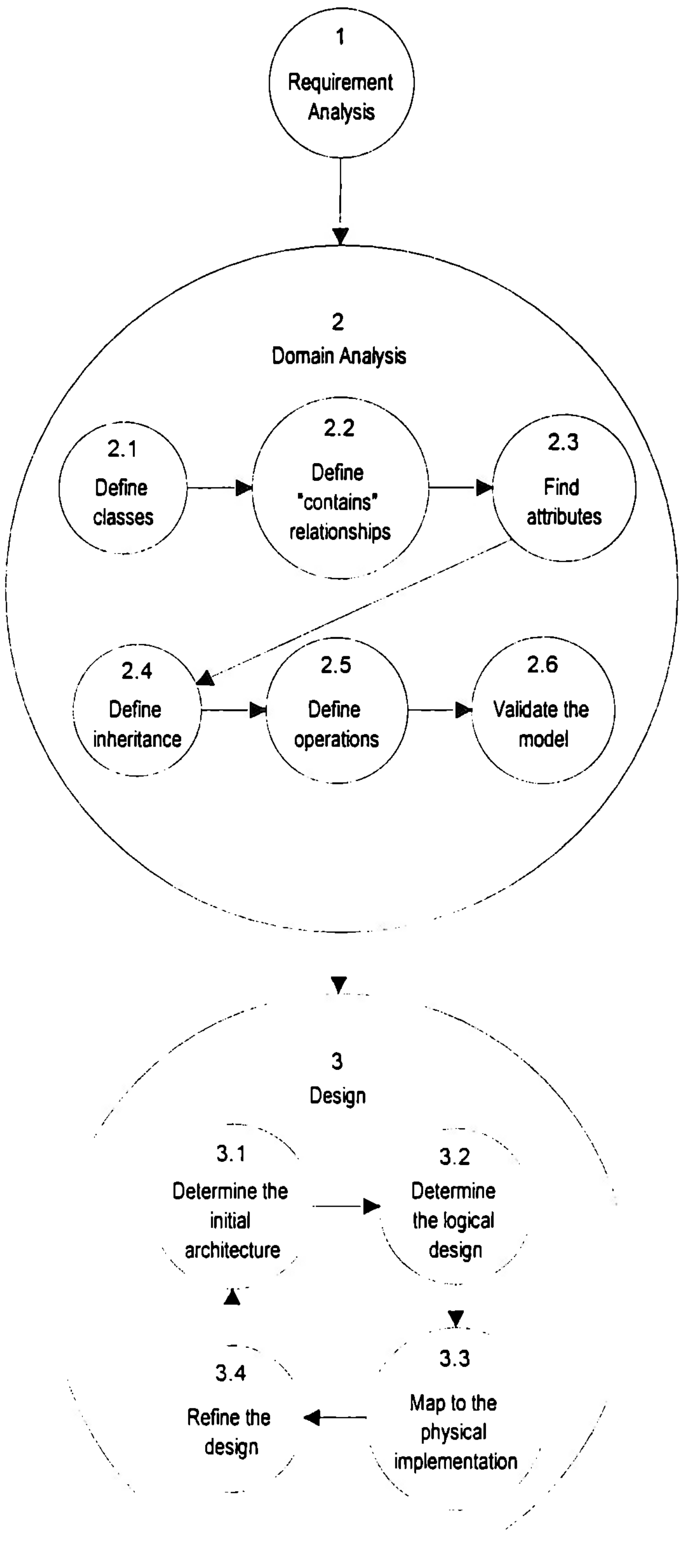
The following steps are performed during domain analysis:

1. Define classes. In this step the major types of domain objects are identified, such as "companies", "products", etc.

2. Define "contains" relationships. The "contains" relationship between objects is specified. A "contains" relationship can be explained as the relation between two objects, a "container" one and its contained object. In this step every "container" and "contents" object, and their relationship, are identified.

3. Find attributes. Every attribute of each object is stated and clearly specified. For example: for a "company" object we may find several attributes such as "name", "country", "city", "address", "owner", etc.

Figure 4.2.The process of the Booch Method (prepared by J.Prieto-Magnus).



4. Define inheritance. It includes finding generalizations and specializations within similar domain types. For example, we could find that the "manager" and "clerk" categories are more specific definitions of the generic category "employee".

5. Define operations. It defines the major process of information, its sources and destinations.

6. Validate (and iterate over) the model. It includes the review and testing of the model. If it is proved inconsistency in the model, the whole domain analysis should be iterated to adjust it.

This is a highly iterative process, and it may have not a particular sequence. As we find new relations, attributes, or operations, it could be clear the need of new elements to be added to the model.

The third phase of the Booch method is the Design. The purpose of design is to determine the most effective, efficient, and cost-effective real-life implementation possible of the system as it was defined in the domain analysis. Design produces a specification of a software structure capable to carry out the operations defined in the domain analysis.

In the design the model is extended and refined. We can find the following steps in the design stage:

1. Determine the initial architecture. A supporting structure should be defined to provide for the needs of the objects and operations that are going to be implemented.

2. Determine the logical design. The classes, relationships, attributes and operations are specified with further detail.

3. Map to the physical implementation. Physical interfaces are developed to communicate the elements specified in the logical design with their corresponding physical devices

4. Refine the design. At the end of the previous steps some prototypes, i.e., preliminary models of the system, may have been prepared. If the performance of these prototypes does not meet the customer requirements, it should be needed a review of the design, in order to implement more efficient alternatives.

## IV.2. THE COAD, YOURDON, AND NICOLA OOA, OOD & OOP , METHODS.

The object-oriented method developed by Coad, Yourdon, and Nicola [28] is composed by three parts: object-oriented analysis (OOA), object-oriented design (OOD), and object-oriented programming (OOP). Besides the traditional problems focused by other methodologies, the Coad, Yourdon, and Nicola method addresses the following issues:

1. The growing complexity of applications.
2. The importance of quality software development.
3. The relevance of teaming (interdisciplinary, creative and innovative).
4. The growing need of business to re-engineer their processes.
5. Business growth in a very competitive global marketplace.

The method is intended to be conceptually simple, reduced and practical. It is not intended to be a full-size method; perhaps it is "just enough to get the job done" and encourage creative and innovative system building.

The process in this method is not intended to be developed in "steps", but in "activities". The authors argue "steps" are intended for a sequential and not iterative method, while they say "activities" reflect the iterative, non-sequential nature of their method. The authors depict their method as a "baseball model," shown in figure 4.3.

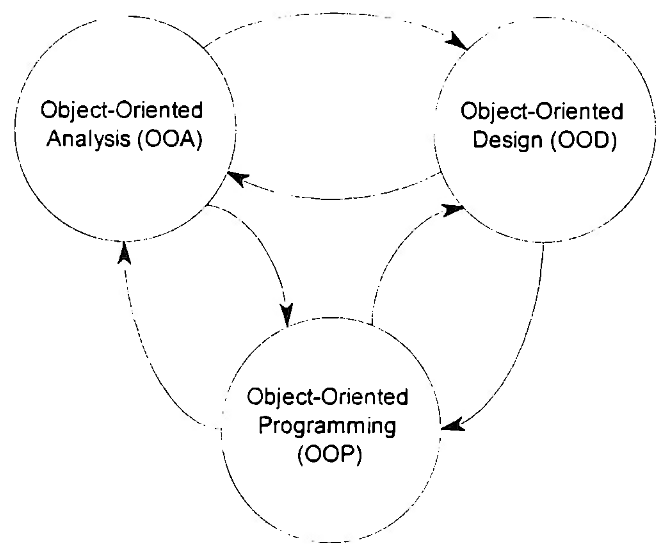



Figure 4.3. The baseball model of Coad, Yourdon and Nicola [28].

The Object-Oriented Analysis (OOA) works with the classes and objects of the problem domain. Classes are abstract and generic representations of real-world items, such as "person" , "company", etc. Classes are generic definitions that can be applied to a set of items, these items should have at least the same collection of individual attributes. Objects are instances (examples) of a class, while a class defines only the relevant attributes and domains of a set of items. An object represents the values of this attributes for a specific, real-world item.

The Object-Oriented Design (OOD) works with the human interaction, task management, and data management classes and objects. The human interaction component is concerned with the way the information is presented by the computer which the user controls by generating events in the computer (like pressing the mouse button) . The task management component is concerned with the interaction between the real-world events and the computer system. The data management classes and objects ensure the effective and efficient storing and retrieval of the information.

The Object-Oriented programming (OOP) implements the results of OOA and OOD in a specific computer system. The method provides guidelines to map the OOA and OOD in their equivalent structures in object-oriented programming languages. Besides the OOA and OOD defined structures, the method also provides strategies to build "helper objects." These objects are functions intended to support the requirements of the main structure. Finally, the method includes a variety of strategies to produce software components that can be used in future developments.

## IV.3. OBJECTORY METHOD.

Objectory [29] is an object-oriented method which is driven by the way the users use a system, through analysis of sequences of user operations and actual usage scenarios, Objectory builds robust and usable software, which can be smoothly adapted to changes in the company. Objectory has been applied to the CASE tool Ory SE (Objectory Support Environment).

The Objectory method is divided in 3 phases (see figure 4.4) :

1. Requirement analysis.
2. Robustness analysis.
3. Construction.

The requirement analysis is composed of a "Use Case" and a "Domain Object" model. Every Use Case is a sequence of actions performed by an "actor." Actors can be any person, program or computer external to the system. The actors interact with the system, and it is necessary to describe every actor's Use Case. The Domain Object model is composed of objects that represent entities of the solving problem, and it is used as a support for the requirement analysis.

The purpose of the Robustness Analysis is to transform the Requirement Analysis into a robust and extensible base for the construction of the system. The Robustness Analysis is not concerned with the specific hardware, language, or operating system. Its main interest is to produce a conceptual model. The Robustness Analysis generates three types of objects: interface, entity and control. The objects are independent modules that will perform specific tasks. Interface objects are responsible of the communication between the actors and the system. Entity objects are the containers used to store the information generated in after the execution of every Use Case. Entity objects mostly represent real-world objects, such as employees, items, etc. Control objects are exceptionally used to represent some special cases that can not be performed adequately by interface or entity objects.

The construction phase receives as input the previous analysis and builds a useful system. The construction phase is composed of design, implementation and unit testing. The design is a further refinement of the analysis. The design must consider at this stage how the implementation environment (that is, programming language, operating system, hardware, performance needs, etc.) will affect the earlier analysis. After several iterations the design becomes stable and it is possible to continue with the implementation. The implementation stage uses the previously designed objects to produce the needed code using the programming language of choice. Finally, testing ensures the system correctness.

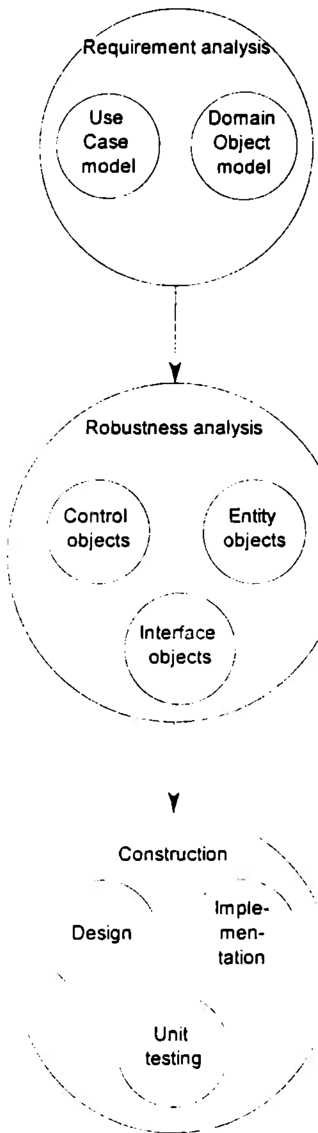



Figure 4.4. Structure of the Objectory Method, prepared by J.Prieto-Magnus.

## IV.4. THE RUMBAUGH METHOD: OBJECT MODELING TECHNIQUE.

The Object Modeling Technique (OMT) was developed by a team leaded by James Rumbaugh at General Electric Research and Development Center at Schenectady, NY, USA [30]. OMT was originally intended to develop real-time software systems and programming environmets. The OMT development process has four phases : Analysis, System Design, Object Design, and Implementation (see figure 4.5).

After the problem has been clearly stated, the analysis model is divided into three submodels: the object model, dynamic model, and the functional model. The object model defines objects and their relationships. The functional model identifies actors, process, data flows, and control flows. Actors are "black-box" objects consuming or producing values outside the boundaries of the system. Processes transform input values to produce output values. Data flows transport data between actors and objects. The control flow uses Boolean values to determine the execution of a process.

The dynamic model contains actions, activities, conditions, and guard condition. Actions are instantaneous operations, such as the turn of a switch, while activities are operation that takes time to complete. The conditions represent a discrete set of values valid over a time, while guard conditions are Boolean expressions that must be true in order for a transition to occur.

The system design concentrates on the overall architecture of the system. Here the system will be organized into subsystems, and these subsystems will be assigned to processors, then the control mechanisms for the system would be chosen .

The object design concentrates on optimizing the object model. The object design obtains operations from the dynamic and functional models to produce algorithms to implement operations. Then object design optimize the object model, to finally group the objects into modules.

The implementation starts with the design of the required databases after the design stages. Finally, the design products are converted to programming language code.

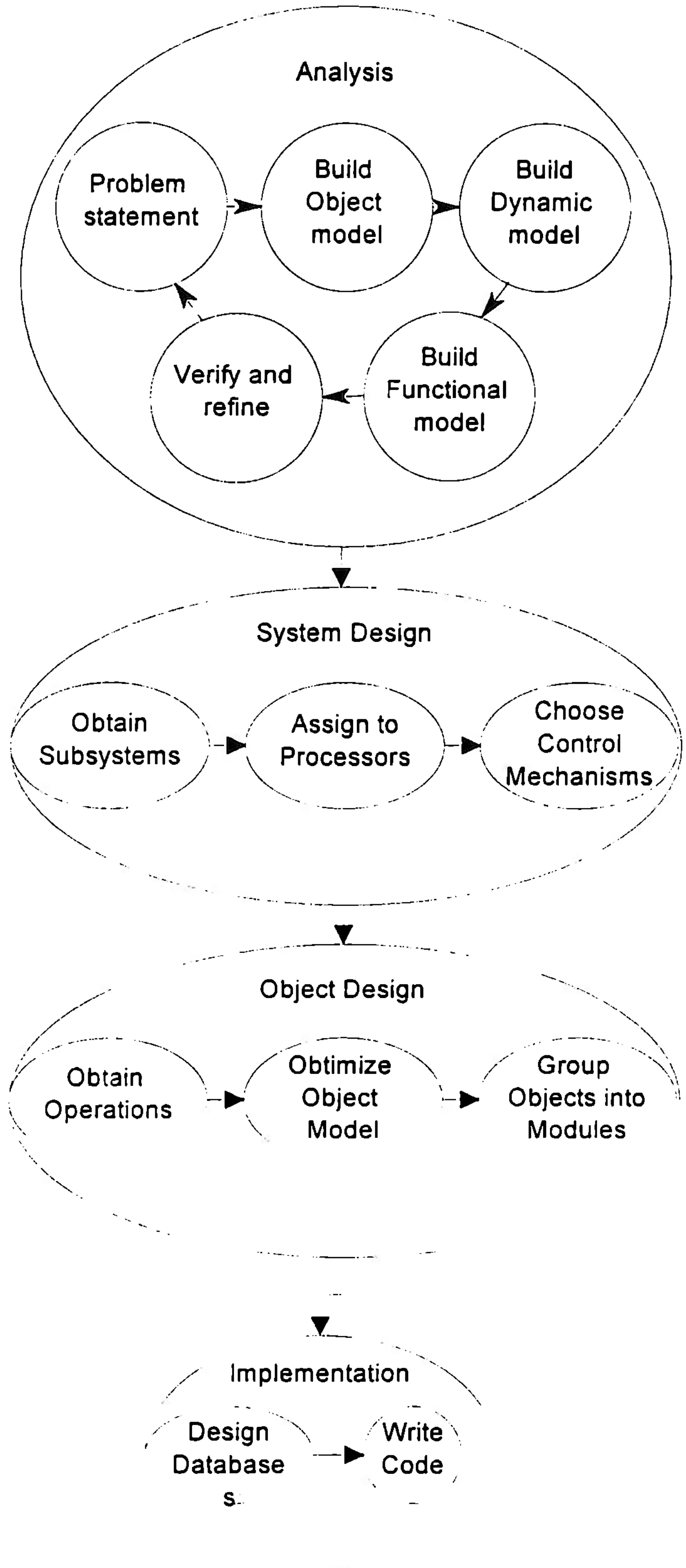



Figure 4.5. Rumbaugh method: Object Modeling Technique (prepared by J.Prieto-Magnus).

## IV.5. COMPARISON OF THE METHODS.

In the following paragraphs a comparison of the methods described above will be given. A clear comparison can be made taking a look into the structure diagrams of each method.

The OMT method of Rumbaugh was a strong emphasis on the analysis phase and on the construction of object models of the problem, so it is very good for identifying objects and the relationships between them. The Booch method also has an emphasis on constructing object models but not so detailed as in the OMT method, but the Booch method is good for constructing object-oriented design models which can be mapped easily to object-oriented languages like C++. These two methods OMT and Booch are based primarily on object models.

The Objectory Method is more focused on the user, because it bases the development in use-cases (scenarios of the use of the system by different users) of the information system. This has the advantage of staying user focused, in a way that the system works as the user wanted, this is good for the users but for the developers is not so easy to imagine how to start building the system.

The OOA,OOD & OOP method is a simpler and practical method, in which the object-oriented analysis and the object-oriented design can be done at the same time, this is good for practical purposes and for an easy understanding of the method by developers, but it is not so comprehensive and detailed as the other methods, however it is practical and close to what real programmers do when they develop a system in practice.

The main advantage of each method as mentioned above is presented in table 4.1. to get a clear perspective of the real benefit of each method:

Table 4.1. Advantage of each of the object-oriented methods.

| METHOD | MAIN ADVANTAGE |
|---|---|
| OMT (Object Modeling Technique) | Analysis and construction of an Object Model. |
| BOOCH | Detailed Object-Oriented Design. |
| Objectory | Centered on the users and their interactions with the system. |
| OOA, OOD & OOP | Very practical and simple method. |

In these table we can see that the first three methods presented in this table have a strong point, but it is difficult to use only one method for the complete development of an information system, and that the last method is very practical and simple but perhaps not so comprehensive as the others.

IV.6. CONCLUSIONS.

From the previous comparison it can be concluded that it is not convenient to use only one of these methods, but that it is better to combine some features of these methods into another method. This problem of not being able to use a single method has brought the need to combine some of these methods taking into account the strong points of each one, this has given rise to the so called "Second Generation of Object-Oriented Methods" which combine some of the original methods (now called First Generation Methods), for example there has been an article on combining the OOA,OOD & OOP method with the Booch Method [31], and also other articles in combining OMT and the Booch methods [32]. So as this second generation is being created, the conclusion that it is not convenient to use a single method of the originals is being reinforced.

# CHAPTER V. A METHOD FOR IMPLEMENTING INFORMATION SYSTEMS FOR CIM IN MEXICO.

## INTRODUCTION.

This chapter presents a method for implementing information systems for CIM in México. In the questionnaire which was presented in chapter 3 the need to have a method for constructing information systems for graphical environments and focused on the modern object-oriented languages was detected. Also the characteristics of operative mexican information systems were determined. Another very important aspect is that the information system should be highly integrated in order to be able to use the system to respond fast to the manufacturing environment presented in chapter 2.

The methods presented in chapter 4 have advantages and disadvantages, but these methodologies do not have an evaluation phase for evaluating the information system projects. Also these methods of chapter 4 do not have a simplification phase that guarantees that the system being modeled is as simple as possible. These methods do not have an integration phase that takes care of all the information that flows between the subsystems of a company. There is also a need for simple techniques that are not too complex as the techniques in chapter 4, in order to be used by small mexican companies. For these reasons the author will not use a particular method as defined in chapter 4 but proposes a method presented in this chapter that uses object-oriented techniques simplified and focusing on constructing integrated information systems.

This method begins with the evaluation phase in which the areas of opportunity to implement information systems will be detected. This evaluation phase would find the information systems that would help in certain areas of the company according to the manufacturing strategies that the company wants to follow. In this phase the actual software and hardware resources of the company will be identified also in order to determine the potential area to improve. This evaluation phase would finish with an economic evaluation of the project to determine the feasibility of the project and the expected time to see practical benefits.

The next phase of this method is the analysis phase in which the operation of the company will be analyzed to determine which are the processes and data which are going to be represented by objects and the interactions between the different entities of the company. The analysis phase would build an object-oriented model of the company which would serve as a starting point in the construction of the information system.

Following the analysis phase the simplification phase would take place, in which the processes, objects and interactions detected in the analysis phase would be simplified. This is necessary to obtain the simplest model. It would be easier to design without redundancies or overhead. The simplification phase would transform the analysis models to obtain a simplified object-oriented model which is going to be the base for the design phase.

The design phase would follow the simplification phase. Here the simplified processes, objects and interactions obtained from the simplification phase would be combined to form the data dictionary of the system, the procedures (called methods in object-oriented terminology) and the user interface of the system. In the last part of this phase the objects will be grouped into components which can be re-utilized to form the different modules of the system.

The last phase of the method would be the integration phase in which the modules of the systems are going to be grouped in subsystems (called domains here), these domains have to be interconnected to each other to have an integrated system, so the interactions between domain is also going to be analyzed in this phase. The databases are going to be determined as a group of domains, and finally the changes in the organizational structure will be analyzed to plan how the people will work in the future when the information system would be implemented.

The structure of the whole method is shown in figure 5.1.

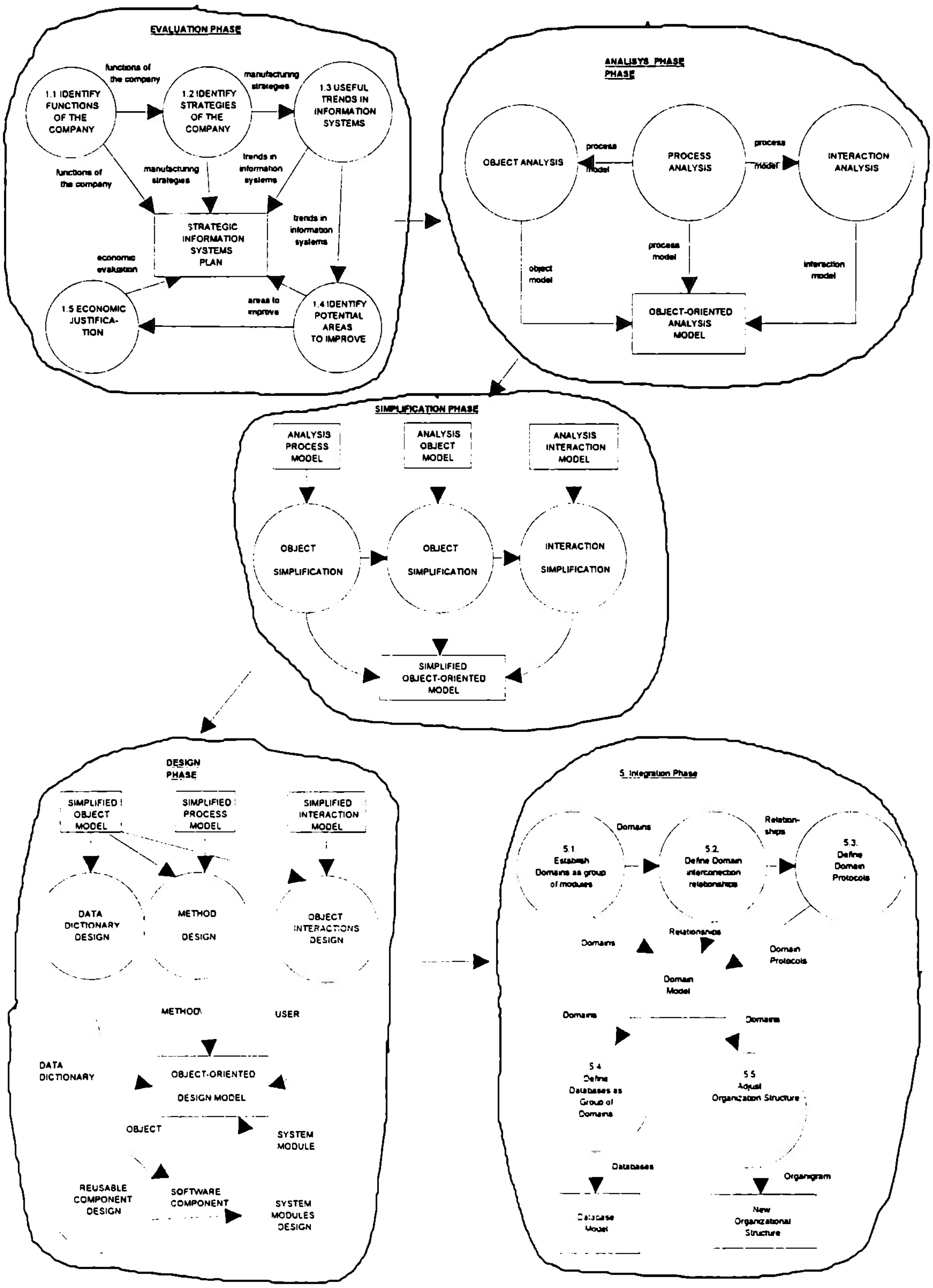



Figure 5.1. Structure of the method. (By J.Prieto-Magnus)

If we compare the structure of this method with the structure of the methods presented in chapter 4, we can see that there is an initial evaluation phase that the methods of chapter 4 do not have, in which the idea is to develop information systems that help to achieve the company strategies.

The second phase is similar to the analysis phase of the Booch and OMT methods in the sense that the objects, processes (or functions) and the interactions of the system are defined here, but in this method the analysis starts with the process analysis and not with the object analysis, because it is a good starting point for later identifying the objects of the company.

The simplification phase does not exist in the methods of chapter 4, because in these methods the simplification is done mainly in the design phase. In this method the author wanted to make the simplification more explicit, to be able to apply some principles of reengineering to the processes, and to make the object and interaction models as simple as possible.

The design phase is similar to the design phase of the OMT in the sense of the definition of the operations (or methods) and the definition of modules. And it also has some similarity to the OOD, OOP phases of Coad, Yourdon, and Nicola in that the user interactions are defined and that software components are taken into account.

The integration phase does not exist in the methods of chapter 4, because the methods of chapter 4 assume that the integration will be done implicitly by the analysis process, but this is not always the case especially in large projects that are done in several phases of long periods of time, which is in the case of most CIM projects in which the integration of the information systems of the whole company is not trivial.

All the phases of this method will be explained in detail the following sections of this chapter.

V.1. EVALUATION PHASE.

This is the initial phase of the method in which the areas of opportunity to improve the operations of the company will be detected, the steps of the evaluation phase are shown in figure 5.2.

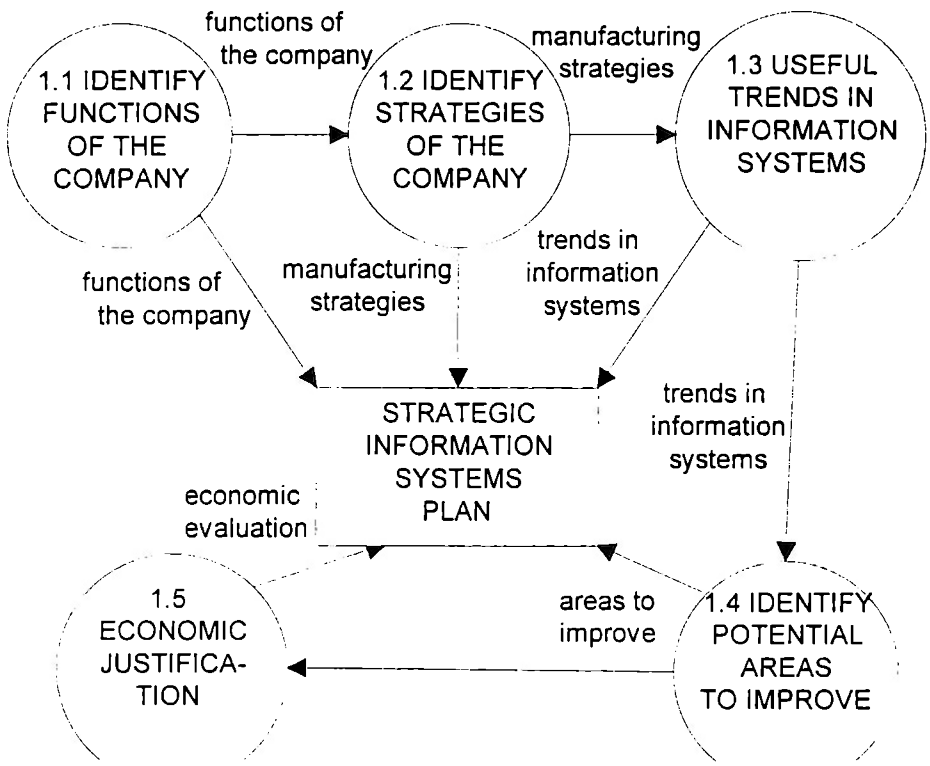



Figure 5.2. Evaluation Phase by J.Prieto-Magnus.

One of the main goals of this phase is to assure that the strategies of the company have a direct relation with the strategies of the information systems department. This would allow the information systems to contribute to the achievement of the company strategies (see figure 5.3). Sometimes the trends in information systems can be beneficial to the company and sometimes not, so this phase would align the strategies of the company with the useful trend in information systems that the computer department can use.

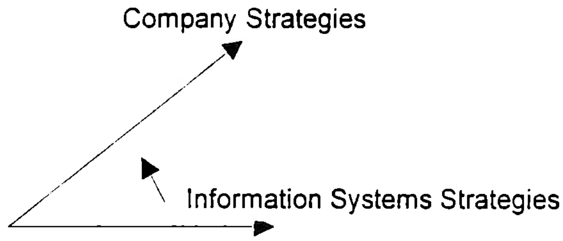



Figure 5.3. Aligning company strategies with information systems strategies.

Another important goal of this phase is to give an economic justification of the projects of information systems that are proposed. This economic justification has to show the potential economic benefits of introducing information systems in certain areas. Of course the future cannot be predicted accurately but estimate values can be calculated showing pessimistic and optimistic values. The next important goal is connected with the evaluation of the current software and hardware resources of the company. This would give us additional information about potential areas to improve.

This phase would be producing an strategic information systems plan that can be implemented by phases, so that the partial investments can produce results to be used in the subsequent phases. This plan would show the schedule of dates of each phase, the resources allocated to each phase, and the expected results of the phases.

V.1.1. IDENTIFY THE FUNCITONS OF THE COMPANY.

This is the first step of the evaluation phase, in which the functions (or departments) of the company are identified. In this step the functions of the company will be divided as functions of value and support functions, because according to Porter [11], only certain functions provide value for the company, these activities are commonly sales, marketing, product design, manufacturing, etc. So these functions are the most important for the company in terms of generating profit. The support functions do not add value directly to the company, rather they support the operation of the company, and the value that they contribute to the company can only be determined by the efficiency in which they operate, and to their role as integrators of the information of the company.

Once the functions have been divided in functions of value and support functions the value chain of the company can be constructed (see figure 5.4). In this value chain the activities of value are ordered from left to right according to the degree of contact with the customer, the functions to the left are more in contact with the customer, for example sales, marketing, etc. The support functions would be placed horizontally and their role is to support and integrate the company.

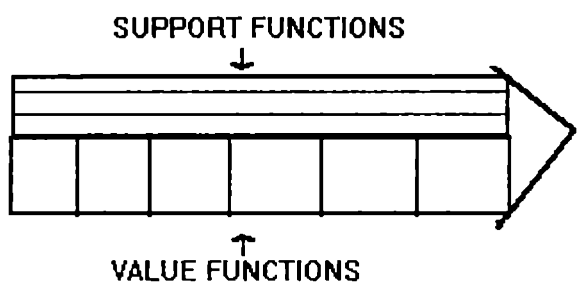



Figure 5.4.Value chain according to Porter [11].

This value chain filled with the functions of the company will be the result of this step of the evaluation phase. The value chain of Porter was used because it permits to identify the activities of value for a company in order to be able to direct efforts to achieve the company strategies.

V.1.2. IDENTIFY THE STRATEGIES OF THE COMPANY.

In this step the manufacturing strategies of the company will be identified. These strategies will respond to the characteristics (or pressures ) of the manufacturing environment (see figure 5.5). The identification of these strategies is of crucial importance to the company and these strategies should be related and derived from de mission of the company.

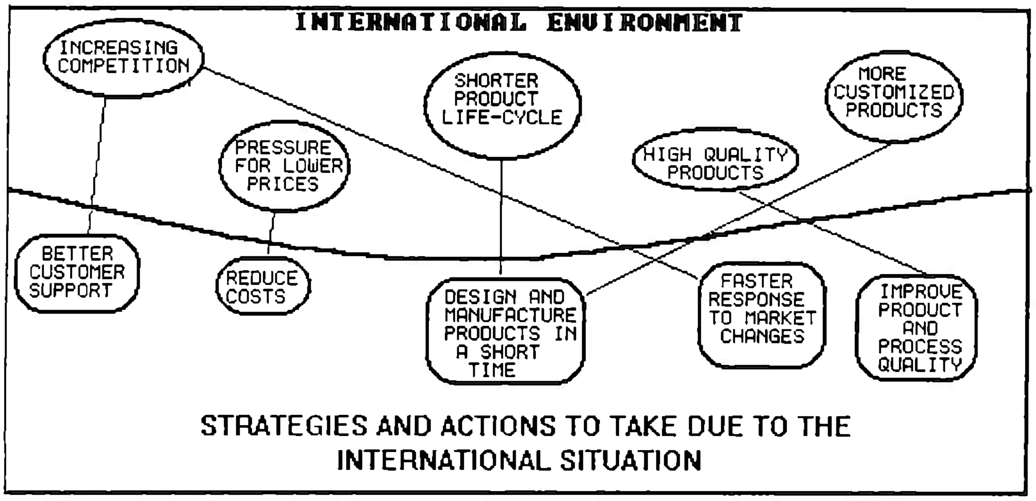



Figure 5.5. Manufacturing Strategies (by J.Prieto-Magnus).

Of course these strategies would be different from one company to another, and the determination of them by the directors of the company will be guided by the knowledge of the particular industry in which the company is working and from their experience accumulated through the years.

The information systems should contribute to achieve these strategies and in this sense the information system will be aligned with the manufacturing strategies of the company.

V.1.3. USEFUL TRENDS IN INFORMATION SYSTEMS.

To be able to achieve the strategies determined in the previous step, the company can use technology of information systems. In this step the current trends of information systems should be analyzed to select the technology which is more useful to the company. The choice of this trends is very important because the selection of the right technology for a certain project can determine how the system would work and would influence the success or failure of the project.

Some of the current technological advances to be analyzed (at the time of this writing) are the following [33] [34]:

Object-Oriented Programming.

Distributed Databases.

Open Database Conectivity (ODBC).

Fast-Ethernet Networks.

Graphical User Interfaces (GUI).

Object Components.

The selection of one or several of these technologies should be carefully analyzed with experts in the information systems area, taking several opinions, as the choice of the right technology would be crucial to the success of the project.

### V.1.4. IDENTIFY POTENTIAL AREAS TO IMPROVE.

To identify the potential areas to improve the strategies of the company should be compared with the functions of value of the company to determine which functions contribute to the achievement of each strategy. Also the technical trends have to be related with the strategies and functions of the company and the current situation of information technology of the company. This relation of strategies, functions, and technology would be done with the help of an evaluation matrix as it is shown in figure 5.6. A similar approach for using a matrix to relate the strategies of the company to the information systems was proposed by R. Andrew in his book Information systems strategic planning [35].

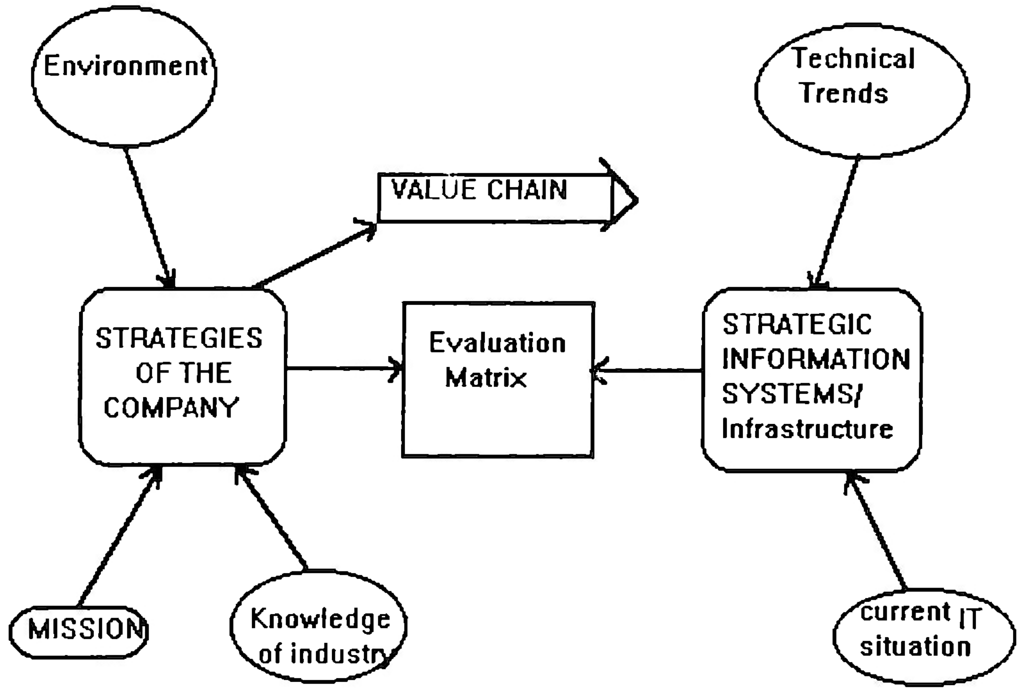



Figure 5.6. Mission, Knowledge of Industry and Manufacturing strategies (by J.Prieto.Magnus).

The purpose of the matrix is to show the relation of the information systems to be proposed with the strategies of the company and which functional departments participate with this information systems.

The structure of the matrix is shown in figure 5.7.

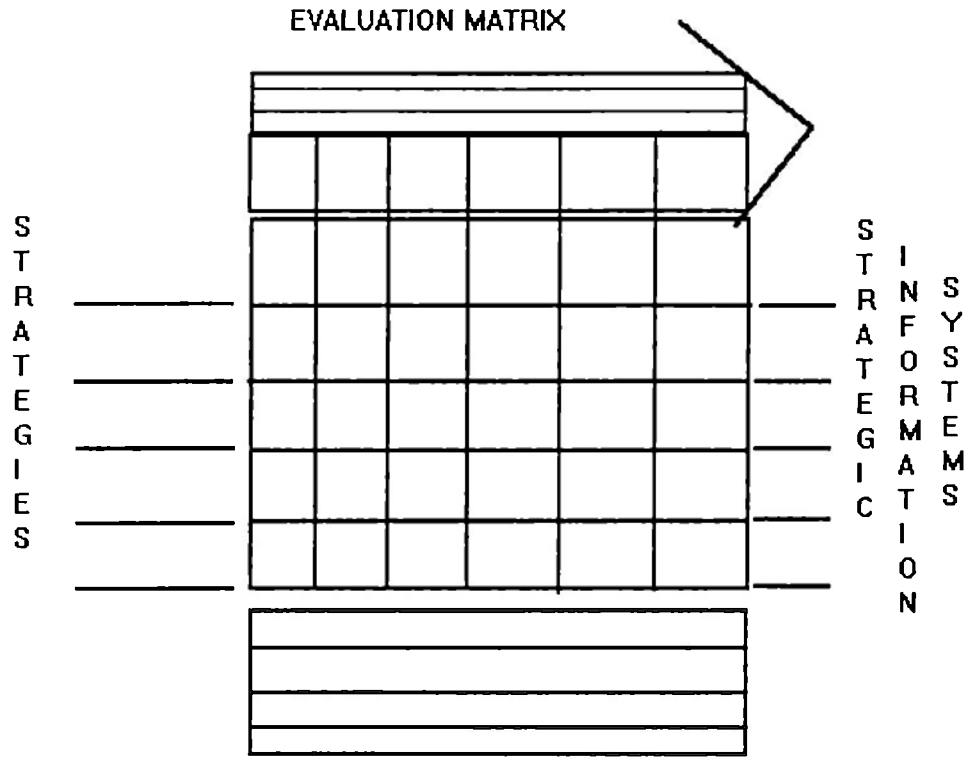



Figure 5.7. Evaluation Matrix (by J.Prieto-Magnus).

In the upper part of the matrix the value chain of the company determined in the step 1 of this phase would be drawn. In the left part of the matrix the manufacturing strategies would be written (this strategies were determined in step 1.2). The strategic information systems that would help the company achieve its strategies would be placed in the right part of the matrix. This strategic information systems would be derived from de technological trends analyzes in step 1.3. Finally the technology for the integration of business functions and systems would be placed in the lower part of the matrix.

Several matrixes would be needed to show the benefits of using the information system technology in the several areas of the company. The matrixes proposed are listed in the following points:

1. Relation Matrix.
2. Time-Reduction Matrix.
3. Economic-Benefit Matrix.

The Relation Matrix. The first matrix would show only the relation of the strategic information systems to the strategies an the functional departments of the company. This matrix would help to determine only which functions will have a benefit and the contribution of the information systems to the company strategies. An example of this matrix is shown in figure 5.8. In the lower part of the matrix, the lines represent the departments that have to send information between them. For example the Production department sends information about the finished orders of the customers to the Accounts Receivable department (A/R) in order to track the payment of the order.

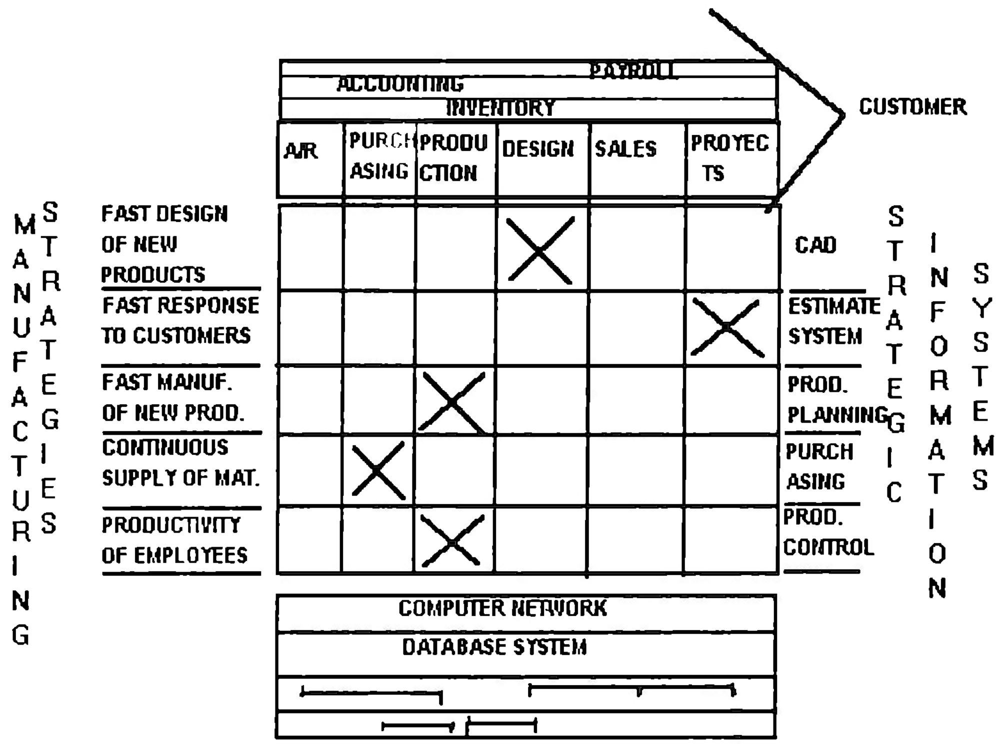



Figure 5.8. Relation Matrix (by J.Prieto-Magnus).

The Time-Reduction Matrix. This matrix would show the time reduction expected in certain functions of the company, compared to the actual time that it takes to do a certain function (see figure 5.9). The upper part of each slot of the matrix shows the current time that it takes to do a certain function. The quantity on the lower part of the slots shows the desired time according to what the company considers to be a reasonable time to achieve each function. For example: now the company has a current time of 72 hours to make a proposal to a customer, but the company considers that a reasonable time to respond to the customers would be 24 hours, so the slot related to fast response to the customer would have the form 72 / 24.

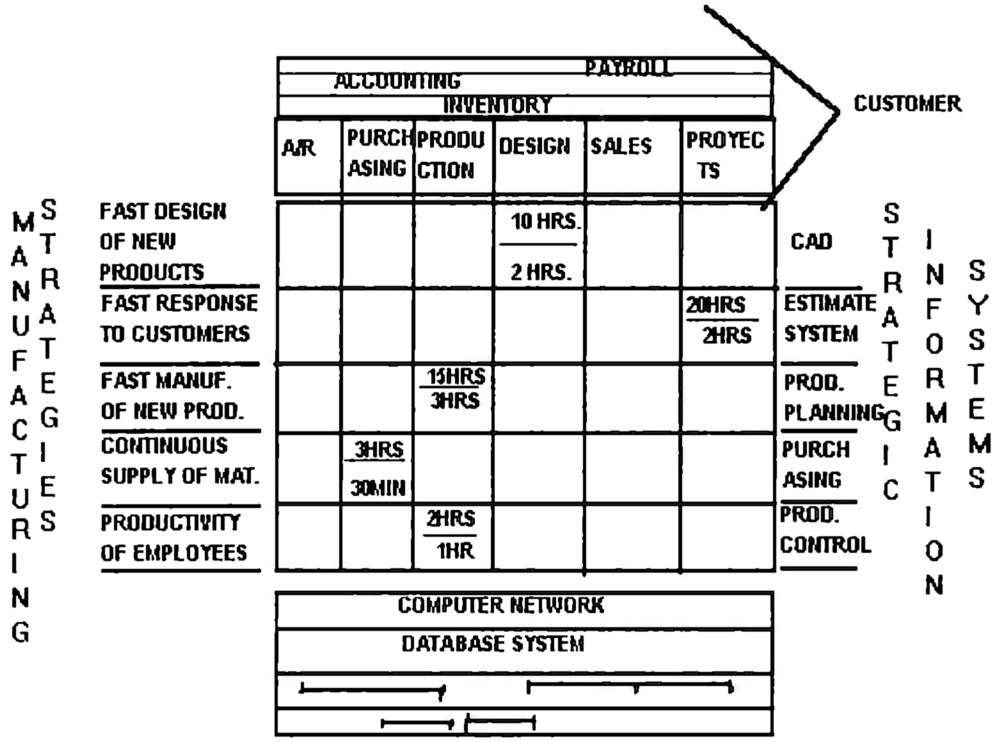



Figure 5.9. Time-Reduction Matrix (by J.Prieto-Magnus).

This matrix would show the expected time reductions as a benefit of applying information systems technology in certain areas. Some of these time-reductions would have an economic benefit which would be shown in the cost-reduction matrix. Other time reductions would have more subjective benefits more difficult to evaluate, for example improved customer support, but these type of time reductions do have an economic benefit in a longer period of time.

The Economic-Benefit Matrix. This matrix would show the expected economic benefits or cost reductions of applying information systems technology. Some of these economic benefits would be derived from the time reductions expected from the time-reduction matrix, these kind of economic benefits are mainly cost-reductions as a result of reducing the time to do a certain function. Other type of economic benefits can be derived from the expected increased capacity to attend the market of the company or doing new businesses in the future. Other cost-reductions can be obtained from reducing inventory or the better allocation of resources to the production. An example of this matrix is shown in figure 5.10.

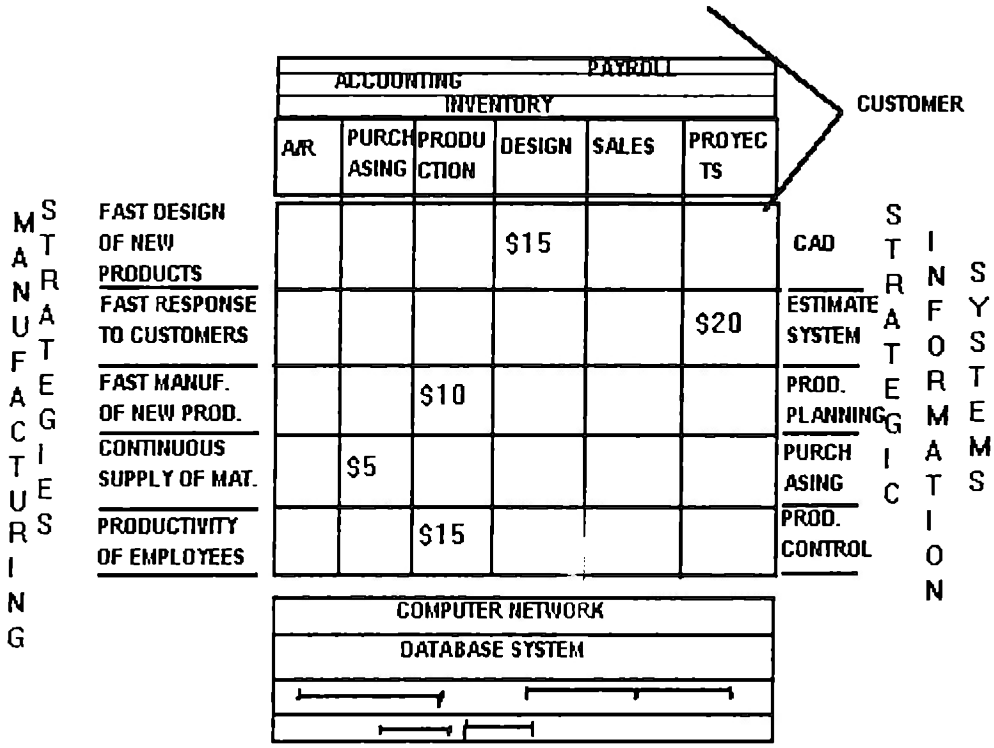



Figure 5.10. Economic-Benefit Matrix (by J.Prieto-Magnus).

The determination of which information systems are the most beneficial to certain areas of the company will be derived from the time and economic benefit matrixes. The slots of the matrixes that have a bigger ratio will be most feasible to implement.

After having a list of the information systems and its benefits, the time and order of implementing each system would be grouped in phases. The duration and the cost of integrating the information systems is generally high, so the project has to be divided in phases, the first phases are generally the ones that have a greater expected benefit, because this would provide more cash flow for the next phases. A pert chart would be useful to illustrate the start date and duration of each phase graphically.

So the result of this step would be a list of the information systems and the expected benefit of each one. This would be used as input to the economic justification phase which will be described in the next step.

## V.1.5. ECONOMIC JUSTIFICATION.

In this step of the evaluation phase the economic justification of the projects will take place. The economic justification will be the base for the acceptance of the information system plan. This initial economic justification can be revised when after each phase of the project is completed, because the initial justification will be based on the estimates of benefit obtained from the previous step and also from the estimates of the cost of implementing each system determined in the following activity. The economic justification will be divided in the five activities listed here (see Prueitt, and Park in The Economic Justification of the Sequential Adoption of a New Manufacturing System, for a similar discussion [36]) :

1. Determine the expenditures to be made.
2. Estimate the benefits compared to the actual situation.
3. Develop a PERT cash flow.
4. Develop a decision tree for partial implementation.
5. Calculate the expected value of the cash flow and calculate the probability of success and start the first proyect.

(See Appendix C. for the theoretical basis of the method of economical justification).

This five activities are explained bellow.

1. Determine the expenditures to be made. In this activity the cost of the projects will be estimated. These costs include hardware cost, software cost, installation cost, training, etc. This expenditures can be based on actual list price of each item or service and later be indexed to the expected inflation, as the project is going to be done on phases and it is probable that the costs will vary with time. The only item that might be considered to go down in price is hardware, because the cost of computer equipment has been going down in recent years. An example outline of this list of expenditures can be seen in table 5.1

Table 5.1. List of expenditures.

| | |
|---|---|
| Computers | $20,000.00 |
| Software | $25,000.00 |
| Networks | $15,000.00 |
| Machines | $20,000.00 |
| Training | $10,000.00 |
| Consulting | $15,000.00 |
| TOTAL COSTS | $105,000.00 |

2. Estimate the benefits compared to the actual situation. In this activity the benefit of the project will be estimated in three ranges pessimistic, most-likely and optimistic. The most-likely range will be obtained from the economic benefit matrix.

The pessimistic range will be based on negative factors. For example; some negative factors could be:

1. Competitors.
2. Instability of the economy.
3. Machine broke downs.
4. Quality Errors.

etc.

The optimistic range would be based on some positive factors. For example; some positive factors could be:

1. Growth of the economy.
2. Marketing Efforts.
3. Recommendations of new customers.

etc.

This benefits will be based in the results obtained from step 1.4 of the method, but here only economic-benefits will be taken into account. An example is shown in table 5.2.

Table 5.2. Estimated benefits in ranges.

| Concept: | Pessimistic | Most-Likely | Optimistic |
|---|---|---|---|
| Potential New Business | $50,000.00 | $65,000.00 | $80,000.00 |
| Savings due to efficiency | $10,000.00 | $15,000.00 | $20,000.00 |
| Savings in inventory | $27,000.00 | $35,000.00 | $42,000.00 |
| etc... | $... | $... | $... |
| Total estimated benefits | $87,000.00 | $115,000.00 | $142,000.00 |

3. Develop a cash flow . In this activity a cash flow of the net present value of the project divided in periods is going to be calculated with the results of the previous two activities. The periods can be months, semesters or years depending on the duration of the phases of the project. This cash flow will also be calculated in the same three ranges as the previous activity, to obtain pessimistic, most-likely and optimistic amounts in the cash flow as shown in table 5.3. The negative values in this table represent that the investment in the first period were greater than the profits of the same period.

Table 5.3. Cash flow.

| Period | Pessimistic | Most-Likely | Optimistic |
|---|---|---|---|
| 1. | -10000 | -8000 | -5000 |
| 2. | 20000 | 30000 | 35000 |
| 3. | 25000 | 30000 | 40000 |
| 4. | 10000 | 30000 | 40000 |
| 5. | 8000 | 25000 | 30000 |
| TOTAL | 53000 | 107000 | 140000 |

4. Develop a decision tree for partial implementations. A decision tree for the project will be developed in this activity to establish the possible decision paths that can be taken depending on the results of each phase of the project. This decision tree will help to determine what are the possible decisions to take in a partial implementation of the project, because some phases can give a positive or negative result for the company and determining in advance what is going to be done in each case give most certainty to the company. The decision tree together with the cash-flow can help to determine in which circumstances the project should go on or be stopped, or take an alternative action. An example of this tree is shown in figure 5.11.

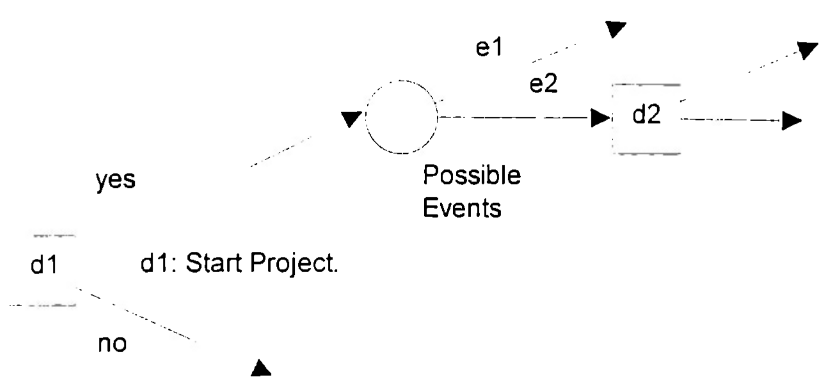



Figure 5.11. Decision Tree.

5. Calculate the expected value of the cash flow and calculate the probability of success of the first project.

The media E(VPN) and the variance VAR(VPN) of the cash flow that resulted from activity number 3 will be calculated in this activity. The triangular and beta distribution are used for analysis of the risk of investment projects [37], both distributions are based in pessimistic, most-likely and optimistic estimates, however the triangular distribution was chosen in this method for its simplicity, because it is easier for the managers of the company to interpret the meaning of the results. The triangular distribution has the shape that is shown in figure 5.12, where the a value is the pessimistic estimate, the b value is the most-likely estimate and c is the optimistic value.

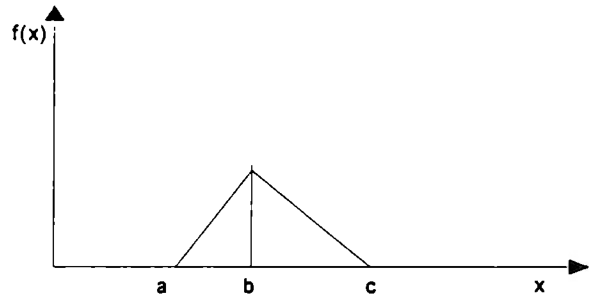



Figure 5.12. Triangular distribution.

The expected value for each period will be calculated according to the following formula:

$$e(x) = \int x\, f(x)dx \qquad (5.1a)$$

where:

$$f(x)= \begin{cases} 2(x-a)/ ((c-a)(b-a)) & \text{for } a<=x<=b \\ -2(x-c)/(c-a)(c-b) & \text{for } b<=x<=c \end{cases} \qquad (5.1b)$$

After calculating the integral we obtain:

$$e(x) = (a + b + c ) / 3 \qquad (5.1c)$$

where : a - is the value for the pessimistic range, b - is the value for the most likely range

c - is the value for the optimistic range.

And the variance will be calculated will the following formula:

$$var(x) = \int (x - u )**2\ f(x)\ dx \qquad (5.2a)$$

where u = e(x)

and finally:

$$var(x) = ( aa + bb + cc - ab - ac - bc ) / 18 \qquad (5.2b)$$

First the media and the variance of each cash flow in each period is calculated as shown in the first two columns table 5.4.

Table 5.4. Expected value and variance of the cash flow.

| MONTH | e(x) | var(x) | Cj | Cj*Cj | E(VPN) | VAR(VPN) |
|---|---|---|---|---|---|---|
| 1 | -7.667 | 1055556 | -1,00 | 1 | 7667 | 1055556 |
| 2 | 28.333 | 9722222 | 0,98 | 0,95 | 27642 | 9253751 |
| 3 | 31.667 | 9722222 | 0,95 | 0,91 | 30141 | 8807853 |
| 4 | 26.667 | 38888889 | 0,93 | 0,86 | 24763 | 33533767 |
| 5 | 21.000 | 22166667 | 0,91 | 0,82 | 19025 | 18193216 |
| TOTAL | | | | | 109237 | 70844143 |

After that the expected net present value (VPN) of the project's cash flow is calculated using the following formula [37]:

VPN = SUM(Cj xj ) ; j = 0..n (5.3a)

and

E(VPN) = SUM( Cj E(Xj) ) ; j = 0..n (5.3b)

VAR(VPN) = SUM( Cj**2 var(X)**2 ) ; j = 0..n (5.4)

where :

Cj = IF j = 0 THEN -1 (5.5)

ELSE 1 / ( 1 + i )**j.

and : "j" is the number of period, "i" is the interest rate and ** denotes exponential.

(i = 2.5% for the example of table 5.4).

In column 3, 4 and 5 of table 5.4 an example of the use of formulas 5.3 to 5.5 is shown.

As a result of this activity the expected value and the variance of the net present value is obtained. And in the next activity the decision to start or not with the project will be evaluated.

The decision to start or reject the project will be taken now. First the manager of the company has to establish the criteria of acceptance of the project. This criteria of acceptance will establish what is the probability that the expected value be greater than a certain degree of confidence. If this criteria of acceptance is accepted the project would start, otherwise the project would be rejected and would have to be revised. To calculate the probability of the criteria of acceptance a normal distribution will be used and the values would have to be standard. An example of the criteria of acceptance will be the following:

Criteria of acceptance: Start the project only if the probability that the expected value of the net present value is greater than 100,000.00 with a degree of confidence of at least 80%.

For the results of table 5.4 the probability would be calculated as following:

$P\{ VPN > 100000 \} = P \{ Z > ( 100,000 - 109237 ) / SQR(70,844,143) \}$

$P\{ VPN > 100000 \} = P \{ Z > -1.10 \}$

looking into a table of the area under the normal curve we obtain:

$P\{ VPN > 100000 \} = 0.86433$

So for this example the decision would be to start the project. After the first phase is finished its values would be updated in the table of cash flow and the same analysis would take place to take the decision of going on to the next phase. This kind of analysis permits to be refining the decisions based on the results of the first phases of the project.

This is the end of the evaluation phase . Next the analysis of the first phase of the project would take place in the next phase of the method.

V.2. ANALYSIS PHASE.

The purpose of the analysis phase is to analyze the operation of the company, the information that is used in the company and the interactions that take place in the company. This analysis would lead to the construction of an c' ject-oriented analysis model which will be the result of this phase.

This phase would have the structure shown in figure 5.13.

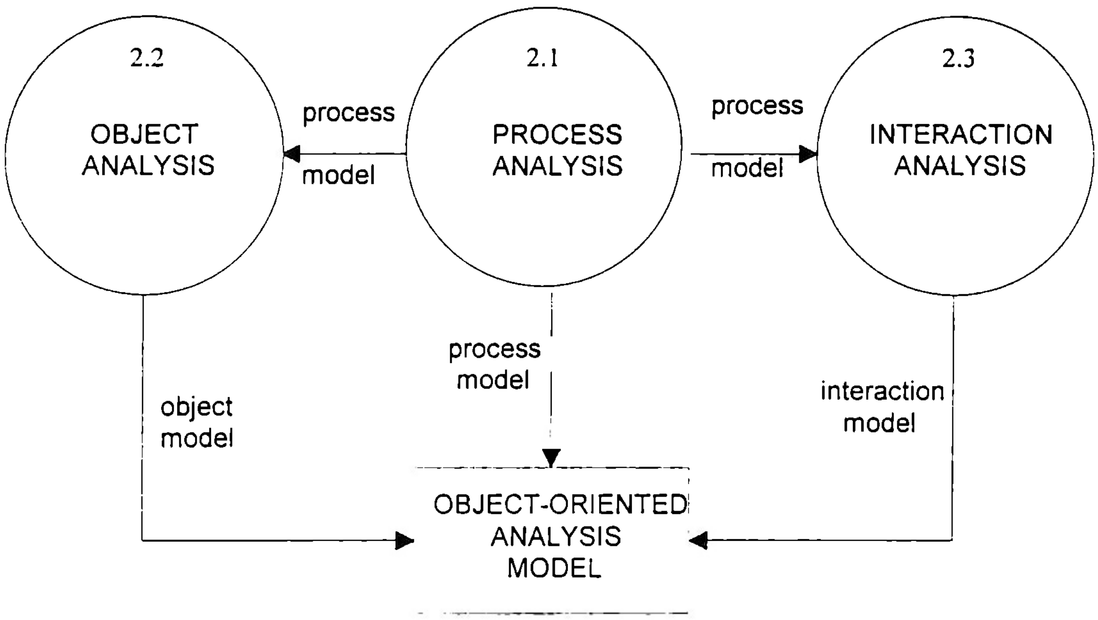



Figure 5.13. Analysis Phase, by J.Prieto-Magnus.

As this figure shows the analysis would start with the process analysis in which the processes of operation of the company would be analyzed. This step would produce a process model which would serve as input to the other two steps. The second step would be the object analysis in which all the objects of the company will be identified and a model of objects would be produced. The third step would analyze the interactions between the objects of the company and will produce a model of the interaction of the objects. These three models would form the object-oriented analysis model. Following this introduction each step of this phase would be explained in detail.

V.2.1. PROCESS ANALYSIS.

In this step the analysis of the processes of the company takes place. This process analysis is done in a top-down manner, starting with the high level processes of the company, which later can be decomposed into more detailed processes. This process analysis produces a process model which is documented with the use of process diagrams, these process diagrams use a similar notation to the process diagrams of IDEF which is a method for CIM definitions of the US Air Force [38]. This process diagrams show the information about the processes of the company and have notation shown on figure 5.14. As can be seen in this figure there are three basic components of these process diagrams which are: the objects on the top, the processes on the center and the databases which store and retrieve the information for the process.

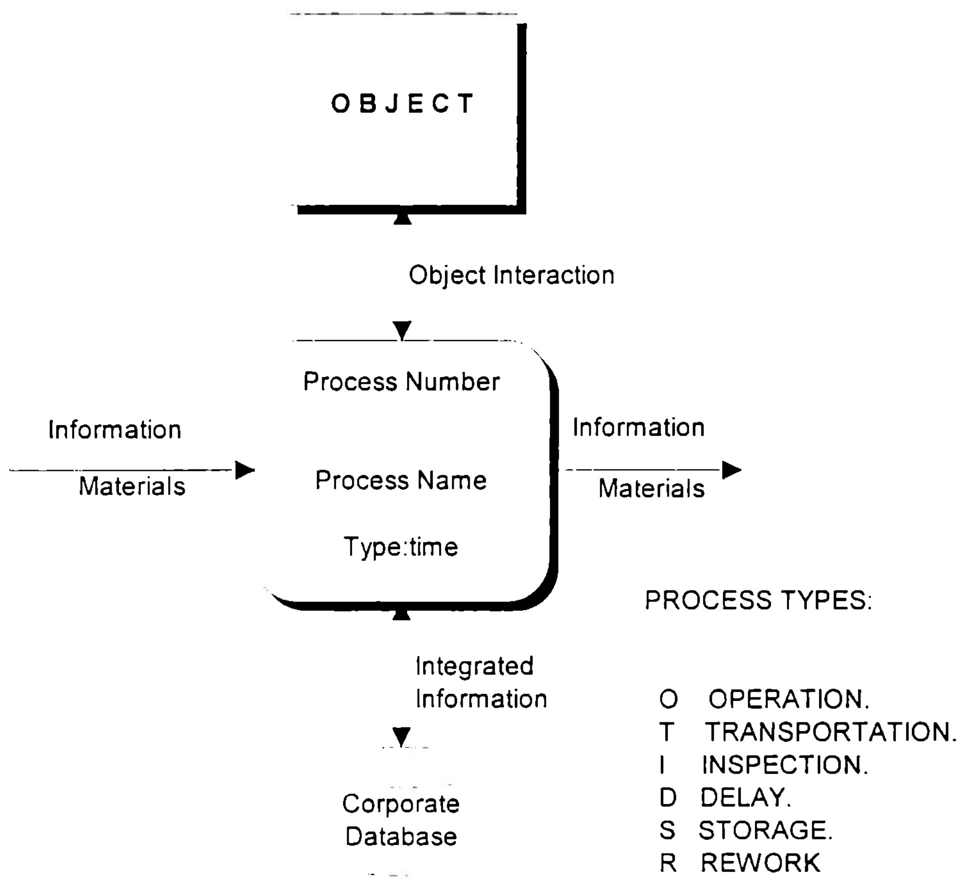



Figure 5.14. Process model diagram notation.

Processes are identified by a process number and a process name. The process numbers on the high level processes are positive integers 1,2..n. In diagrams which are a decomposition of a higher level process the process numbers are preceded by the number of the parent process. For example: 1.1, 1.2, ... , 1.n. Process names should be assigned as short and meaningful as possible, as later a process description would be developed for each process.

In the lower part of each process (see figure 5.14) the type of the process is defined. There are six types of processes [39] which are listed here:

1. Operation
2. Transport.
3. Inspection.
4. Delay.
5. Storage.
6. Rework.

The Operation type of process (denoted by O) is a process which does useful work for the company, these types of processes add value directly to a product or service of the company. The time of the operation is indicated following the opration type (see figure 5.14) for example: O:10min indicates a process of type operation which takes 10 minutes to complete. The objects that perform operations are machines or employees

The Transport type of process (denoted by T) is a type of process which transports materials or documents from one place to another. Transport processes also take time to complete depending on the distance involved. The objects that perform transport operations are transport equipment, electronic transmission equipment or employees.

The Inspection type of process is related to the quality inspections of materials, the authorization of a document, the inspection of documents, the filling of checklists, etc. The time of the inspection should also be registered. The objects that perform the inspections are generally employees or in the case of automated inspections machines.

The Delay processes refer to a not programmed delay that a material, document or person spends waiting for some event to occur. Delays also involve the time to search for information, the time that a person spends waiting for a meeting, etc. The time of the delay also has to be specified, although it might be only an average delay time because it is a not programmed delay. Delay processes are not associated with any object, because no object performs the delay, rather no object is doing anything upon that material or document during the delay process.

Storage processes involve a programmed delay in which a material or document is going to be stored for a certain period of time. This storage delay is programmed because it is necessary to store the materials or documents in certain places where they can be retrieved later for subsequent processes. As in the case of delay processes, storage processes have no relation to an object that performs the storage, rather the storage object is transported to the warehouse where it is going to be stored for a certain period of time.

Rework processes are processes which repeat an operation process, because an error in some other process arises the necessity to do a rework. Rework processes generally come after an inspection process where the fault is detected. Rework processes are also related to the reentry of the same information twice on a computer or the refilling of the same information in several forms. The objects that perform the rework are the same as in the case of operations, machines or employees.

The arrows that enter or leave processes horizontally (see figure 5.14) denote information above the arrow or materials below the arrow. The arrows that enter or leave the processes on the top denote the interaction of the object and the process, sometimes this interaction is transfer of information or a physical operation on a material. The bottom arrows that enter or leave processes denote the retrieval or storage of information into the databases of the company, which is the information that the process needs or the information that the process generates.

The flow of information or work can also have alternate paths where decisions are taken, the notation for desicions is shown in figure 5.15.

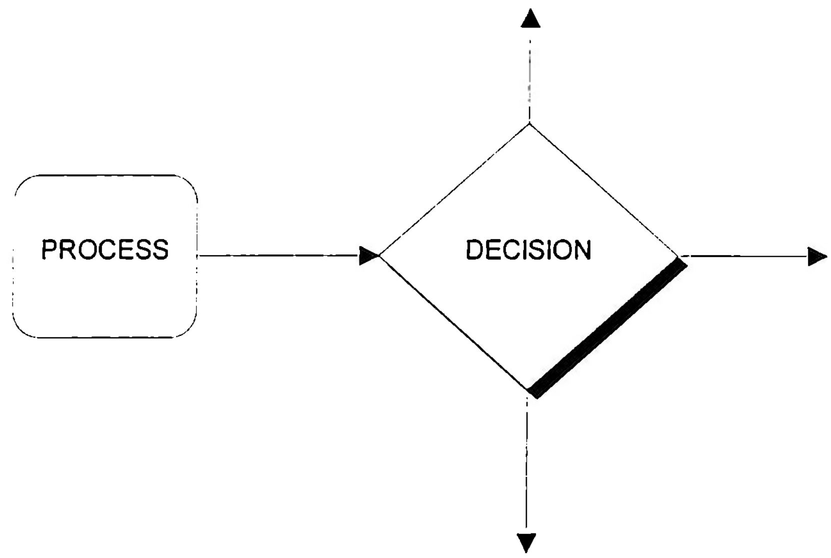



Figure 5.15. Decisions in process diagrams.

The detail of what a process does in depicted in the process descriptions, this process descriptions define what the process does with its inputs (information or materials) and what outputs produces with the help of the object that performs the process. It also describes what information is retrieved from the databases and what information would be stored in the databases.

Process descriptions are done in pseudocode as functions that return outputs and have input parameters, these descriptions will have the following outline:

- **Process Number** : Process name.
- **Inputs**: information, material, database information.
- **Outputs**: information, material, database information.
- **Events**(with objects): events.
- **Description**:

  if .....

  then do actions

  else do actions

As this outline shows there are five parts of a process description, the first part is the number and name of the process as it appears in the process diagram, the second part is the inputs of the process which are information, materials and information retrieved from the database. The third part are the outputs of the process which are information for the next process, materials and information stored on the database. The next part is the events that occur with the objects, this events involve the transfer of information, materials or the execution of an operation. The last part of the description is the pseudocode that describes what the process does. This pseudocode would be written in a Pascal Like Pseudocode to be easy to read.

Complete process diagrams would be written in sheets that would have a diagram number, a title and a date as shown in figure 5.16. The numbers of the top level diagrams would be positive integers 1 , 2 , ... , n and the numbers of the child diagrams would be preceded by the number of the parent diagram, for example 1.1 , 1.2 , ... , 1.n.

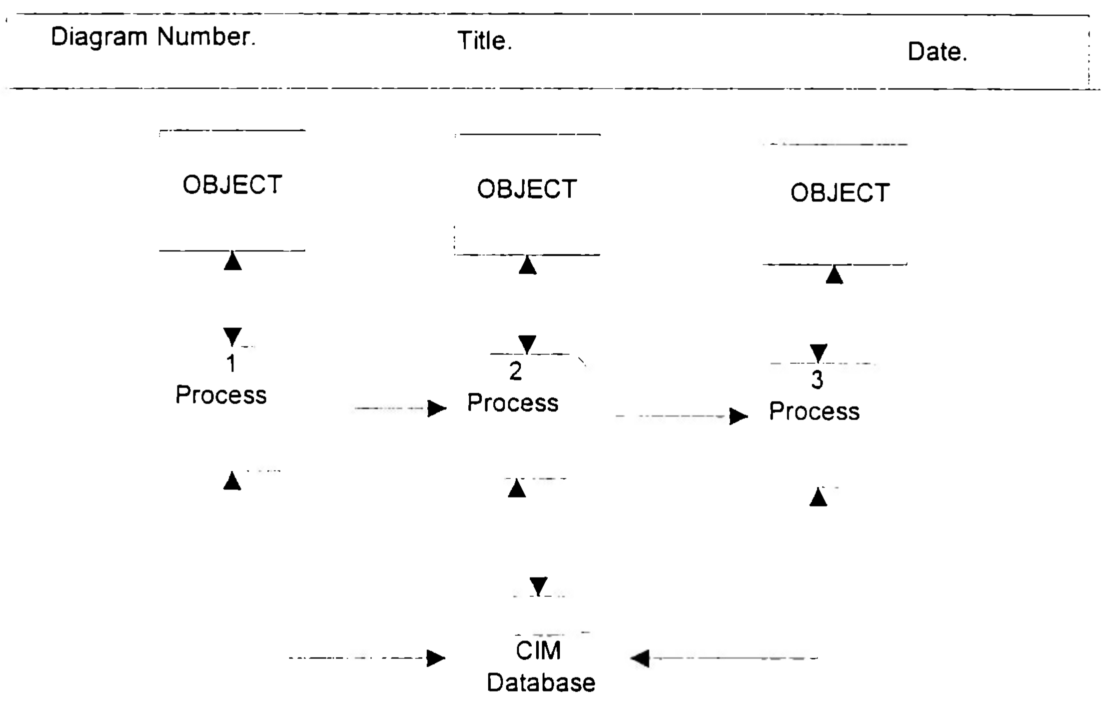



Figure 5.16. Process Diagrams.

The objects discovered here are mainly objects that produce and consume materials or information (customers, suppliers) as well as objects that transform information or materials (employees, machines).
These type of objects are called **actor objects**, because they perform the processes. This would help to differentiate this objects from the objects discovered in the following steps.

The process diagrams and the process descriptions would form the process model.
Process Model = Process Diagrams + Process Descriptions.
This process model would be used in the next steps to determine the object model and the interaction model. The process model would be refined later on in the simplification phase.

V.2.2. OBJECT ANALYSIS.

This step would determine the data structure of the system by identifying the objects that exist in the system, the attributes of each object and the relations between objects. This step would produce an object model which would be the base for the structure of the system. The notations for object diagrams is similar to the notation of the OMT method [30] which is one of the best notations for object analysis, but here are simplified for increasing the understanding of these diagrams.

First lets clarify what is an object. Objects are physical entities like employees, customers, suppliers, machines, tools, etc. Some of these objects are actor objects which were determined in the previous step. Objects also include management forms like invoices, orders, requisitions, etc. All this are the objects that are going to be determined in this step. There are other kind of objects which are computer objects like buttons, browsers, windows, etc. Avoid this type of objects in the analysis phase, because this computer objects will be determined in the design phase.

To discover the objects of the system this step uses three activities listed bellow:

1. Identify objects and attributes.
2. Group objects into classes.
3. Determine object relations.

1. Identify objects and attributes is the first activity in which the objects of the system are going to be identified. In the process model the actor objects are identified and are going to serve as a starting point for this activity together with the process model. The materials that go from one process to another are objects that are transformed. The information that goes from one process to another sometimes are objects (like production orders), and sometimes are just attributes of other objects (for example: part.no.). Other objects can be identified in the process description, these objects are generally **nouns** in the description, for example, if the process description says: "load tool a4, advance and make a 2 inch perforation", here the tool is another object.

2. Group objects into classes is the second activity. Once objects have been identified they are grouped into clas

Classes are groups of objects with similar properties, for example two customers are different object instances have the same properties (name, address, etc).

Some criteria for grouping objects into object classes are the following:

- Avoid redundant classes, example: customer, user.
- Eliminate irrelevant classes, classes that are outside the scope of the system.
- Avoid vague classes. Classes must be specific. For example : manufacturing facilities is a vague class you should rather use: machines, transports, computers.

The notation for object classes is shown in figure 5.17.

**OBJECT CLASS NOTATION**

**class name**

**attributes**

attribute : type

Figure 5.17. Object Class Notation.

In the upper part of the class the class name is placed. In the centered part of the object classes are the attributes of the class associated with its data types.

3. Determine object relations. In this activity the relations between objects are going to be identified. These relations will determine which objects are related to other objects and which type of relations do they have. There are three basic types of binary relations shown in figure 5.18.

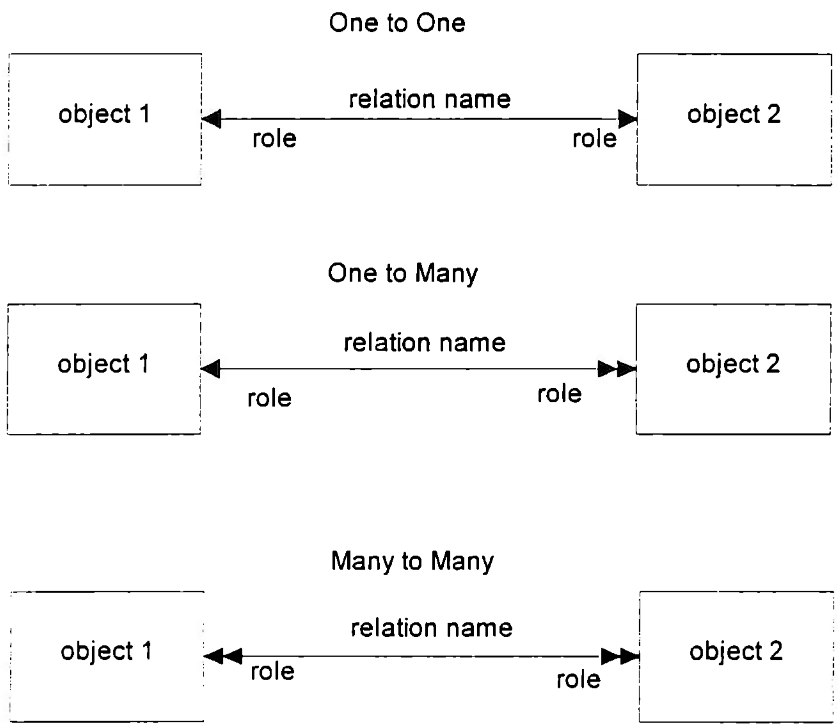
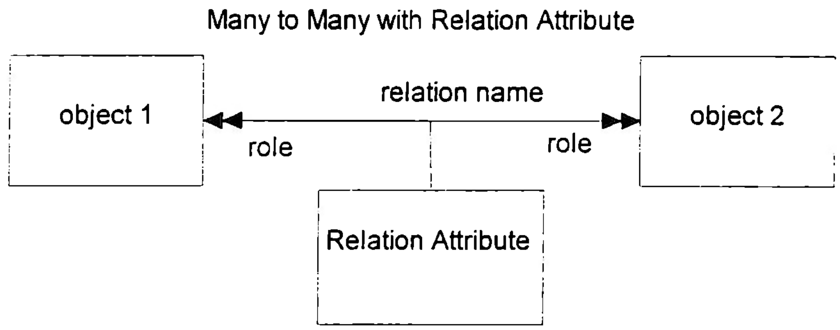



Figure 5.18. Simple object relations.

The first relation is a one to one relation, in which one object corresponds exactly to other object. The second relation is a one to many relation in which one object correspond to several objects of the second class. The third relation is a many to many relation in which many objects relate to other many objects of the second class.

The name of the relation is shown in the upper part of the arrow and the role of the relation for each object is placed on the lower part of the row: the role is a special name given to the object in the context of the relation with the other object.

There are other relations which are less common, shown in figure 5.19. The first one is a many to many relation with attribute. This relation is a many to many relation that has an attribute of the relation itself; this attribute only exists for the relation but not for each object.



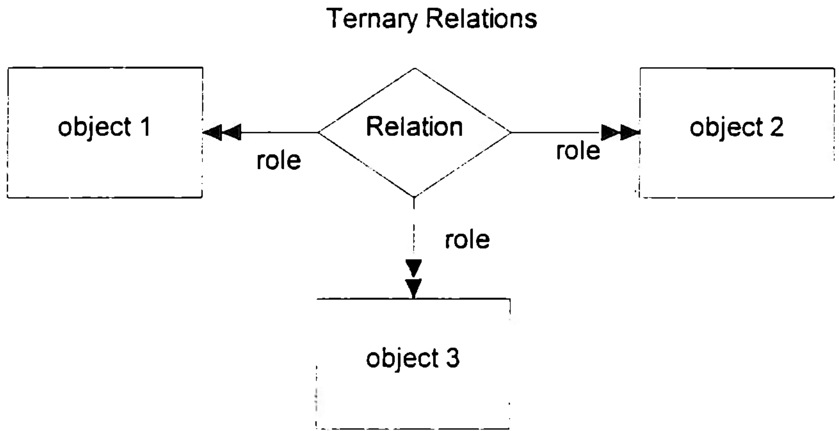




Figure 5.19. Less common object relations.

The second relation presented in figure 5.19 is a ternary relation. This one relates three objects; the name of the relation is placed inside the rhomboid and the roles behind the arrows. This kind of relation should be avoided when possible. The ternary relation should be divided in two binary relations when possible.

This three activities will complete the object model, this object model shows a view of the objects that will be used in the system, but it is only a static view, the interactions between each object are going to be described in the following step.

V.2.3. INTERACTION ANALYSIS.

Interaction analysis covers the dynamic aspects of systems. This dynamic aspects cover the control mechanisms and the sequencing of operations in a system of concurrent objects.

The main concept of interaction analysis is the concept of **event**. An event is something that occurs at a given point in time. An event may follow or precede another event. Events can also occur concurrently. An event passes information from one object to another.

The events of the system must be identified, to identify events the following guidelines are given:.

- a list of events must be identified for every object.
- in the process diagram the events with actor objects are identified.
- an event is something that changes the current state of an object.
- an event generally causes an action to execute.

This would produce a list of events of the system. each event names the interaction between two objects of the system. When the interactions between two objects are simple identifying the events is enough, but when the interactions between two objects are complex, a state diagram must be constructed.

A state diagram is constructed for a pair of objects which have a non-trivial interaction. A state diagrams shows the states of one object and the transitions between states caused generally by the events that other object generates.

A state diagrams relate events and states. A state diagram specifies the state sequence generated by an event sequence. The notation for constructing state diagrams is given in figure 5.20.

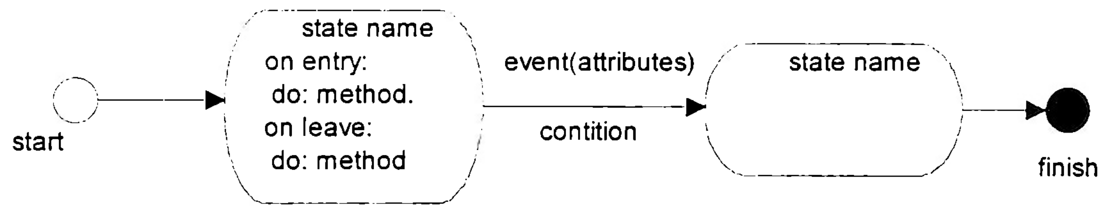



Figure 5.20. State diagram notation.

The state diagram would begin with a start symbol to go to the initial state of the object. Each state would have a name and the methods to execute when the state is entered or left. An event causes a transition to another state, this event can have attributes of the event, for example the date and time when the event occurred. Events can also have conditions, which specify requirements for executing the event. The state diagram finishes with an ending state.

A state can also be expanded to show further detail in another state diagram as shown in figure 5.21.

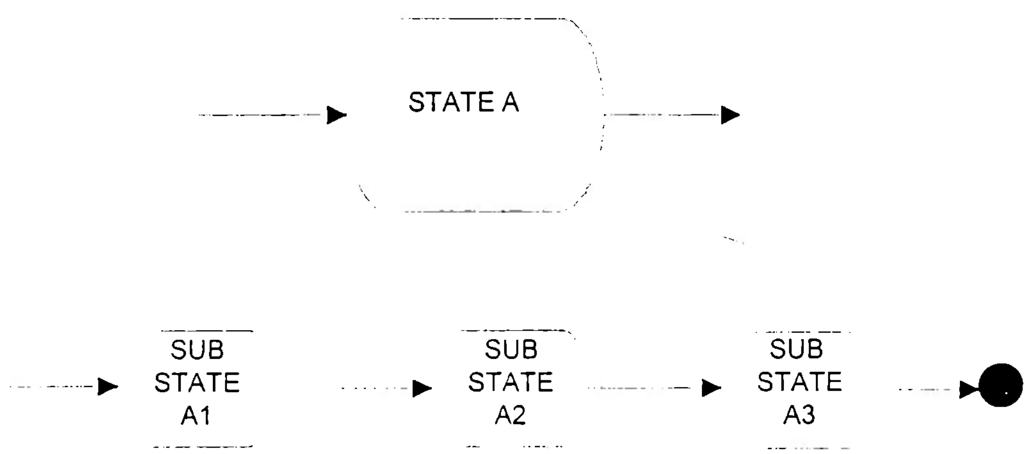



Figure 5.21. Expansion of a state.

This expansion of a state shows a detailed sub-state explanation of the parent state, this would be useful when the state diagrams are complex or when the state diagram has several levels of abstraction.

This would form the interaction model which would consist of :

Interaction model = Event List ÷ State Diagrams.

This would be the end of the interaction analysis step, and also the end of the analysis phase. The outputs of the steps of the analysis phase would form the object oriented analysis model.

Object Oriented Analysis Model = Process Model + Object Model + Interaction Model.

This model would be refined in the following phase which is the simplification phase, but this model up to this point constitutes the base from which the information system would be constructed.

## V.3. SIMPLIFICATION PHASE.

In the simplification phase the three models that form the object-oriented analysis model (process model, object model, interaction model) will be simplified. The purpose of this phase is to refine and improve the models obtained in the analysis phase, this would bring a good benefit in the design phase because the analysis models would already be simplified. The idea behind this simplification phase is that if we automate an inefficient system, the wrong things would just happen faster, so it is necessary to simplify a system before trying to automate it, as Underwood says in Intelligent Manufacturing [16] it is necessary to first analyze a system, then simplify it and then integrate it and then try to automate it.

The simplification phase would have three steps : process simplification, object simplification and interaction simplification. Each one of these three steps corresponds to the simplification of the analysis models. The structure of the simplification phase is shown in figure 5.22.

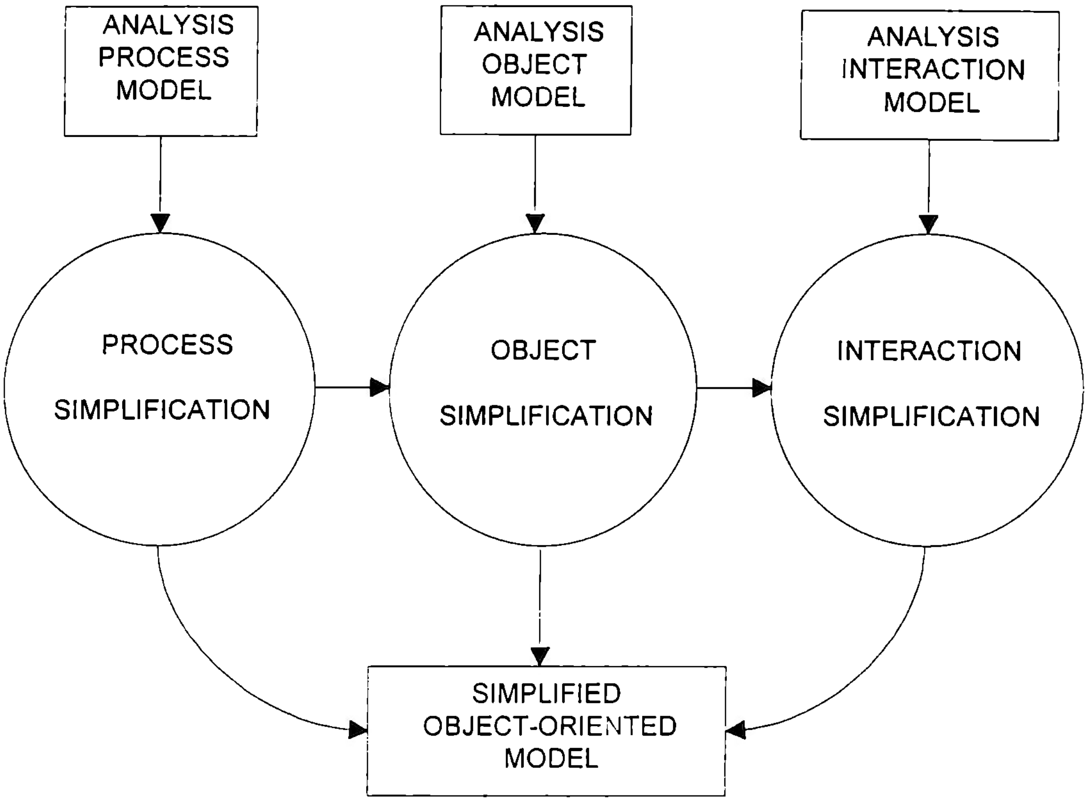



Figure 5.22. Simplification Phase (by J.Prieto-Magnus).

The simplification phase would produce a simplified object-oriented analysis model which would be the base for the design phase. Each step of the simplification phase is explained in detail below.

V.3.1. PROCESS SIMPLIFICATION.

The main idea behind process simplification is to eliminate steps of the process that do not add value to the product. This is one of the basic concepts behind reenginering [39], in which the process that do not contribute directly to add value to a product or service will try to be eliminated or combined with other processes of value.

Recalling the process types explained in step 1.1. of the analysis phase, there are six basic process types:

O OPERATION.

T TRANSPORTATION.

I INSPECTION.

D DELAY.

S STORAGE.

R REWORK

The only type of process that adds value to the product or service is the operation type. Because is the only type of process that performs a modification to the product that is useful to the customer. The customer does not care how many times the product was inspected or how many times the product was transported to another work area, the customers cares about the quality and the features of the finished product. So the idea behind process simplification will be to eliminate, reduce or combine all the processes that do not add value to the product.

The simplification will be done with the help of the following guidelines [39] listed below:

1.- Eliminate when possible all the types of process which are not of type operation.

2.- Reduce to the minimum the types of process which are not of type operation.

3.- Make the chain of process as simple as possible.

4.- Combine processes with others.

5.- Design process with alternate routes for the exceptional cases and make the main path as simple as possible.

6.- Make process in parallel (if possible).

7.- Storage data where it is originated.

8.- Use technology to improve the process.

9.- Let suppliers or customers help in the process.

These nine guidelines will help to simplify the process model, each one of these guidelines will be explained below.
1.- Eliminate when possible all the types of process which are not of type operation. This guideline tell us to eliminate when possible all types of processes which are not of type operation, this is not always possible but it is important to analyze which processes can be eliminated and which process are necessary. To determine if a process can be eliminated the true purpose of the process has to be identified. Once the purpose of the existence of a process is clear it then can be determined if that process can be eliminated or not.

2.- Reduce to the minimum the types of process which are not of type operation. After analyzing the processes according to guideline 1, there will probably be process which are not of type operation that cannot be eliminated, but we should reduce this processes to the minimum. For example if there is a process of calculus that does not add value directly to the product but it is necessary and is done by hand and it takes 50 minutes, it could be done with the help of a computer and reduce the time perhaps to 10 minutes. So these calculus process has not been eliminated but the time it takes has been reduced to the minimum.

3.- Make the chain of process as simple as possible. The chain of processes should be as simple as possible, this helps to understand and identify the processes and of course helps to execute them. This means that the chain of processes should have the fewest possible of processes. Longer chains of processes have more probability that an error occurs. Shorter cycle times are obviously cheaper and faster.

Sometimes the chains of process grow in the life of an organization because processes are added to try to solve problems or improve the product, but generally processes are never eliminated, so process chains tend to make longer with time, which also implies that there would be more people involved. To reduce the number of processes it is important to make the most amount of work possible in a single process, this means redesigning the tasks to be done in each process so that it can contain more work, in order to eliminate other processes and make the process chain simpler. The resume of this guideline is that process chains should have the fewest number of processes.

4.- Combine processes with others. As it is not always possible to eliminate all processes which are not of type operation, it is convenient to combine processes which do not add value with processes that do add value. For example, a process of delay can be combined with an inspection process, or an operation process in which a product is assembled can be combined with an inspection process. Combining processes is a way of combining work that does not add value with work that do adds value to the product. This of course permits to achieve a reduced cycle time for the product.

5.- Design process with alternate routes for the exceptional cases and make the main path as simple as possible. This guidelines refers to processes in which there are decisions for exceptional cases but when there is a main path of the processes. The idea here is to reduce the main path of processes to a minimum and treat the exceptional cases in alternate paths. This means that exceptional cases will be handled separately to the main path of the processes. This would allow to reduce the cycle time of the product and to treat explicitly exceptional cases with a separate path of processes.

6.- Make process in parallel (if possible). We are accustomed to think of sequential chain of processes and this tendency leads to long chains of processes. It is important to analyze long sequences of process to see if some of them can be done in parallel. When it is possible to make some processes in parallel the overall cycle time is reduced. To determine which processes can be done in parallel the dependencies of the processes has to be analyzed, so if a process does not depend of another process to do it then it can be done in parallel. Analyzing which process can be done in parallel can be of great benefit to reduce the time to make a product or give a service to a customer.

7.- Storage data where it is originated. Sometimes data is generated in one place of the company (sometimes by filling a form) and then it goes to some other part of the company where it is entered into the information system with the help of a computer. This chain of processes has a pattern of operation - > transport - > rework. This guideline suggest that information should be entered where it is originated to eliminate the transport and rework processes, this can be done placing a computer connected to a network in the place where the information is originated. Another benefit of doing this, is that the number of errors are reduced because the information is entered only once.

8.- Use technology to improve the process. In some points of the process chain it is possible to use technology to improve the process; these permits a certain process to reduce dramatically the time which it takes to perform it. It is important to detect points in the process chain where technology could be useful, but it should not be forgotten that the processes have to be simplified first, to avoid purchasing a technology which does not longer helps after simplifying the processes. Another point to take into account here is that first it is necessary to think how the technology would help and if it is possible to make a try or demo before buying technology.

9.- Let suppliers or customers help in the process. This guideline suggest that there are certain parts of the process chain that can be done by suppliers or customers specially at the beginning or end of the process chains. For example if a customers already provides the design of the product he wants, the company does not have to spend time or money in the design. Or if a supplier provides his prices with a comparison of the prices of its competitors the company does not have to spend time in making comparisons of different prices of suppliers. Of course these suggestions imply more work of the supplier or customer but if an arrangement can be achieved the company would save a lot of money and time in tasks that can be done by external entities.

These guidelines form the basis of the process simplification step which would produce a simplified process model which would be ready to be used in the design phase. It is very important to try to simplify the processes to the minimum, as this would greatly impact the cost and time to design and implement the information system.

V.3.2. OBJECT SIMPLIFICATION.

The object model obtained from the analysis phase consists of an object diagram which contains classes and the relationships between those classes. It is convenient to simplify this analysis object model to obtain a simpler design and to reuse object structures and methods.

The best way to simplify the object model is by using inheritance to organize classes of objects to share a common structure and methods. Inheritance means that an object can inherit characteristics of another object like the attributes and methods, so that it does not have to redefine them again, this is done by generalizing the attributes and methods that are common to two or more classes of objects. An example of inheritance can be seen in figure 5.23.

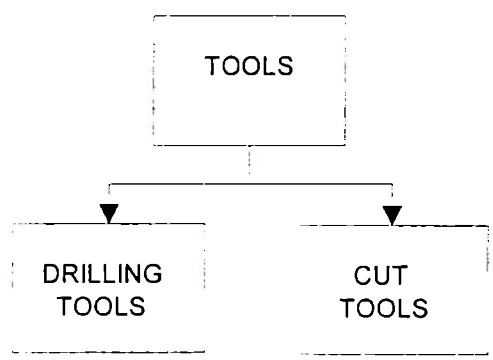



Figure 5.23. Using Inheritance.

In this figure we can see that the object class drilling tools inherits all the attributes and methods of the class tool and may define its own particular attributes and methods. The same holds for the class cut tools which is also an specialization of the class tools.

The following guidelines will be used to simplify the object model [30]:

1.- Find classes with a name that has the same noun and a different adjective.

2.- Find duplicate relations with the same purpose.

3.- Find similar attributes in different classes that have different names.

4.- Eliminate classes that have no attributes or methods.

5.- Eliminate relations that do not add information.

6.- Eliminate redundant attributes, or attributes that are outside the scope of the system.

This guidelines will help to simplify the object model using inheritance and to eliminate unnecessary classes or associations. Each one of these guidelines is explained below:

1.- Find classes with a name that has the same noun and a different adjective. When there two or more classes which have have the same name but with a different adjective, sometimes is possible to create a parent class that generalizes the characteristics of the other classes. For example; if there is a class named *local customer* and another class named *foreign customer*, it is possible to create a parent class named *customer* which generalizes the characteristics of both classes, in this way the class *local customer* and *foreign customer* would inherit the attributes and methods of the class *customer*.

2.- Find duplicate relations with the same purpose. If there are duplicate relations which have the same purpose this might indicate that there is a missing generalized class that can handle only one relation to other class of object. For example is there is a relations named *works-for* between *worker* and *project* and another relation named *assigned-to* bettwen *employee* and *project*, this indicates that a generalized class *general-employee* can be created with the common characteristics of *worker* and *employee*; thus there would be only one relation *works-for* between *general-employee* and *project*. This suggests when duplicate associations may help to detect when it is possible to use inheritance.

3.- Find similar attributes in different classes that have different names. When there are similar attributes in different classes, these attributes might be placed in a common class under a common name. For example if there is an attribute named *customer-city* and another attribute named *supplier-city* it might be convenient to make a class *cities* and place the attribute *city-name* there and then relate the class *cities* with the classes *customer* and *supplier*.

4.- Eliminate classes that have no attributes or methods. When there are classes that have no attributes or methods this classes can be eliminated. Sometimes after using inheritance there might be a class which ends having no attributes because all the attributes were transferred to a parent class; in this case these class might be eliminated. For example if there are originally two classes named *common-patient* and *private-patient*, and applying inheritance a class named *patient* is created, but the class *common-patient* ends having no attributes, then the class *common-patient* can be eliminated.

5.- Eliminate relations that do not add information. After applying inheritance there also might be redundant relations that add no further information, these relations can be eliminated. In the example of guideline number two, the relation *assigned-to* adds no further information, so it must be eliminated because in the parent class *general-employee* there is already a relation *works-for*.

6.- Eliminate redundant attributes, or attributes that are outside the scope of the system. If there are two attributes that have the same purpose, one might be eliminated, this can also be the case after applying inheritance in guidelines one to three. For example in the example of guideline number three the attributes *customer-city* is redundant with *city-name*. Attributes that are not relevant to the system should also be eliminated, these attributes are outside the scope of the system and therefore are not useful in the system. For example and attribute of *social-security-number* for a class *supplier* might not be useful in the system, because it is only useful for the supplier, this attribute is outside the scope of the system and should be eliminated.

These guidelines help to simplify the object model and thus making it clearer and easier to implement. The output of these step is a simplified object model which is ready for the design phase. The correct simplification and application of inheritance is very important to obtain an object model that does not have redundancies, the elimination of redundant attributes and methods help a lot in the design of the system.

### V.3.3. INTERACTION SIMPLIFICATION.

The interaction model generated in the analysis phase consists of the list of events and state diagrams for complex interactions. When there are complex state diagrams it is convenient to simplify them before proceeding to the design phase, because complex interactions can take a lot of time. It is valuable to simplify them to be able to achieve those tasks in a shorter period of time. The interaction between objects must be as simple as possible, but without losing paths or functionality.

The following criteria for simplification of state diagrams is going to be used [30]:

1.- Identify default events and eliminate them if possible.

2.- The initial state must include all default events.

3.- Group together under a single name events that have the same effect on the flow of control.

4.- Do not represent quantitative values as separate events.

5.- Identify a main default path from the start to the finish state and try to reduce the states in this path.

6.- Group together states that do not add a significant distinction.

7.- Reduce the states in alternate paths.

8.- Merge cyclical paths that join the main path in the same states by adding a parameter to the event.

9.- States without predecessors or successors should be initial or final states.

10.- Every event should have a sender and a receiver.

11.- Backward paths should go back the fewest states.

These criteria will be explained in detail below:

1.- Identify default events and eliminate them if possible. Default events are events that occur always, these events should be eliminated, thus eliminating the transition and states related to these default events. This is a way of simplifying the interaction of the system.

2.- The initial state must include all default events. When the default events occur at the beginning of the interaction these default events can be included in the initial state, then from this initial state other events can cause transitions to other events. Adding all default events that occur at the beginning of the interaction can save a lot of time in the interaction. For example in the interaction of a user with a terminal all the default values should already be assumed by the system and the user should enter just the exceptional information.

3.- Group together under a single name events that have the same effect on the flow of control. Two events that have different names may cause a different transition to the same state, so events that finally end in the same state should be grouped under a single name.

4.- Do not represent quantitative values as separate events. Quantitative values such as a range of integer values should not be represented as separate events, rather the values should be parameters of the event. For example if there is a machine that has a numeric key pad, pressing each number does not mean a separate event, the event is entering a number which might consist of several digits.

5.- Identify a main default path from the start to the finish state and try to reduce the states in this path. It is important to identify the main default path of the state diagrams, the main path has no exceptional conditions and this path defines the interaction between two objects in most of the cases, the exceptional cases are treated by alternate paths. For example in a payroll system the path to process the payroll should be the default path and exceptional events should be entered only when they are needed.

6- Group together states that do not add a significant distinction (difference). If two states in a system do not help to produce a significant distinction, this means that it is irrelevant for the system to be in one state or the other, these states should be merged in just one state. This might occur when there is optional information which might be entered but that does not cause a change of flow in the interaction of a system. For example in a system for invoicing if the postal code is optional, if the user enters the postal code or not this should not lead the interaction to two different states, because it would be irrelevant for the system to be in one state or the other.

7.- Reduce the states in alternate paths. After reducing the states in the main path of the state diagram, the alternate paths should be considered for reducing the states there. Sometimes too much attention is taken in reducing the main path but alternate paths are neglected. The alternate paths that occur more frequently should be reduced first, as these are the paths that might accumulate more time in the system.

8.- Merge cyclical paths that join the main path in the same states by adding a parameter to the event. When there are cyclical paths, for example an event that occurs three times, each occurrence of the event should not be treated as a separate transition, rather a parameter should be added to the event indicating the number of times that the event has occurred. A typical example of this is entering a password in a system, generally the systems gives you a number of tries, so the user can try for example three times to enter the password, if the password is wrong this causes an event which prompts the password again. The number of times that the password has failed should be treated as a parameter of the event, but it should be the same event.

9.- States without predecessors or successors should be initial or final states. If there are some states in the diagram which have no predecessors or successors they should be distinguished as initial or final states, because otherwise a state without predecessors would not be reachable, or a state without successors would block the interaction.

10.- Every event should have a sender and a receiver. An event should always have an object that sends the event and another object that receives the event. Eliminate events from the event lists that have no sender or receiver, also analyze all the events in state diagrams to determine if they are indeed received by the object of the diagram.

11.- Backward paths should go back the fewest states. When there is a backward path in a state diagram it should go back the fewest states possible, because it is desirable to loose the least amount of work when going back in a certain task. When a user keys wrong data in an information system, he wants to go back the fewest possible fields, he does not want to recapture a complete screen of data.

These criteria for simplification are going to be used to simplify the state diagrams, sometimes these simplification reduces significantly the time to operate a system and the benefit obtained from these simplification depends on the redundancy that exists in the state diagrams generated in the analysis phase.

This step ends the simplification phase and the simplified models would form the simplified object-oriented model. Simplified object-oriented model = Simplified Process model + Simplified object model + Simplified interaction model.

These models are ready to be used in the design phase, in which they would be combined to prepare the object-oriented design model.

## V.4. DESIGN PHASE.

In this phase the simplified object-oriented models from the simplification phase are going to be combined to form the computer objects of the system. In the analysis phase and in the simplification phase the process, object and interaction models were treated separately, here in the design phase these three models are going to be combined to obtain the data dictionary, the methods and the user interface of the system. After that the components and the modules of the system would be obtained.

The design phase is very important in the development of an information system, because here is where the models of the enterprise are going to be translated to computer objects, so the success or failure of the project depends to a great extent of a good design.

In the design phase the solutions to the characteristics of operation of information systems in mexican companies will be addressed, so in this phase the solutions to the problems of mexican information system are going to be proposed, because information systems in the mexican environment have to be designed in a different way to solve the problems generated by the environment.

The design phase would have the structure shown in figure 5.24.

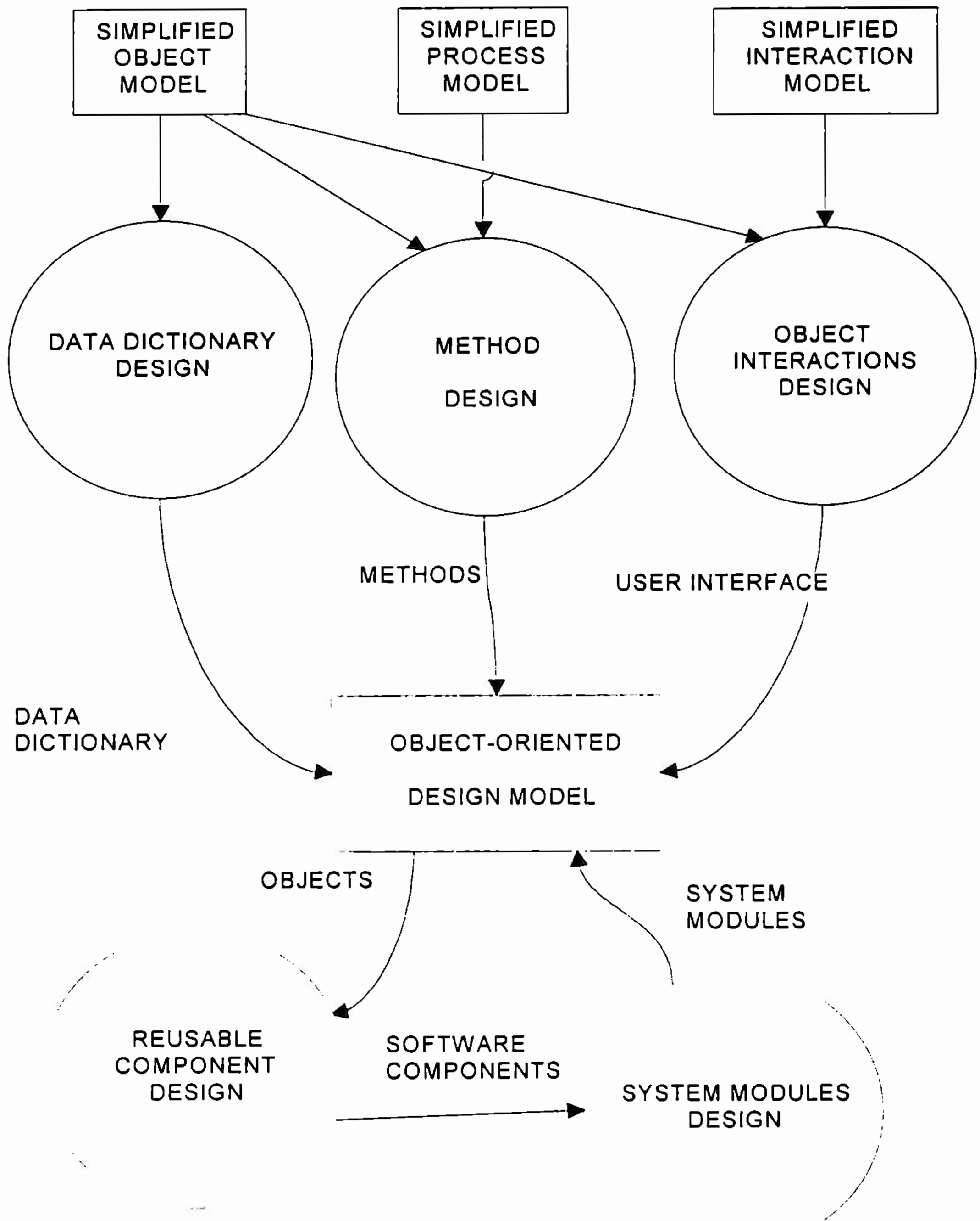



Figure 5.24. Design phase (by J.Prieto-Magnus).

The design phase has five steps : data dictionary design, method design, object interactions design, reusable components design and system module design. Each one of these steps is going to be explained below.

### V.4.1. DATA DICTIONARY DESIGN.

The data dictionary is going to be determined from the simplified object model, the object model consists of classes and relationships. The data dictionary is going to be designed for a relation database, as most of the object-oriented four generation languages in the market use a relational database.

The following rules are going to be used to determine which tables to create [40]:

1.- Classes are going to be mapped directly to tables with the name of the class, with the attributes of the class. This means that each class is going to be a table in the data dictionary.

2.- Subclasses that inherit the attributes from another class are going to have the identifier attributes (key attributes) of the parent class.

3.- If an object o2 participates in a mandatory relationship n:1 with an object o1 then place the identifier attributes of the object o1 in the object o2.

4.- If an object o2 participates in an optional relationship n:1 with an object o1 then create a separate table that has the identifier attributes of both objects.

5.- If two objects participate in a binary relationship n:m then create a separate table that has the identifier attributes of both objects.

6.- If two objects participate in a ternary relationship n:m:o then create a separate table that has the identifier attributes of the three objects.

7.- If an object o1 participates in a 1:1 relationship with object o2, determine the object for which the relationship is mandatory and place in that object the identifier attributes of the other object.

The rules presented above are going to be used to translate the object model and create the relational schema. These rules provide a consistent way of defining the data dictionary, but other considerations have to be introduced to respond to the problems of information systems in México.

At the level of the data dictionary the concept that is going to be introduced to address the problems of information systems in México is the concept of versions, each register of each table is considered an object and this object can have several versions as the value of its attributes changes with time, so we would define a versionable object to be an object which preserves all its changes through time [41].Versions are a key concept to address the problems of multiple changes in prices, exchange rates, costs, salaries, etc.

Object versions permit an object to have several versions by date or time. This permits an object to change its values, but preserving his identity and relations to other objects.

For example:

the object: *currencies* can have multiple versions by date :

| CURRENCY | VERSION | DATE | VALUE |
|---|---|---|---|
| DOLAR | 1 | 01/07/1996 | 7.50 |
| DOLAR | 2 | 02/07/1996 | 7.53 |
| DOLAR | 3 | 03/07/1996 | 7.65 |
| DOLAR | 4 | 04/07/1996 | 7.70 |
| DOLAR | 5 | 05/07/1996 | 7.63 |
| DOLAR | 6 | 06/07/1996 | 7.60 |
| DOLAR | 7 | 07/07/1996 | 7.62 |

This would allow a system to keep track of all the different values of the dollar in different dates. Using object versions in the design of the data dictionary is a key to address the problems of information systems in México, because in an environment of uncertainty the economic variables change fast and it is necessary to preserve all its values as they change in time to be able to respond to the environment.

Object versions can be in two levels : at the object level and at the attribute level. At the object level all attributes would be replicated in each version (see the example above), at the attribute level only one of the attributes of the object would have different versions.

Some suggestions about which objects could have versions would be for example: objects which have a list price or cost, objects which have a due date, objects that have a currency value. All this objects should be analyzed to determine if it is convenient for them to have versions.

### V.4.2. METHOD DESIGN.

Determining object methods, methods have to be determined from the process diagram of the simplified process model, once the methods are identified they have to be assigned to an object class, this is because in object-oriented programming the data and the procedures (methods) have to be encapsulated in a class, so that the method acts only on the attributes of that object class.

The following rules will be used to determine methods from the process diagram and to assign them to object classes [42]:

1.- If a process has an output to an actor object then the process should be a method of the actor object.

2.- If a process gets information from an input which is an object then the process is a method of the input object.

3.- If a process has an output to a database file, then the process is a method for the database file object.

4.- If a process has an input object information and the output is the same object, then the process is a method for that object.

5.- If a process has several attributes as inputs and has an object as an output then the process creates (builds) the output object.

6- If a process does an operation on an input material and outputs the same object transformed, then the operation belongs to the material object.

7- If there is a function which has several objects as input, the method would not belong to any of those objects. Rather a separate method would be created, and this method would have the two objects as inputs.

These rules would determine which methods are assigned to each object class, in this way the object-model and the process model of the simplification phase would be integrated into the object classes, which will have information about data and processes. So the main objective of this step is to integrate the object-model and the process-model into the object-classes.

V.4.3. OBJECT INTERACTION DESIGN.

Object interactions have to be designed to determine how the users, operators and employees are going to interact with the information system or machines. These object interaction design would produce the user interface design of the information system, this would help to identify the computer objects (buttons, browsers, etc) that the information system is going to have.

The design of the object interactions will be divided into the five activities listed below :

1.- Identify tasks.

2.- Identify subtasks and actions.

3.- Construct object-action pairs.

4.- Define how the action could be implemented.

5.- Link actions to methods.

6.- Define user event lists.

These activities will perform the design of the actions for each object and link the name of each action to a method determined in the previous step. A detailed explanation of each of the activities is given below:

1.- Identify tasks: each event identified in the object interaction model has a response, this response is going to become a task for the user interface model.

For example:

the following event is generated by a customer : place production order.

this event has the following response : register production order.

This response can be a task for the user interface. In that way all the high level responses to events in the system are goint to be tasks for the user interface model.

2.- Identify subtasks and actions: this task is going to be further divided into subtasks which together are going to help to implement the tasks, when a subtask cannot be divided any further it is going to become an action. Actions are the lowest level which later will be assigned to an specific object [43].

For example:

1. Register production order. (task)

1.1. Create production order. (action)

1.2. Identify product. (sub-task)

1.2.1. Browse product catalog. (action)

1.2.2. Select product. (action)

1.3. Enter quantity. (action)

1.4. Calculate promise date (method)

1.5. Confirm promise date. (action)

Notice in this example that actions are the lowest level and that all the subtasks have actions, also notice that methods can also be at the lowest level. These methods do not require human interaction, rather they are operations that the information systems has to make before the interaction with the user can continue.

3.-Construct object-action pairs: this activity constructs object-action pairs, associating actions to each object. In this way actions will be assigned to objects an later can be implemented for each object.

for example:

| <u>object</u> | <u>action</u> |
|---|---|
| production order | create |
| | select product |
| | enter qty. |
| | confirm promise date. |
| | |
| product | browse |
| | create |
| | modify |
| | delete |

In this example it can be seen that the object production order has four actions: create, select product, enter qty and confirm promise date. In the same manner all actions should be assigned to an object, creating object-action pairs.

4.- Define how the action could be implemented: each action can be implemented by a graphical object if the system is going to be implemented with a graphical tool, or by function keys if the system is going to be implemented with a character oriented tool. So, for example; actions like create object, delete object, show object can be implemented by buttons on a graphical interface, actions like browse articles, browse employees can be implemented by browsers in graphical interfaces. For manual machines each action can represent a button on a machine or a handle or anything that activates something on a machine. For numerically controlled machines actions can represent instructions of a numerical control program that perform certain machine operations.

5.- Link actions to methods: each action is going to be implemented by a method on that object. So in this step we will link the actions to methods already defined in the object model, or create new methods if the action does not have a corresponding method. For example: the action "create production order" may already have a method defined in the previous step. But there may be other actions which do not correspond to an existing method. For example; if select product does not correspond to an existing method a new method would be created for that object.

6.- Define user event lists: user event lists help to integrate people through the information system, user event lists are personal event lists per user in a system, this lists inform users of all the exceptional events that have occurred or that are going to occur a few days ahead.

Each event can have up to four different types:

- exceptional : an exceptional event that has already occurred.
- opportunity : event that represents an opportunity for the company
- prevent break : prevent a break (undesirable event) in the future.
- recurrent : common event that repeats in a certain interval.

For example:

event list for user:

USER: ACCOUNTS PAYABLE.

| DATE | EVENT | TYPE |
|---|---|---|
| 01/07/96 | CANCELLED PURCHASED ORDER 197089 | EXCEPTIONAL |
| 02/07/96 | PAY INVOICE 128970 TO OBTAIN DISCOUNT | OPORTUNITY |
| 02/07/96 | PLACE PURCHASE ORDER FOR PRODUCT 90977 | PREVENT BREAK |
| 02/07/96 | PRINT REPORT OF SUPPLIER BALANCES | RECURRENT |

Events can be generated by triggers programmed in the database system which are automatic process that can be invoked when a record is modified in the database, so that they can inform the users automatically of the exceptional events of the day. For example; when a cancellation record for a purchase order is created on the database, a trigger for the create event sends an event to the accounts receivable user automatically.

Event lists help users integrate into the company daily operations, and maintain every user informed of what they have to do in a certain day. User event lists help to prevent the problems that occur internally in companies when they are using the information system, so these would help in the mexican environment to handle the internal problems of operations of the information systems.

This activities conform the object interactions design, and the output of these phase would be the objects that would form the user interface design of the system. This step is linking the object-model, the interactions-model and the methods determined in the previous step. Up to this point all the objects, methods, actions and user interface objects would already be identified.

### V.4.4. REUSABLE COMPONENT DESIGN.

Modern information systems require fast development of software systems, so it is not enough to detect objects and implement software systems at the level of objects, because this level of objects is too low to achieve fast development. Reusable components [44] are a key to achieve fast productivity in developing software systems, because they allow the grouping of objects into components which can be reused in several modules and systems.

The definition of the software components involve three activities that are listed below:

1.- Identify common actions or subtasks.

2.- Identify common methods.

3.- Construct an object component hierarchy diagram.

A detailed explanation of each of these activities is given below:

1.- Identifying common actions or subtasks: from the task model it can be determined which actions are required for several tasks, or which subtasks repeat for several tasks. This would allow us to identify which objects and its associated actions can be grouped in a reusable component.

For example in the following task model:

| | |
|---|---|
| 1. REGISTER PRODUCTION ORDER. | (TASK) |
| 1.1. CREATE PRODUCTION ORDER. | (ACTION) |
| 1.2. IDENTIFY PRODUCT. | (SUB-TASK) |
| 1.2.1. BROWSE PRODUCT CATALOG. | (ACTION) |
| 1.2.2. SELECT PRODUCT. | (ACTION) |
| 1.3. ENTER QUANTITY. | (ACTION) |
| 1.4. CALCULATE PROMISE DATE | (METHOD) |
| 1.5. CONFIRM PROMISE DATE. | (ACTION) |

The action "browse product catalog" is done on the object product. But these action is also necessary to accomplish the register production order task. So the action "browse product catalog" is a reusable component that can be shared by two tasks, one for registering the products and the other task of registering a production order.

2.- Identify common methods: common methods can also be identified from the task model. These methods can be reused by other tasks or subtasks to prevent from duplicating code. These common methods would only be programmed once and would be called by several subtasks. Identifying the common methods can save a lot of time in programming the system, because the common subroutines would be made as functions to be called from serveral programs.

3.- Construct an object component hierarchy diagram: after identifying which actions or subtasks are reused in other subtasks, we will construct an object component hierarchy diagram, which can help to visually detect the relationship between the components as shown in figure 5.25.

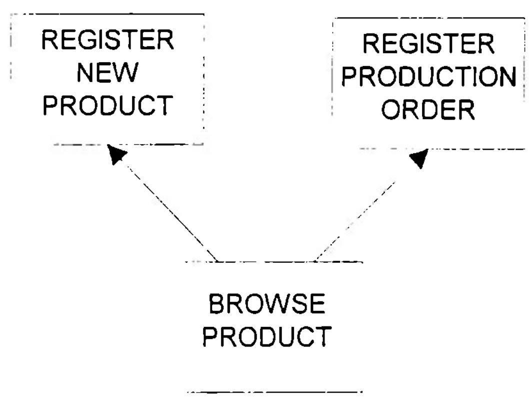



Figure 5.25 Object Component Hierarchy.

In this example the component browse product is used in two tasks, register new product and register production order. In this way you can see visually how object components are related.

### V.4.5. SYSTEM MODULE DESIGN.

In this step the object components would be grouped into modules which would form a system. This grouping of components into modules puts the components that are closely related in one module, modules help to group the functionality of a system into logical groups which in this case are called modules [45].

The construction of modules involve the following activities:

1.- Identify components and the objects that belong to modules.

2.- Identify objects that belong to a common module.

3.- Construct a module relation diagram.

Each of these activities is explained in detail below:

1.- Identify components and the objects that belong to modules. Objects and components can be grouped into modules to provide a cohesive way to structure the application. The components and objects that belong to a common module are closely related in purpose and function.

For example:

the object tools and machines are obviously closely related and can be grouped in a fabrication module.

2.- Identify objects that belong to a common module. There can be some object and components which are used in several modules. These objects can be defined in a common module.

For example:

the following object components can be defined in a common module for all the system:

months. currencies. cities. states.

3.- Construct a module relation diagram. The goal of this activity is to construct a module relation diagram that shows the relation between modules and the hierarchy between them. This diagram will help to understand how the modules are related to each other and how they call each other. An example of this diagram is shown in figure 5.26.

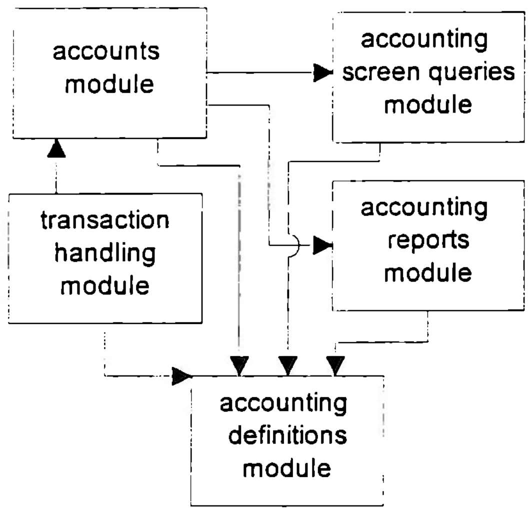



Figure 5.26.Module relation diagram.

The output of these step are the modules of the system, and the information of which components and objects belong to each module. This would be the end of the design phase, which is one of the most important phases in the method, and which would address the problems of the mexican environment with the use of versionable objects and user event lists. This phase also builds reusable components to speed the development process.

The results of these phase would be the Object-Oriented Design Model which would consist of:

Object-Oriented Design Model = Data Dictionary + Methods + User Interface + Reusable Components + Modules.

The modules of the system would be grouped into domains in the next phase and the databases of the system will be determined in the integration phase.

V.5. INTEGRATION PHASE.

The integration phase is the final phase of this method, in which the domains (which can be seen as subsystems) and databases of the system will be defined. At the end of these phase is where all the subsystems will be identified together with the relations between them, the databases that have to be created. It this way the information system would be integrated. The structure of this phase is shown in figure 5.27.

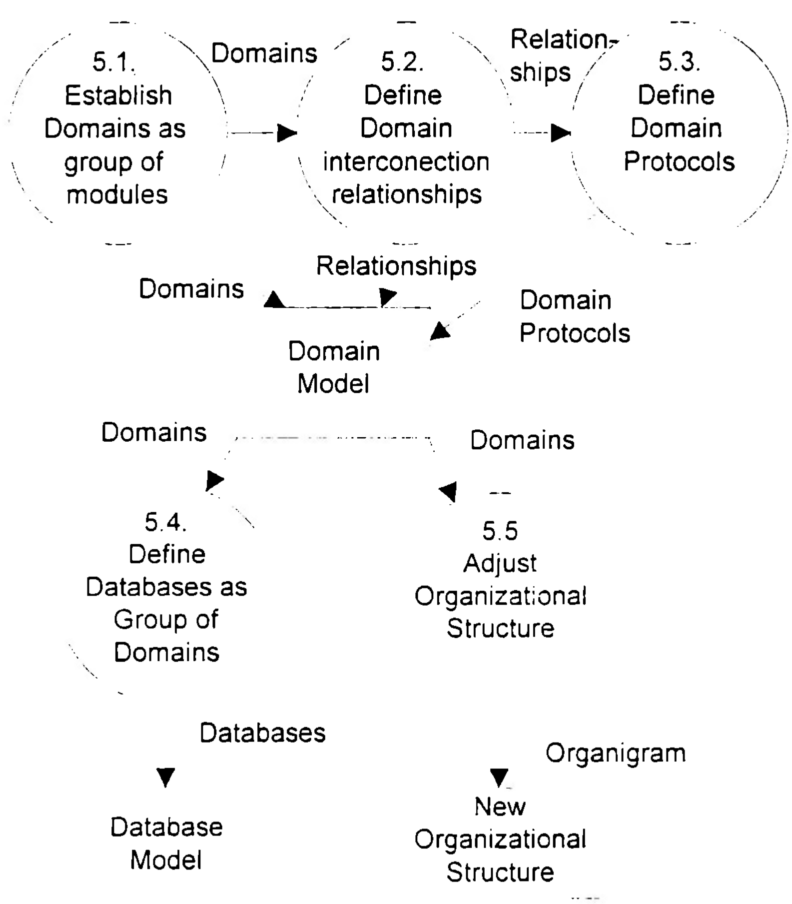



Figure 5.27. Integration Phase (by J.Prieto-Magnus).

As the previous figure show this phase consists of five steps listed below:

1.- Establish domains as groups of modules.

2.- Define domain interconnection relationships.

3.- Define domain protocols.

4.- Define databases as groups of domains.

5.- Preview adjustments in the organizational structure.

Each of these steps is explained in detail below.

V.5.1. Establish domains as groups of modules.

The grouping of modules into domains (subsystems) join the group of modules of a working group not necessarily in the same functional area but having a close interrelation in their work (the concept of domain is explained in the Lean CIMOSA Arquitecture [46]). For example in a company where there are two functional departments : 1.Purchasing and 2.Accounts Receivable we could form a domain called Supplier Relationships, because their activities are closely interrelated.

This grouping could be made analyzing the current organizational structure of the company and detecting departments which work very closely. In some cases this domains are interdisciplinary these cover several functional departments.

There will be 3 types of domains:

1.- Support domains: these support the operation of the company but do not generate value.

2.- Value domains: these domains generate value for the company.

3.- Mixed domains: these domains have functions of value and support functions.

Each domain will have one of these domains types. This would help in identifying which domains generate value for the company and which are support domains which collaborate with the value domains to generate value for the company. Mixed domains have both type of functions included. Generally the support function is to support the same domain.

At the end of this step all domains and their types would be identified. In the next activity the relations between domains will be identified.

V.5.2.- Define domain interconnection relationships.

The domains identified in the previous activity need to be interrelated. In this activity the relations between domains will be identified. The relationships indicate that some transfer of information between each domain has to take place. The result of this step will be a domain interconnection graph as the example shown in figure 5.28.

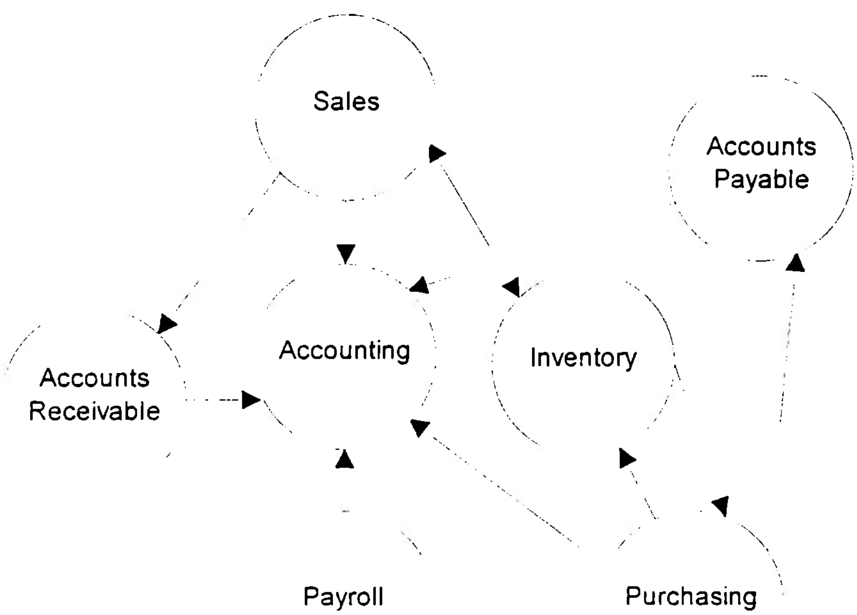



Figure 5.28 Domain Interconnection Graph of Administrative Information Systems (by J.Prieto-Magnus).

Each of the domains shown in the graph will be a subsystem and the relation between these subsystems is indicated by the arrows. In the next step of these phase the information that is transferred between domains will be analyzed.

V.5.3. Define domain protocols.

Domain protocols are the rules for communicating between domains (the concept of communication protocols is widely used in computer network communication architectures [47]), which will clearly define how the communication between domains will take place.

The domain protocols have 3 parts:

1.- Information.

2.- Structure of the communication.

3.- Frequency of the communication.

Each of these parts will be explained below:

1.- Information: the information to transfer for one domain to another will be defined here. This means that it is necessary to define which objects and attributes will be transfer for one domain to another. Sometimes several objects need to be transferred to the other domain, but just certain attributes of each object. This part will contain only the information needed as in the other parts the structure of the communication and the frequency will be defined.

2.- Structure of the communication: it is not enough to establish which data is going to be transferred, it is also necessary to establish the structure of the communication. Normally one of the domains would start sending information to another domain but the other domain has to verify that the information that was sent was correct and could reply with by an acknowledgment. This is the simplest case, but there might be other cases in which information is send bi-directional and has a more complex structure. So the structure of the information would be a list of events indicating what happens in the communication as can be seen in the following example:

a) The sales domain sends the daily sales information to the accounting domain.

b) The accounting domain verifies the information and sends an acknowledge.

c) The sales domain sends the cancellations that were received on that day.

d) The accounting domain responds with an acknowledge.

The structure of the communication defines how the communication would take place; who would send information first, who would respond, etc. The frequency of the communication will be explained in the next part of the protocol.

3.- Frequency of the communication: this part would determine how frequent the transfers of information take place. Some transfers will be done when a new transaction is entered, this is called an on-line transfer, but these transfers requires that the domains maintain an open communication path all the time which can be costly but it is useful to have all the information updated all the time. If the information is not required on-line it might be possible to transfer the information on a daily basis. In this way a domain will transfer all its transactions to other domains at the end of the day. Some domains which transfer tax information, social security information or statistics to other domains can transfer the information monthly or bimonthly. Of course there is a tradeoff between frequency of communication and cost of the communication, because when the information is transferred more frequently it will cost more and when the communication takes place in longer intervals of time it will be cheaper. So if the communication is not needed so frequently generally it is better to do it less frequently to reduce costs.

These will be all the parts of the domains protocols, which will define how the communications between domains would take place. The next step is to define the databases that the system would need.

V.5.4. Define databases as groups of domains.

The databases of the system will contain one or more domains, it is important to define the databases because the number of databases would define how many database servers would be needed in the system and this would affect in the number of machines dedicated to database servers that will be needed as well as the memory that they would need. The systems of the whole company should not be centralized in a single database, rather the systems should be distributed among several databases to facilitate administration and control (for a complete discussion of the benefits of distributed databases see Gorman [48] and Ceri,Pellagatti [49]).

Databases are formed from the domain interconnection graph and from the protocols, with the following rules:

1.- If a single domain has few connections and the frequency of the protocols is low then you can define a single database for that domain. For example: the prospects domain which contains the information about the possible future customers, is only related to the sales domain and the frequency of transfers is several days, in this case the prospects domains could be a separate database, which will only transfer information to the sales domain when a prospect becomes a customer.

2.- If a group of domains has many connections and the frequency of the protocol is high then define a single database for that group of domains. For example if the sales domain needs information from the inventory domain and from the customers domain 200 times a day then all this domains should be placed in a common database.

These rules would be used to define how many databases are going to be in the system. It is not convenient to put all the domains in a single database (except when the frequency of the transfer is high) because it is more difficult to administrate a larger database for backups or reliability purposes.

V.5.5. Preview adjustments in the organizational structure.

Generally the structure of the organization will change because of the information systems, so the organizational structure would have to be adjusted to reflect the change in the way people is going to work with the information system. It is probable that the people will work more efficient thus having more free time which could be dedicated to other activities, or that some people need to be relocated to other areas. This restructuring to be more competitive is sometines called downsizing [50], but we want to point out that sometimes it is better to relocate people than to reduce the number of people in an organization.

The following guidelines are given to plan how this changes will affect:

Guidelines:

1.- Reduce the number of people in domains with a common database.

2.- Change organizational structure if there are many interdisciplinary domains.

3.- Transfer people from support domains to value domains.

4.- Assign more activities of value to people that work in mixed domains.

Each of these guidelines is explained in more detail below:

1.- Reduce the number of people in domains with a common database : some tasks would be made faster with the information system, so the number of people of several domains with a common database could be reduced. For example : when a common database is shared by the inventory, sales and customer services domains all the work in these three departments might be done by less people, so that the remaining people might be transfered to other domains.

2.- Change organizational structure if there are many interdisciplinary domains: when interdisciplinary domains are formed, the structure of the organization could be changed perhaps to a matrix organization, because when interdisciplinary domains are formed the functional barriers imposed by traditional functional organizations are broken. This can lead to more productive teams focused on performing processes and not functions.

3.- Transfer people from support domains to value domains : some people could be transferred from support domains to domains of value to increase sales, customer support, marketing, product design, etc. The people in support domains are generally reduced because the information systems normally makes many support functions automatically, so these people can be transferred to domains of value to increase the profits or service that the company provides.

4.- Assign more activities of value to people that work in mixed domains: in mixed domains the support activities could be done faster, this could lead to a reduction of personnel in the support functions. So that people that work in support functions could also make part of the value functions. In mixed domains the support functions generally will be done faster with the information system so these people could move to the value functions of the same domain.

These guidelines will help to plan how the new organizational structure would change when the information system will be implemented. Some organizations prefer to reduce their personal once information systems are completed, other organizations prefer to relocate the personal to value functions that can help the company to grow. The author recommends the second alternative as companies would retain their current personnel and could transfer people to areas where they could be more productive, although this is not always possible in some organizations. Organizations that use information systems tend to more flat structures or lean structures as the concepts of lean administration and lean production [51], and here is where the benefit of information systems for increasing the efficiency of companies becomes visible.

This is the end of the integration phase. The results of this phase are the following:

- Domain Model = Domains + Domain Relationships + Domain Protocols.
- Databases.
- New Organizational Structure.

The results of this phase is what integrates the information systems developed with the previous four phases. In fact this integration step would take place when there are already a group of systems to interconnect, or when a new system is finishes to interconnect it with the rest of the information system.

## V.6. CONCLUSIONS.

At this point all the information needed to implement the system is ready. The databases or programming languages of several implementations will vary although this method suggests the use of relational databases and object-oriented GUI (Graphical User Interface) programming languages and networks. The selection of the right tools to implement the information systems should be done with the help of experienced professionals in the area of information systems, because choosing a bad implementation tool might lead to the failure of the project, so the language and tools to implement the system should be chosen with expert advice which it is worthwhile taking.

If we take a look at the complete method we can see an initial evaluation phase where the focus is to align the effort in information systems to the company strategies. In the Analysis phase we can see the application of object-oriented techniques. in the design phase we can also see the application of object-oriented techniques but using some features like versions and user-event lists to solve the problems of operation of information systems in the mexican environment. We can also see the use of some concepts of reengineering in the simplification phase, and the final application of the lean CIM concepts in the integration phase together with distributed databases. So we have a method that goes from the strategies of the company to the design of information systems and finishing with the reorganization of the company into a more lean organizational structure which increases the efficiency of the company.

# CHAPTER VI. A PROTOTYPE IMPLEMENTATION.

## INTRODUCTION.

This chapter presents a prototype implementation of the method to show how to make all the steps of the method. The implementation was made at a company called MYMCE, all the phases of the method were documented to show how to make the diagrams, tables, descriptions, etc, that are part of the method. In the following paragraphs a description of the company is presented.

MYMCE.S.A. de C.V. (Maderas y Materiales del Centro S.A. de C.V.) is a small company located at San Luis Potosi, Mexico. The company was founded on 1982, it started as a retail company selling wood and materials for the construction industry. In 1994 it started to manufacture wood products for big manufacturing companies and actually it manufactures the following products:

- Wood products for big manufacturing companies.
- Home products for export.
- Furniture for the national and export market.

The first products for big manufacturing companies are generally simple products that help in the production process of big manufacturing companies. The home products for export are also simple products which consist of a few parts, but this products are produced in large quantities. Furniture products are more complex products that have hundreds of parts and require several operations on each part, these furniture products are produced in small quantities, the planning and programming of furniture products is more complex.

The company has two plants and the layout of each one is presented in figure 6.1a.

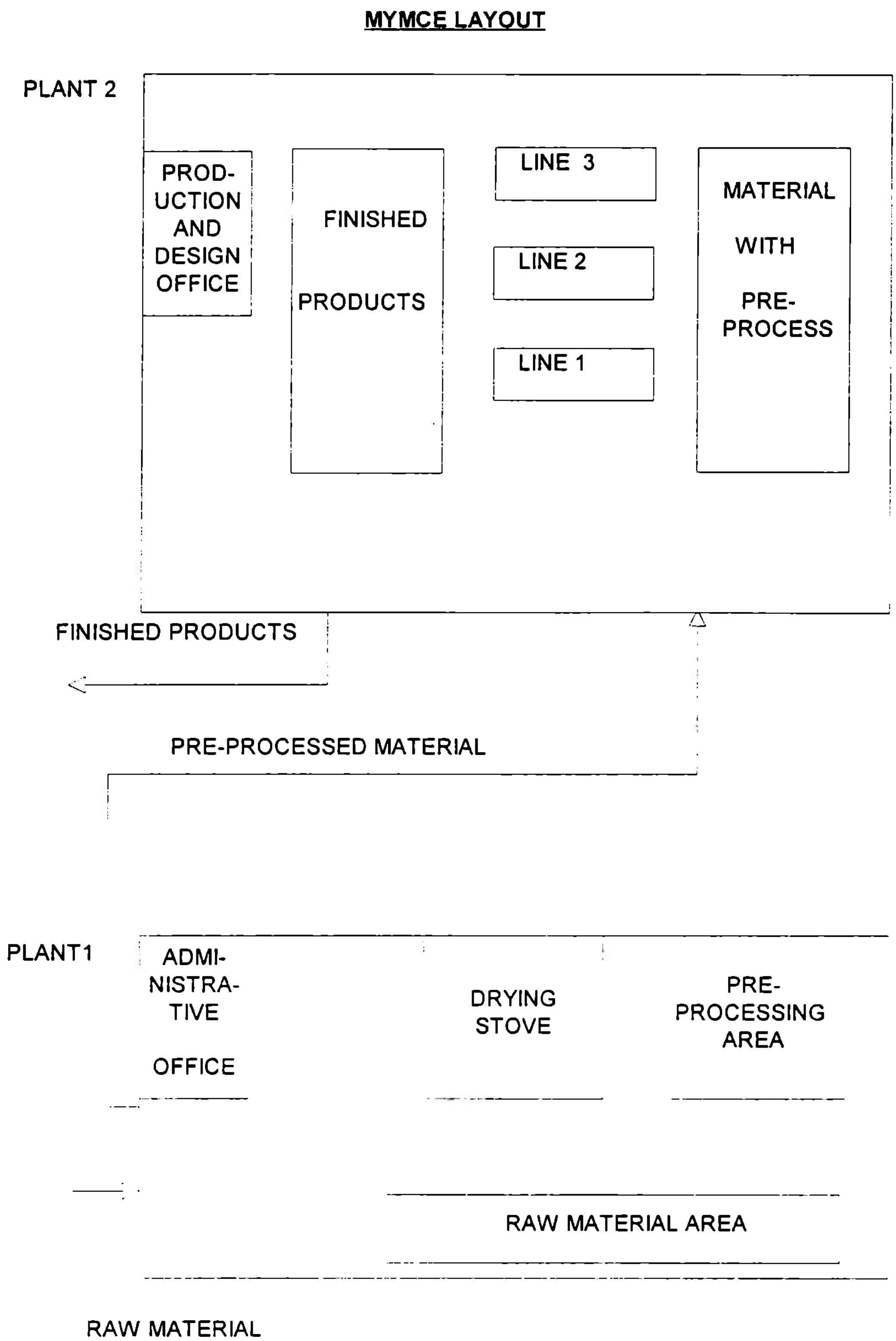



Figure 6.1a. MYMCE Layout.

In the first plant there is an area where the raw material is stored upon arrival. There is also a drying stove which is used to dry the wood before processing it. There is also a preprocessing area where the wood is cut to certain sizes before sending it to the second plant. The administrative offices are also located in the first plant. In the second plant there is an area where the pre-processed material is stored before starting to make the processes in the assigned line for an specific product. There is another area where the finished products are stored before sending them to the customer. The production and design office is also located on the second plant.

MYMCE is a company oriented to production now, this means that there are very few people in the administrative areas and most of the work in the administrative areas is done with the help of information systems. MYMCE organization is shown in figure 6.1b.

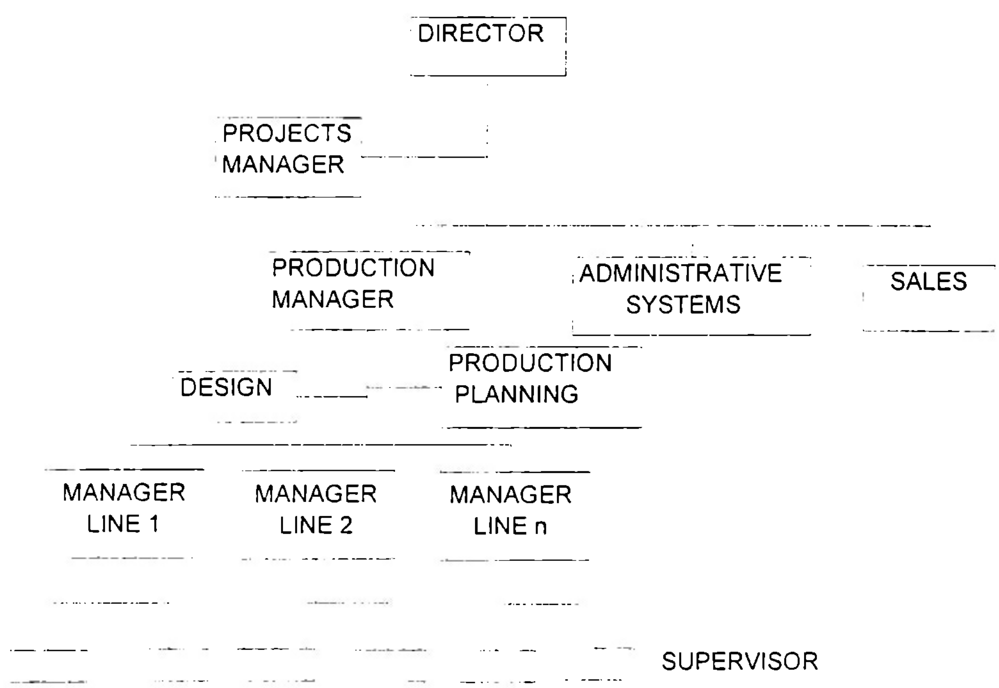



Figure 6.1b. MYMCE Organization.

In figure 6.1b. we can see that the company works by projects. There are some projects which are continuous projects in which there is a fixed amount of production per week, so this lines of products are permanent in the plant. Other projects require just to produce a certain quantity of products during a specific period of time. For this kind of projects a production line is created and this production line would just be there for the duration of the project.

The questionnaire of information systems that was presented in chapter 3, was answered also by MYMCE (see Appendix B). Here we will discuss the answers of the questionnaire. We can see that at the time when they answered the questionnaire the company had 40 employees. They had two lines of product for export and two lines of products for the local market. They had 70 percent of administrative information systems complete and no production systems. In hardware they had five personal computers, one local network and two modems. They use a fourth generation language called Progress. They had invested in hardware and software since 1991. They have not used a specific methodology until now. The external factors that affect them most are : the exchange rate of the dollar and the change of fiscal laws and labor laws. The internal factors that affect them more are : that people do not enter the information correctly, that other departments do not handle information on time and that users do not know how to operate the system. Most of these answers coincide with the results obtained from the questionnaire (see Appendix A). The only points that are different are that these company is using a fourth generation language (which only 9% of companies use in the results of the questionnaire), and that two lines of products of a total of four are for the export market (only 14% is the average in the results of Appendix A).

The information systems that MYMCE had before the project of this thesis are shown in figure 6.2a. All this information systems are integrated and were developed by the author of this thesis from 1991 to 1994. All this systems were developed in a relational database, using several databases to distribute the information.

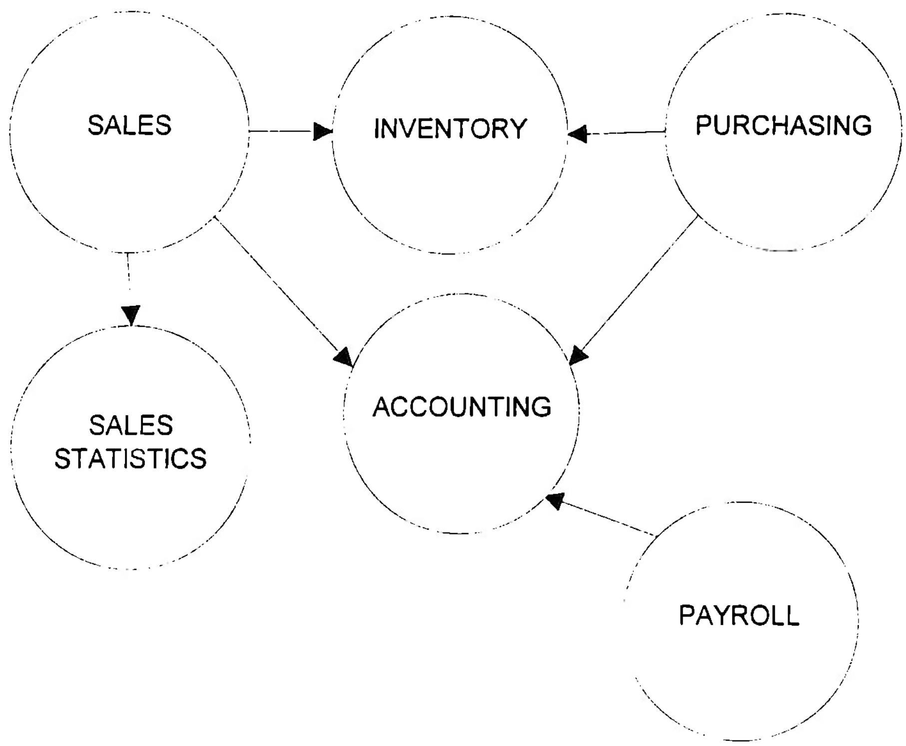



Figure 6.2a. Project at MYMCE from 1991 to 1994.

All the information systems at MYMCE are interconnected to other systems to share information, which eliminates the need to reenter information in the other information systems. All the information from the sales and purchasing is concentrated on the inventory system, this is done automatically so there is no need to enter information in the inventory system. the information entered into the inventory system is just the catalog of products and the prices. The sales, purchasing and payroll systems generate information to the accounting system, where all the transactions of the operation of the company are registered, so the information that is entered in the accounting system is just for the closing periods or for special accounting transactions.

Since the focus of MYMCE from 1994 to now is to manufacture wood products, rather than just selling materials for the construction industry. The need to have a product design system and a production system integrated with the rest of the systems arised. So the project presented to MYMCE in 1995 is shown in figure 6.2b.

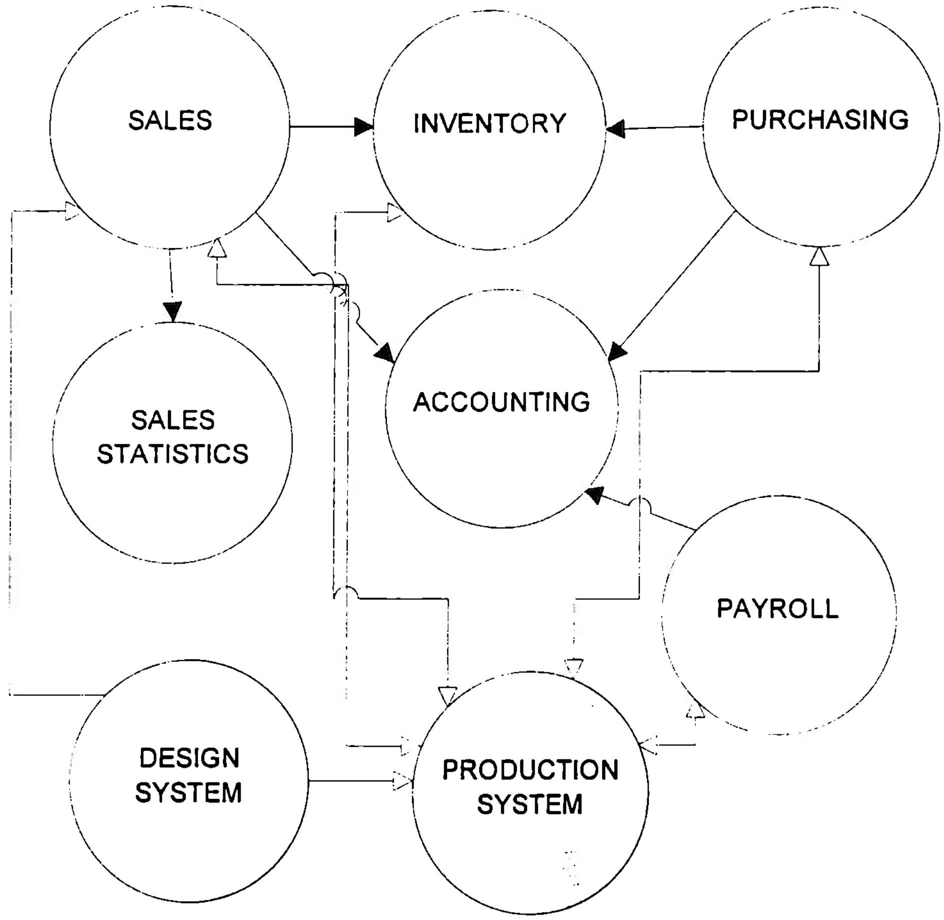



Figure 6.2b. Project at MYMCE from 1995 to 1996.

The shaded areas are the new systems to implement, which are the design system and the production system. Of course there is the need to integrate these systems with the rest of the information systems of the company. The idea of the project is to have all the information systems integrated in MYMCE, so that all the people would have all the information they need to work and everyone would know what to do. The company plans to grow in the variety and quantity of products produced and the information systems would help to control this growth and later be able to use numerical control machines for the production.

VI.1. THE EVALUATION PHASE.

The evaluation phase as we saw in chapter 5, has the objective of detecting the areas to improve. The first step of the evaluation phase is to identify the functions of the company.

V.1.1. IDENTIFY THE FUNCTIONS OF THE COMPANY.

The functions of MYMCE are the following:

- purchasing
- sales
- inventory management
- product design
- production
- projects
- accounts/receivable (A/R)
- general accounting
- payroll

After identifying the functions of the company these are classified into activities of value and support functions and the value chain is constructed (see figure 5.4) which is shown in figure 6.3.

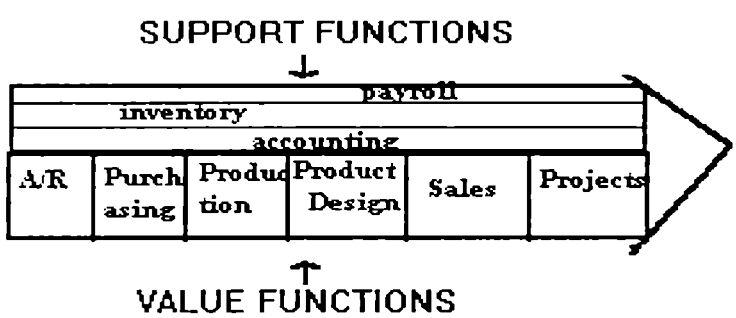



Figure 6.3. MYMCE value chain.

In MYMCE's value chain the support activities are accounting, inventory and payroll. The value activities are projects, sales, product design, production and accounts receivable. The activities that are closer to the right are the ones that are closer to the customer.

### VI.1.2. IDENTIFY THE STRATEGIES OF THE COMPANY.

In this step according to section V.1.2. the strategies of the company were identified, the strategies are listed below:

- Design new products in a shorter time.
- Give fast response to customers.
- Manufacture products in less time.
- Have a continuous supply of material.
- Improve productivity of employees.

These strategies will give the direction that the information systems would follow, as the information systems have to contribute to each of these strategies.

### VI.1.3. USEFUL TRENDS IN INFORMATION SYSTEMS.

MYMCE wanted a system that could be easy to learn and use; they also wanted to have their data secure and to be able to obtain information easily. They also wanted a system that could be easily maintained. According to these and taking into account the considerations from section V.1.3, the trends identified that were useful for the project of MYMCE were the following:

- Graphical User Interfaces
- Distributed Databases.
- Computer Networks
- Object-Oriented Programming.

Graphical user interfaces would provide a system easy to learn and use. Distributed databases would permit security and availability in the data, computer networks would allow interconnection of systems and object-oriented programming would allow a low cost on the maintenance of the system.

VI.1.4. IDENTITY POTENTIAL AREAS TO IMPROVE.

The next step in the evaluation phase (see figure 5.1) is identifying the potential areas to improve. So the areas of the company where information systems could be introduced to help achieve the company strategies were identified. According to the general form of the evaluation matrix (see figure 5.8) in figure 6.4a the relation matrix fulfilled the conditions of MYMCE and shows the information systems that could be helpful in certain areas.

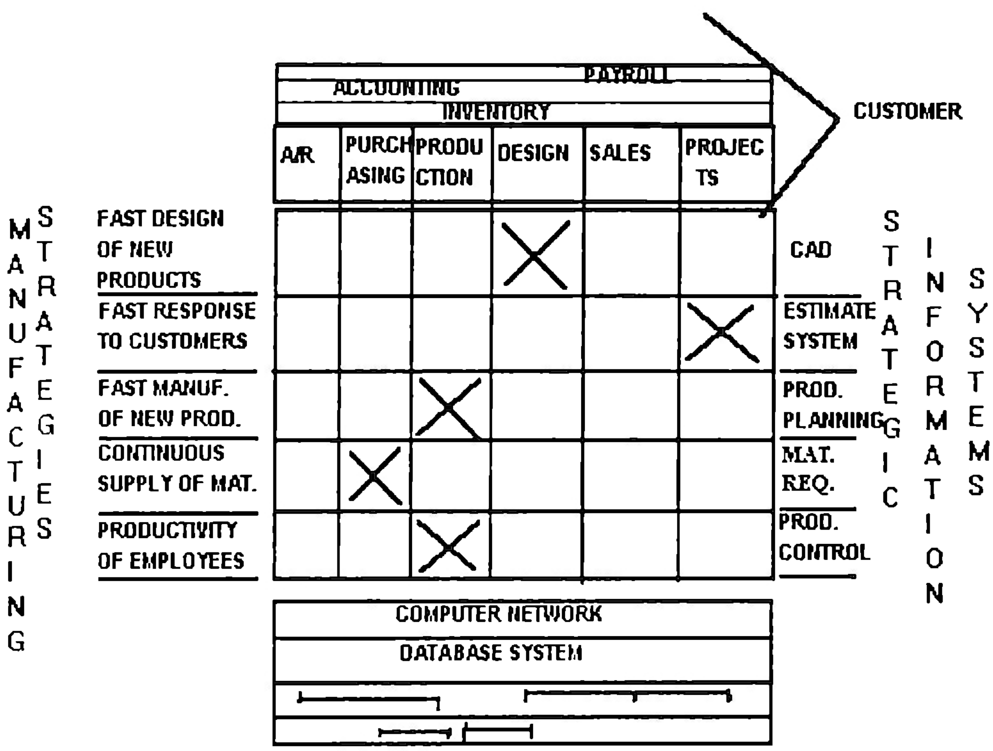



Figure 6.4a. Relation matrix of MYMCE.

In this matrix we can identify that the systems that would be useful according to the strategies of the company would be a CAD system for the design department, an estimate system for the projects department, a production planning system and a production control system for the production department, and a material requirements system for the purchasing department. The accounts receivable department (A/R) does not participate in the strategies cause the company works by projects. The sales department already has its information systems complete. The support functions like inventory, accounting and payroll already have their information systems. The infrastructure which is the network and databases are already established. Below the infrastructure systems the lines show which systems would be interconnected.

Once the information systems were identified, according to the general time-reduction matrix (see figure 5.9) the benefit of each systems in terms of improved efficiency would be stated in the time-reduction matrix shown in figure 6.4b.

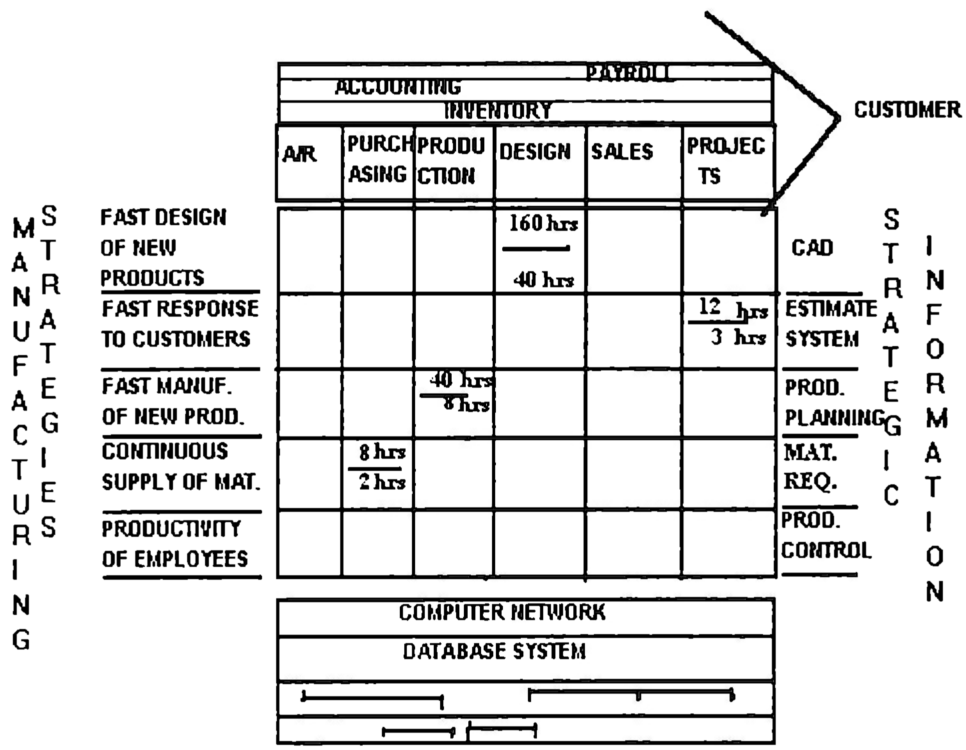



Figure 6.4b. Time-reduction matrix of MYMCE.

In this figure we can see that the design of a new product by hand would take 160 hours and the people at MYMCE want to make it in 40 hours. To make a project by hand they take about 12 hours by hand, and to give a reasonable response to customers it would have to be done in 3 hours. The production planning of a new product takes about 15 hours by hand and they want to do it in 4 hours. To calculate the supply of material they need about 8 hours to calculate what material would be needed, they want to do this in 2 hours with the help of the information systems. The benefit of having a production control system that could help the productivity of the employees could not be quantified because the machines are manual at this time, but if numerical controlled machines are introduced this might have a benefit. In this matrix we can see that there are four areas where information systems could bring a benefit in the time that it takes to develop the respective tasks. These areas are design of products, the projects department, the production department and the purchasing department.

With the time-reduction matrix, according to the economic-benefit matrix of chapter 5 (see figure 5.10), the economic-benefit matrix would be developed, the economic-benefit matrix of MYMCE is shown in figure 6.4c.

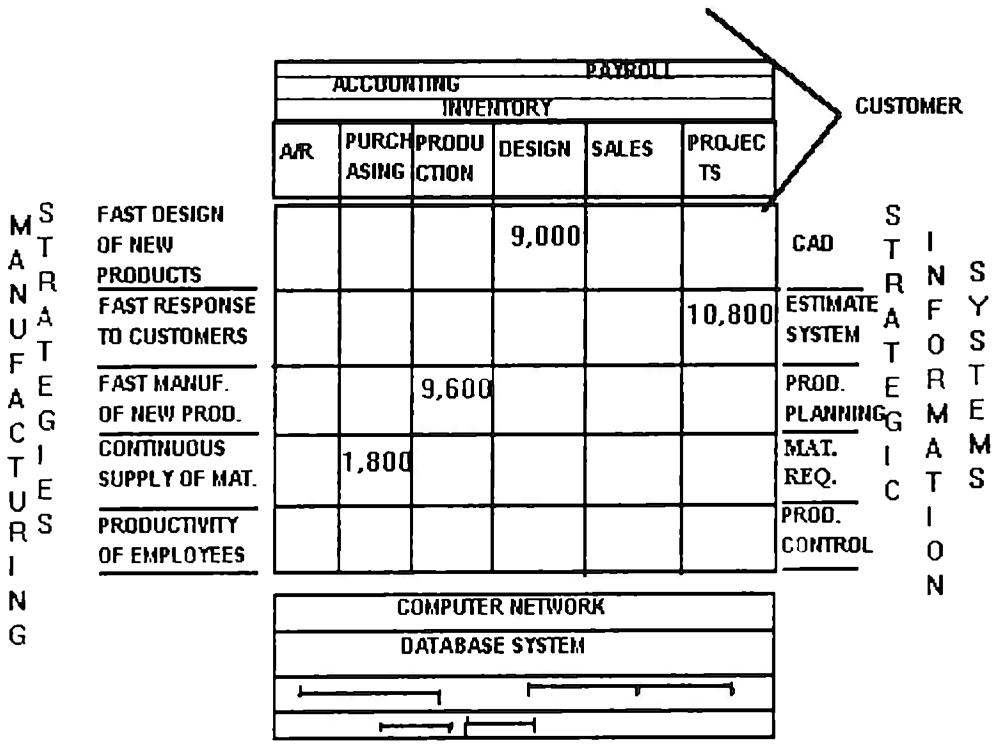



Figure 6.4c. Economic-Benefit Matrix of MYMCE.

These economic benefits show the amount of money that would be saved in a year from the reduction of time in the activities presented here, calculated on hours times an average salary of $25 pesos. The number of new product designs (furniture designs) in a year would be three, so the benefit of desing would be: 3 designs x 120 hours x 25 pesos/hour = 9000 pesos. Four estimates are made per month, so the benefit of project would be : 4 estimates x 12 months x 9 hours x 25 pesos / hour = 10,800 pesos. It is also considered that each month a new product would be planned for production , so the benefit of production would be : 12 products x 32 hours x 25 pesos/hour = 9,600 pesos. For these 12 products the requirements for material supply are also needed, so the benefit of purchasing would be : 12 products x 6 hours x 25 pesos/hour = 1,800 pesos.

VI.1.5. ECONOMIC JUSTIFICATION.

In this phase the economic justification of the project is presented. First the investment required was calculated and as it was shown in chapter five ( see table 5.1), they are presented in table 6.1 (amounts are in mexican pesos). The month indicates when the expense would be made.

Table 6.1. Expenditures to be made.

| NUMBER | DESCRIPTION | AMOUNT | MONTH |
|---|---|---|---|
| 1 | COPROCESSORS | 1,600.00 | 1 |
| 2 | DISK DRIVES | 1,600.00 | 2 |
| 3 | AUTOCAD LT | 4,000.00 | 3 |
| 4 | TRAINING IN CAD | 2,000.00 | 4 |
| 5 | PROGRESS VERSION 8 DATABASE | 2,700.00 | 5 |
| 6 | PRODUCTION SYSTEM (Analysis, Design, Programming) | 10,000.00 | 6-10 |
| 7 | TRAINING IN PRODUCTION SYSTEM | 500.00 | 11 |
| 8 | TECHNICAL SUPPORT | 2,400.00 | 12 |
| TOTAL | | 24,800.00 | |

After the expenditures to be made were calculated, the potential benefits were determined according to three ranges pesimistic, most likely and optimistic (as table 5.2 presents), this is shown in table 6.2.

Table 6.2. Estimated benefits in ranges.

| CONCEPT | PESIMISTIC | MOST LIKELY | OPTIMISTIC |
|---|---|---|---|
| PRODUCT DESIGN | 4500 | 9000 | 12000 |
| ESIMATE | 5400 | 10800 | 14400 |
| PROD. PLANNING | 4800 | 9600 | 12800 |
| MATERIAL REQUIR. | 900 | 1800 | 2400 |
| | | | |
| TOTAL | 15600 | 31200 | 41600 |

In this table we can see the estimated benefits with a pessimistic, most-likely and optimistic numbers, and total estimated benefits also in a pessimistic, most-likely and optimistic total benefit.

The pessimistic range was based on the following negative factors:

1. Competitors. 23% Less

2. Instability of the economy. 19% Less

3. Machine broke-downs. 13% Less

4. Quality Errors. 7% Less

If these events are independent we can calculate the pessimistic value with:

$(1 - 0.23)(1 - 0.19)(1 - 0.13)(1 - 0.07) = 0.50$

If all these events occurred, it was estimated that the worst case would be a 50% less of the benefits.

The optimistic range was based on the following positive factors:

1. Growth of the economy. 12% More

2. Marketing Efforts. 17% More

3. Recommendations of new customers. 5% More

If all these events are independent we can calculate the increase with:

$(1 - 0.12)(1 - 0.17)(1 - 0.05) = 0.69338$

$(1 - 0.69338) = 0.30612$

If all these events occurred the optimistic situation would be a 30% increase on the benefits.

So the column of pessimistic was obtained by multiplying the most-likely by 0.50. And the optimistic was obtained by adding 30%.

Next a cash flow was developed on a monthly basis (as shown in table 5.3), to show the cash flow in each month with the three values of pessimistic, most-likely and optimistic. This is shown in table 6.3.

Table 6.3. Cash flow.

| MONTH | PESIMISTIC | MOST-LIKELY | OPTIMISTIC |
|---|---|---|---|
| | | | |
| 1 | -300 | 1000 | 1.867 |
| 2 | -300 | 1000 | 1.867 |
| 3 | -2700 | -1400 | -533 |
| 4 | -700 | 600 | 1.467 |
| 5 | -1400 | -100 | 767 |
| 6 | -700 | 600 | 1.467 |
| 7 | -700 | 600 | 1.467 |
| 8 | -700 | 600 | 1.467 |
| 9 | -700 | 600 | 1.467 |
| 10 | -700 | 600 | 1.467 |
| 11 | 800 | 2100 | 2.967 |
| 12 | -1100 | 200 | 1.067 |
| | | | |
| TOTAL | -9200 | 6400 | 16800 |

We can see in this table that the cash flow is negative for the pessimistic option, positive in 6.400 for the most-likely option and positive with 16.800 for the optimistic option. The project here can be divided in two phases the implementation of the CAD system which would last four months, and the implementation of the production system which would last the other 8 months. After the implementation of the CAD system (after the first 4 months) a decision can be taken to continue with the production system or not. So according to the model of decision trees presented in figure 5.11, the decision tree in this case is presented in figure 6.5.

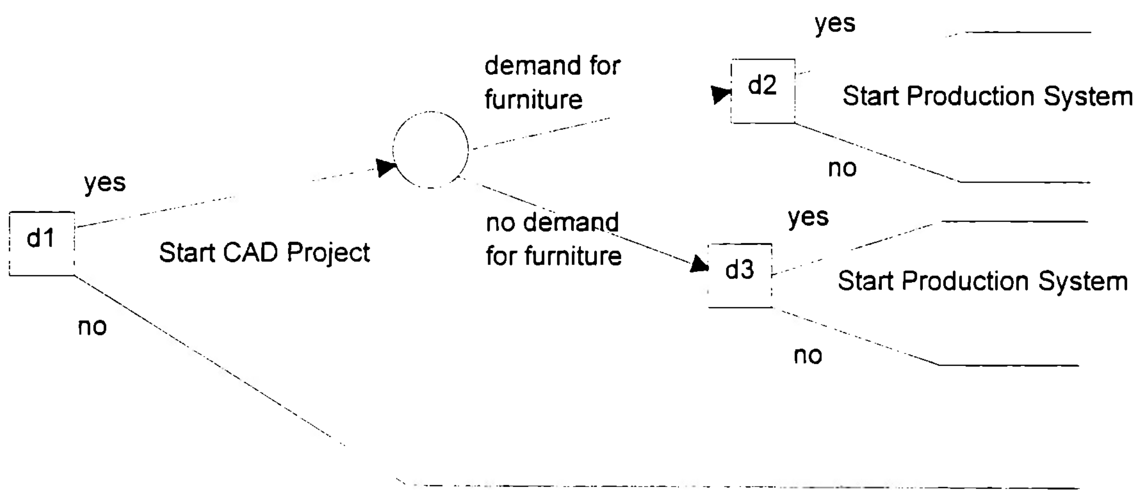



Figure 6.5. Decision Tree for the projects at MYMCE.

In figure 6.5. we can see that an initial decision to start with the CAD project would be made, then after 4 months if there is demand for furniture products another decision would be taken to start the production system or not.

For the initial decision of starting the project, using a triangular distribution for each cash flow of table 6.3 we calculate the expeted value and the variance of each cash flow in the first to columns according to formulas 5.1 and 5.2., Cj and the square of Cj are used to deflate the cash flows (see formula 5.5) with a monthly inflation of 2.5%, then the expected value and the variance of the net present value are calculated according to formulas 5.3 and 5.4.

Table 6.4. Expected value and variance of the net present value.

| MONTH | e(X) | var(x) | Cj | Cj*Cj | E(NPV) | VAR(NPV) |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1 | 856 | 198210 | -1,00 | 1 | -856 | 198210 |
| 2 | 856 | 198210 | 0,98 | 0,95 | 835 | 188659 |
| 3 | -1.544 | 198210 | 0,95 | 0,91 | | -1470 |
| 4 | 456 | 198210 | 0,93 | 0,86 | 423 | 170916 |
| 5 | -244 | 198210 | 0,91 | 0,82 | -221 | 162680 |
| 6 | 456 | 198210 | 0,88 | 0,78 | 403 | 154841 |
| 7 | 456 | 198210 | 0,86 | 0,74 | 393 | 147380 |
| 8 | 456 | 198210 | 0,84 | 0,71 | 383 | 140279 |
| 9 | 456 | 198210 | 0,82 | 0,67 | 374 | 133519 |
| 10 | 456 | 198210 | 0,80 | 0,64 | 365 | 127085 |
| 11 | 1.956 | 198210 | 0,78 | 0,61 | 1528 | 120962 |
| 12 | 56 | 198210 | 0,76 | 0,58 | 42 | 115133 |
| | | | | | | |
| TOTAL | | | | | 2198 | 1839232 |

Then the decision to start the project would be taken if the probability that the net present value be greater than zero is at least 90%.

First to normalize the values to a normal curve of media 0 and standard deviation 1, according to chapter 5 (see section V.1.5) we make:

P( NPV > 0 ) = P( Z > ( 0 - 2198 ) / SQR(1839232) )

then we obtain:

P( NPV > 0 ) = P( Z > -1.62)

then looking in a table of the area under the normal curve we obtain:

$$P(\ NPV > 0\ ) = 0.94746$$

So the project would start because the probability of 94 percent is greater than the criteria acceptance of 90%. Later depending on the demand of furniture products in 4 months, the project would continue or not.

This is the end of the evaluation phase and the analysis of the project is presented in the following phase.

VI.2. ANALYSIS PHASE.

The purpose of the analysis phase is to analyze the operations, the information and the interactions that take place in the company (see chapter V.2). This was done in MYMCE for the production system, that was developed. The first step in this phase is process analysis.

VI.2.1. PROCESS ANALYSIS.

In the step of process analysis, the analysis of the production system took place, and the process diagrams were constructed (see figure 5.16), starting with diagram number 1 that is shown in figure 6.6.

| Diagram Number: 1 | Title:Customer Request | Date: 20-06-96 |
|---|---|---|

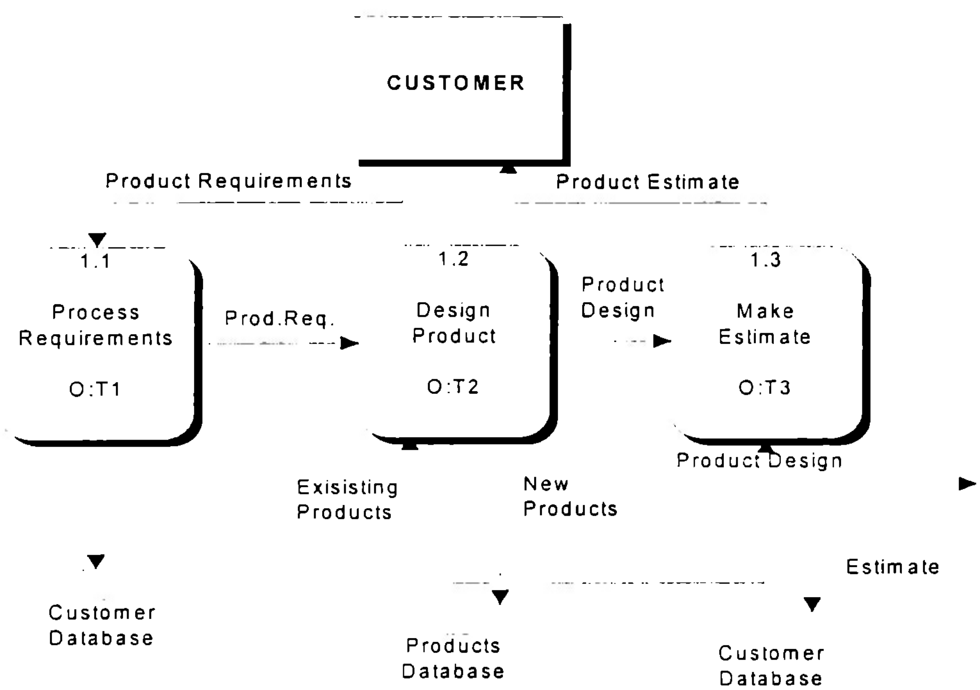



Figure 6.6. Process Diagram of Customer Request..

In this figure we can see that the customer requests a product, the product is then designed and then an estimate of the cost of the product is given to the customer.

The next diagram constructed is shown in figure 6.7, this diagram shows how the company will prepare for production of the product requested in process diagram number 1 (see figure 6.6). First the customer places an order on process 2.1, then a manufacturing plan is developed in process 2.2, then the raw materials are requested in process 2.3, then the materials arrive on process 2.4, finally the necessary employees for manufacturing the product are hired on process 2.5.

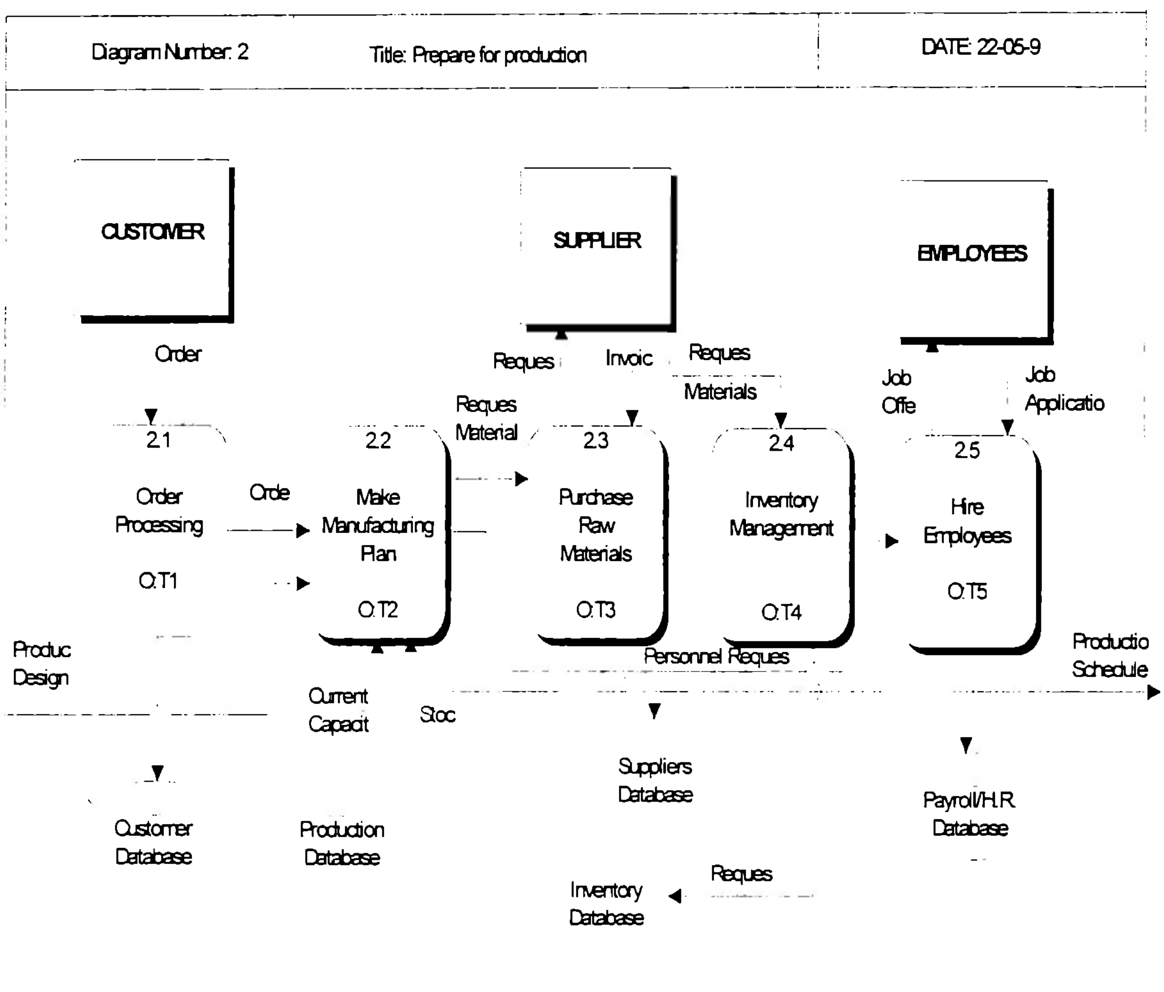



Figure 6.7. Process Diagram Prepare for Production.

The databases involved in this processes are the customer database, production database, suppliers database, the inventory database and the payroll database.

The last process diagram constructed for MYMCE was diagram number 3 shown in figure 6.8. This diagram shows the processes to manufacture a product.

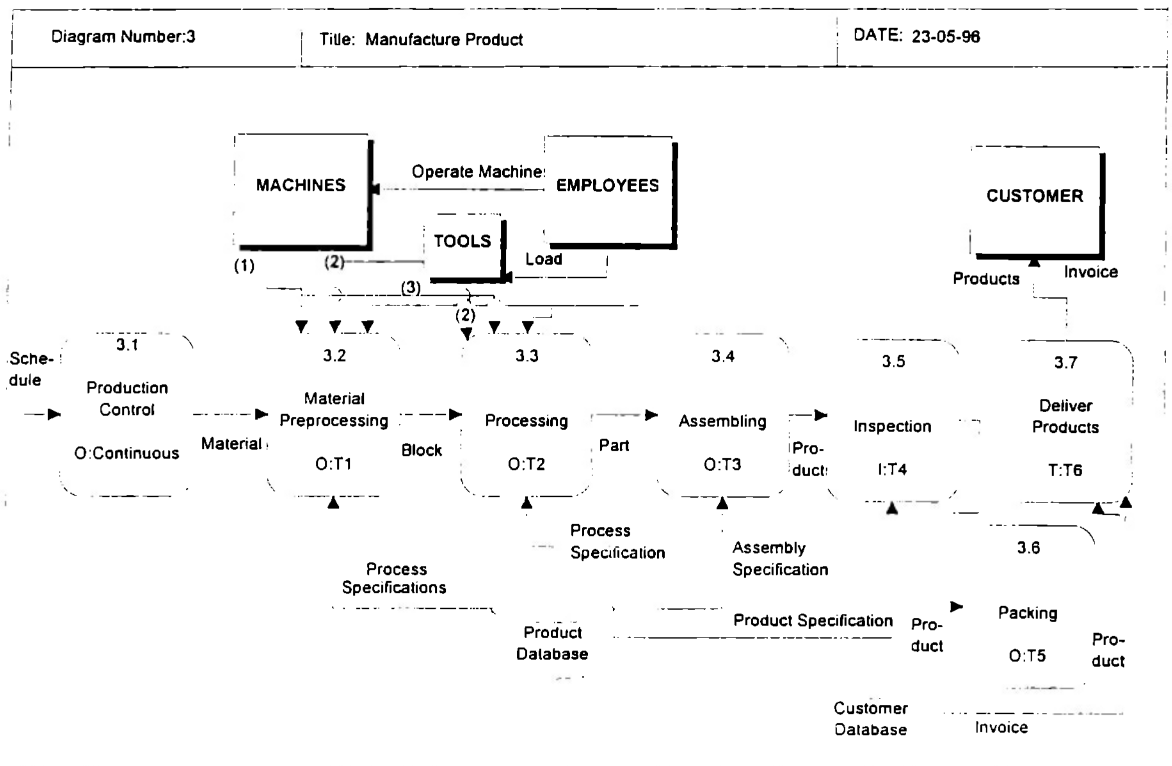



Figure 6.8. Process Diagram Manufacture Product.

In this figure we can see that process 3.1 will control the production with the aid of the production schedule. In process 3.2 the material preprocessing will be done according to the process specifications. This preprocessing for MYMCE implies making blocks of wood of certain sizes and these blocks will be used in the next process to obtain the parts. In process 3.3 the processing of the blocks takes place according to the process specifications and the parts are obtained. In process 3.4 the assembling of the parts takes place according to the assembly specifications to form a product. In process 3.5 the inspection of the product takes place to compare it to the product specifications. In process 3.6 the product is packed and finally in process 3.7 the product and the invoice are delivered to the customer. In this diagram the indication "O:Tn" indicates that it is a process of type operation (see process types in figure 5.14), and that the operation last a fixed time "Tn" for an specific product. The indication "O:continuous" means that this is a continuous activity done all the time. These process diagrams will be the base for the object analysis step.

VI.2.2. OBJECT ANALYSIS.

In this step the objects of the system will be identified. In the process diagrams external real world objects were identified ( called actor objects ) , in figure 6.9 the complete object diagram (see section VI.2.2) is shown.

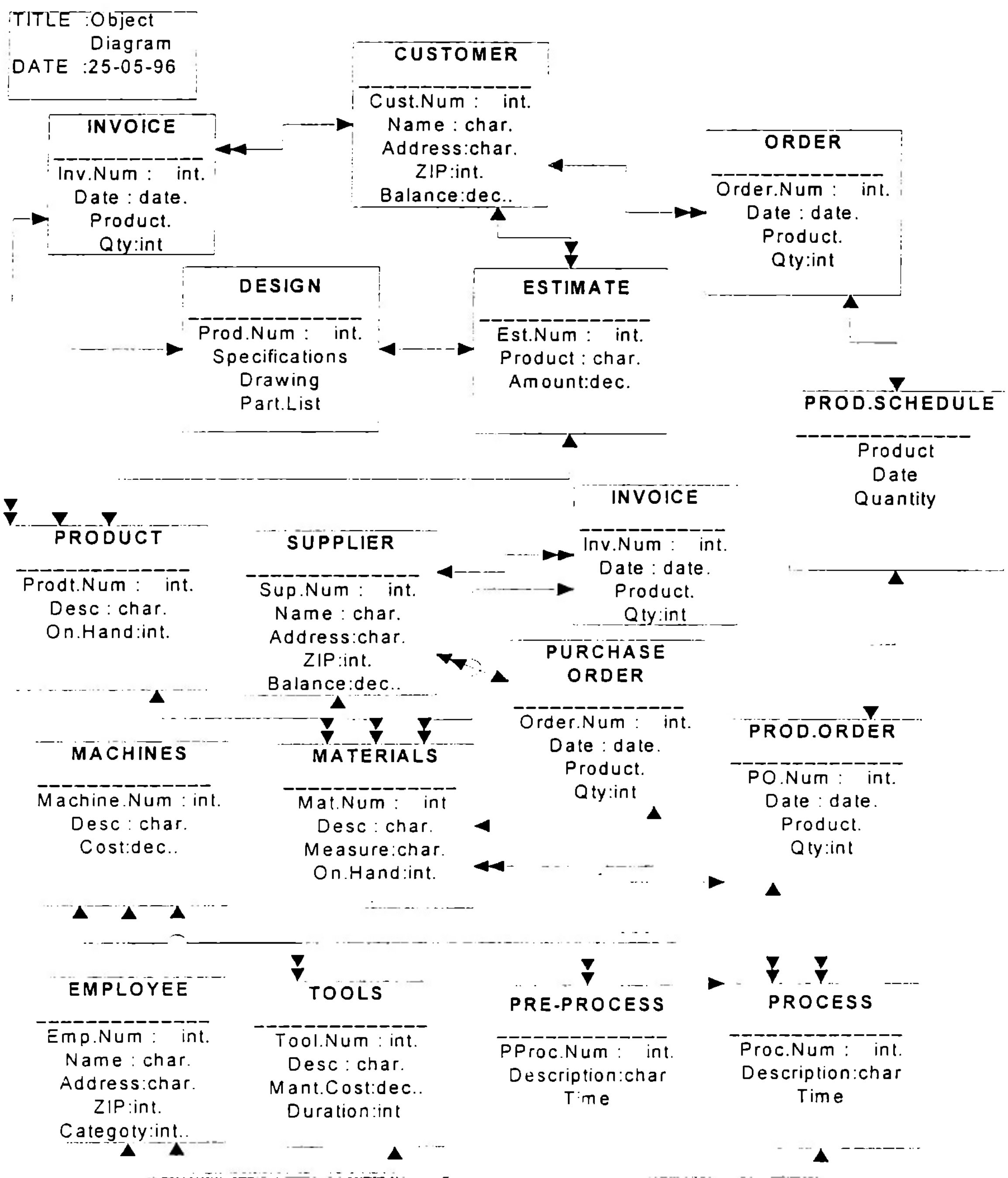



Figure 6.9. Object Diagram.

In figure 6.9 we can see the external objects that were identified in the process diagrams which are:

- customer.
- supplier.
- machines.
- tools.
- employees.

We can also see in this object diagram some attributes of these objects (see figure 5.17). For example the object customer has the attributes: cust-num (customer number), name (customer name ), address (the address of the customer), zip (postal code) , etc; a complete description of the attributes of each object will be given in section 6.4.1. where the data dictionary will be explained.

Other objects obtained in this step from the process diagrams are the following:

- materials
- design
- estimate
- process
- pre-process
- order (customer order)
- purchase order
- production order
- production schedule
- invoice.

A complete description of these object and its attributes will also be given in section 6.4.1. In the explanation of the data dictionary, in this phase the objects and the relations between them (see the kind of relations in figure 5.18) were identified. In the next step the interaction between these objects will be analyzed.

VI.2.3. INTERACTION ANALYSIS.

In this step the events that occur for every object of the system were identified. First the events for external objects are identified, as these are obtained directly from the process diagrams. The events obtained according to the guidelines of section V.2.3 for the external objects are given in table 6.5.

Table 6.5. Events for external objects.

| External Object | Events |
|---|---|
| Customer | Request Estimate<br>Receive Estimate<br>Place Order<br>Request Order Status<br>Receive Products and invoice.<br>Pay Invoice |
| Supplier | Receive purchase order<br>Send invoice<br>Send material |
| Employees | Receive job offer<br>Send job application<br>Operate machine<br>Load/unload tools |
| Machines | Be loaded with tools<br>Be unloaded with tools<br>Receive instruction<br>Do operation |
| Tools | Be loaded into machine<br>Be unloaded into machine<br>Do Operation (Cut, Drill, etc) |

We can see in this table the events for each object, some events are received by the object and some events are generated by the object itself. The events are activities that occur at a single point in time, although most executing the response to an event might last some time, but for the purpose of interaction analysis considering the events as instantaneous is convenient, because the purpose is just to analyze the interactions and the change of state of an object.

After the events for the external objects were identified, the events for the internal objects were obtained, together with the response that the information system has to give to each event. These events and responses of the internal objects are given in table 6.6.

Table 6.6. Events for internal objects.

| OBJECT | EVENT | RESPONSE |
| --- | --- | --- |
| Product Design | Receive Requirements<br>Send Product Design | Develop Design |
| Estimate | Receive Design<br>Send Estimate | Generate Estimate |
| Order (from customer) | Receive Order<br>Send Order to Production Schedule | Register Order |
| Production-Schedule | Receive Order<br>Send Schedule | Calculate Schedule |
| Production-Order | Schedule Ready<br>Send Production Order | Create Production Order |
| Process | Receive Design<br>Assign Machine<br>Assign Tools | Create Process |
| Pre-process | Receive Design<br>Assign Machine<br>Assign Tool | Create Pre-process |
| Purchase Order | Receive Request<br>Send Purchase Order | Create Purchase Order |
| Customer Invoice | Order Finished<br>Send invoice to customer | Register Customer Invoice |
| Supplier Invoice | Receive Material | Register Supplier Invoice |
| Product | Receive Design | Register New Product |

In this table we can see the events that the internal objects receive and generate, and the response that the information system has to give to each event. Some of these events are received from one object and then that object generates another event for third object. The responses that the system gives here are going to be transformed later into operations (called methods in the object-oriented terminology) of the objects in the design phase.

After the events of the system are identified, if there are objects with many events, an state diagram is constructed for explaining the interaction with that object (see figure 5.20). In this case the only object that has many events is the object customer, and an state diagram was constructed and it is shown in figure 6.10.

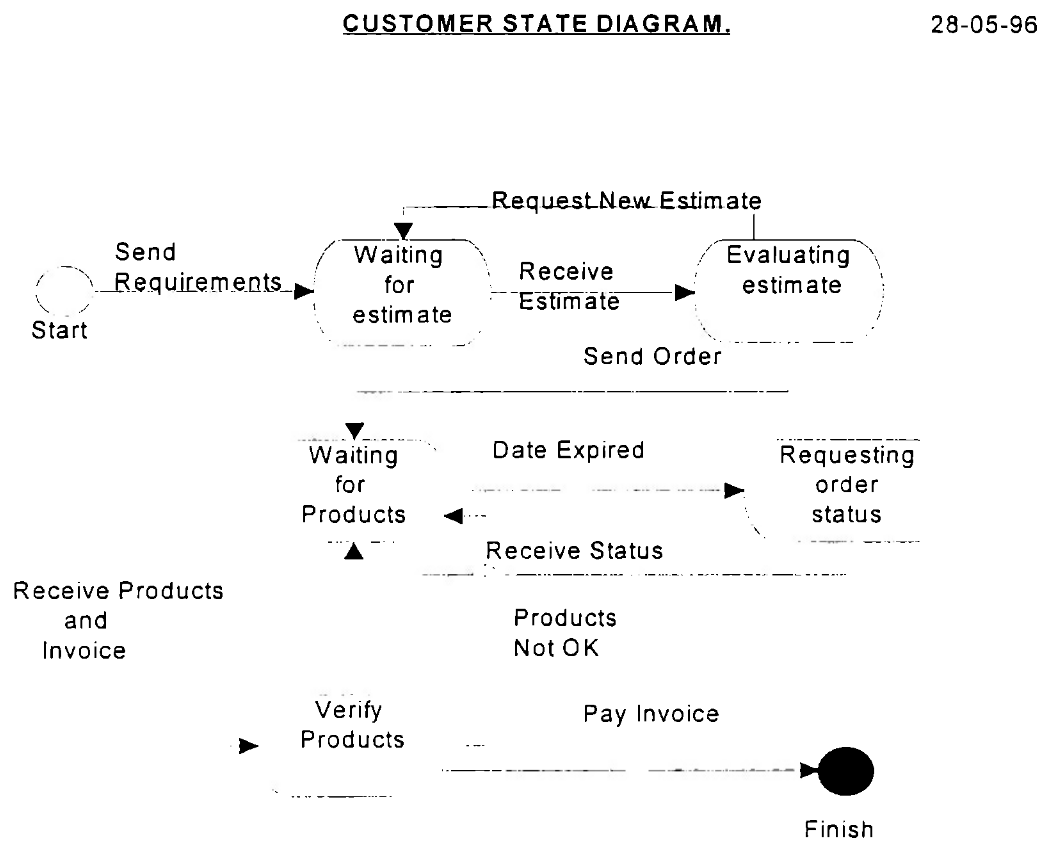



Figure 6.10. State Diagram of Customer.

In this diagram we can see the different states in which the customer is and how it changes from one state to another when it receives or generates an event. Once the events and state diagrams for objects with many events are completed the interaction analysis step is finished. The results of the analysis phase would be simplified in the next phase.

VI.3. SIMPLIFICATION PHASE.

In the simplification phase the models obtained from the analysis step were simplified. The purpose of this phase is to verify that the models are as simple as possible before proceeding to the design of the system.

VI.3.1. PROCESS SIMPLIFICATION.

This step eliminated processes that do not add value to the product, so that the processes are simpler and focused on generating added value for the company. The first process diagram (see figure 6.6) was simplified according to the guidelines of section V.3.1 and is shown in figure 6.11.

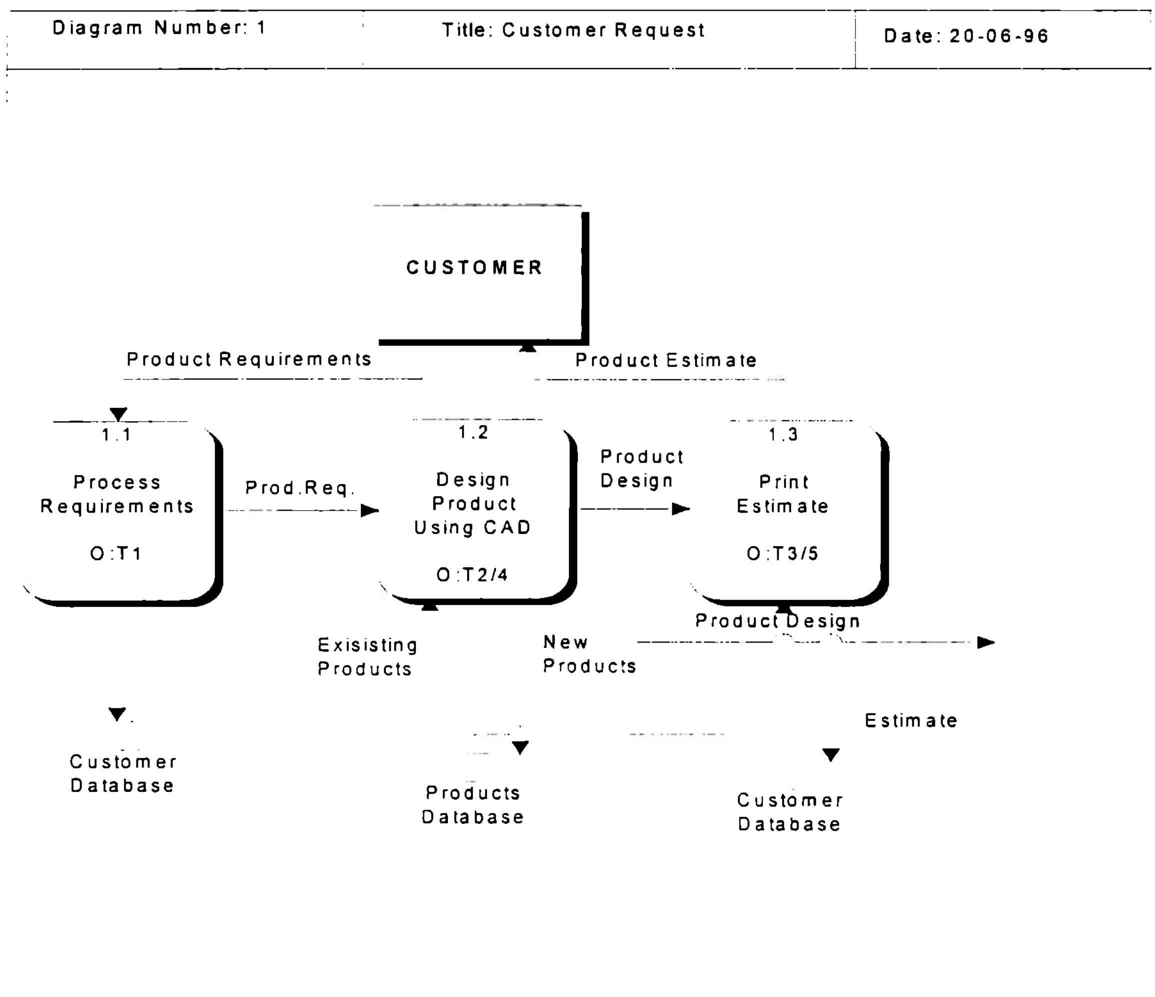



Figure 6.11. Simplified Process Diagram of Customer Request.

In figure 6.11. the guideline number eight (use technology to improve the process) was used of the process simplification guidelines of section V.3.1. In this manner process 1.2 will be done with a CAD system and according to the evaluation phase the time that it takes to design a product would be 25% of the time it takes to design it by hand. Also the printing of the estimate with the help of the computer in process 1.3 can be simplified, the time would be 20% than the time it takes to make the estimate by hand. So in this diagram the technology was used to reduce the time of processes 1.2 and 1.3.

The third process diagram was also simplified and it is shown in figure 6.12. In this diagram two processes

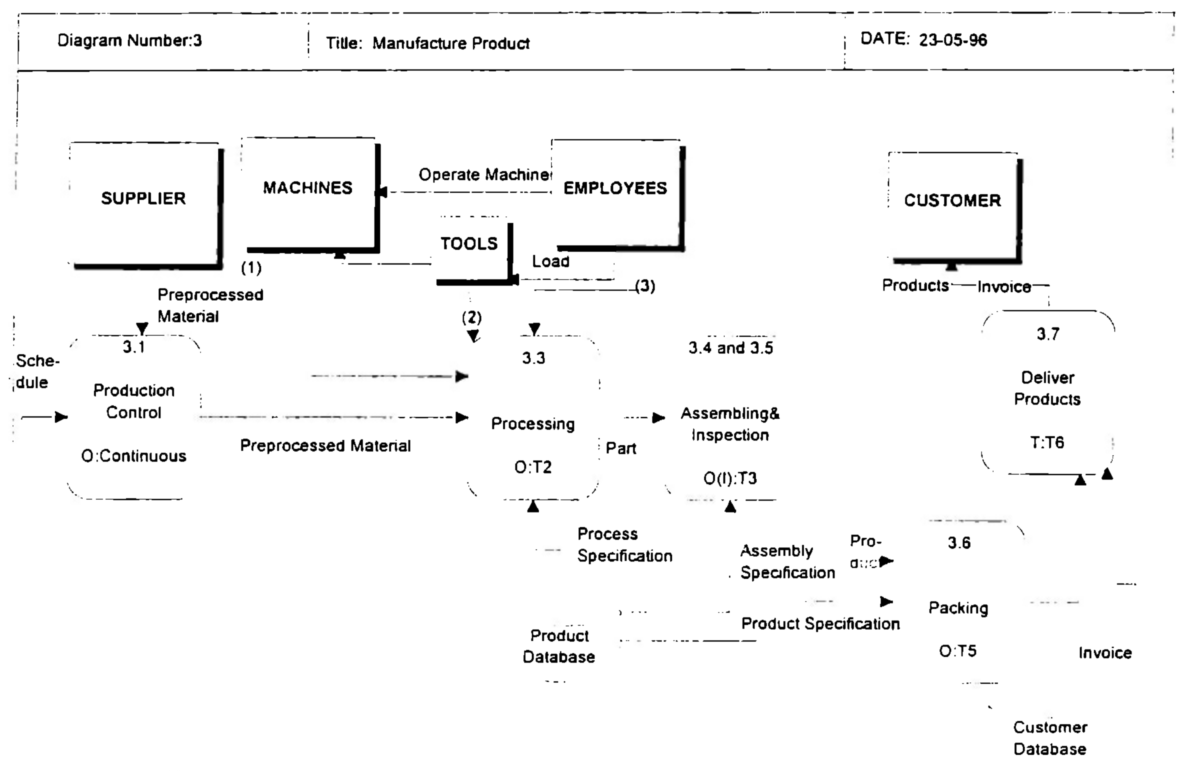



Figure 6.12. Simplified Process Diagram Manufacture Product.

were eliminated (compare with figure 6.8), process 3.2 was eliminated using guideline number nine 9 (let suppliers help in the process) so the preprocessing of material will be done by the suppliers or by the first plant of MYMCE which is going to be considered for the second plant as a supplier. These leaves only process 3.3 which is the processing of the material. Process 3.4 and 3.5 were combined according to guideline number four (combine processes with others) which suggests to combine a process that does not add value with a process that do adds value. In this case process 3.5 which is of type inspection was combined with process 3.4 which was the assembling of the product. In this way the processes would be combined in just one process called assembling and inspection. Once the process were simplified, the object diagram was simplified in the next step.

## VI.3.2. OBJECT SIMPLIFICATION.

In this step the object diagram was simplified (see figure 6.9) to reflect the changes in the process diagrams and to make the objects and relationships between them as simple as possible. The simplified object diagram is shown in figure 6.13.

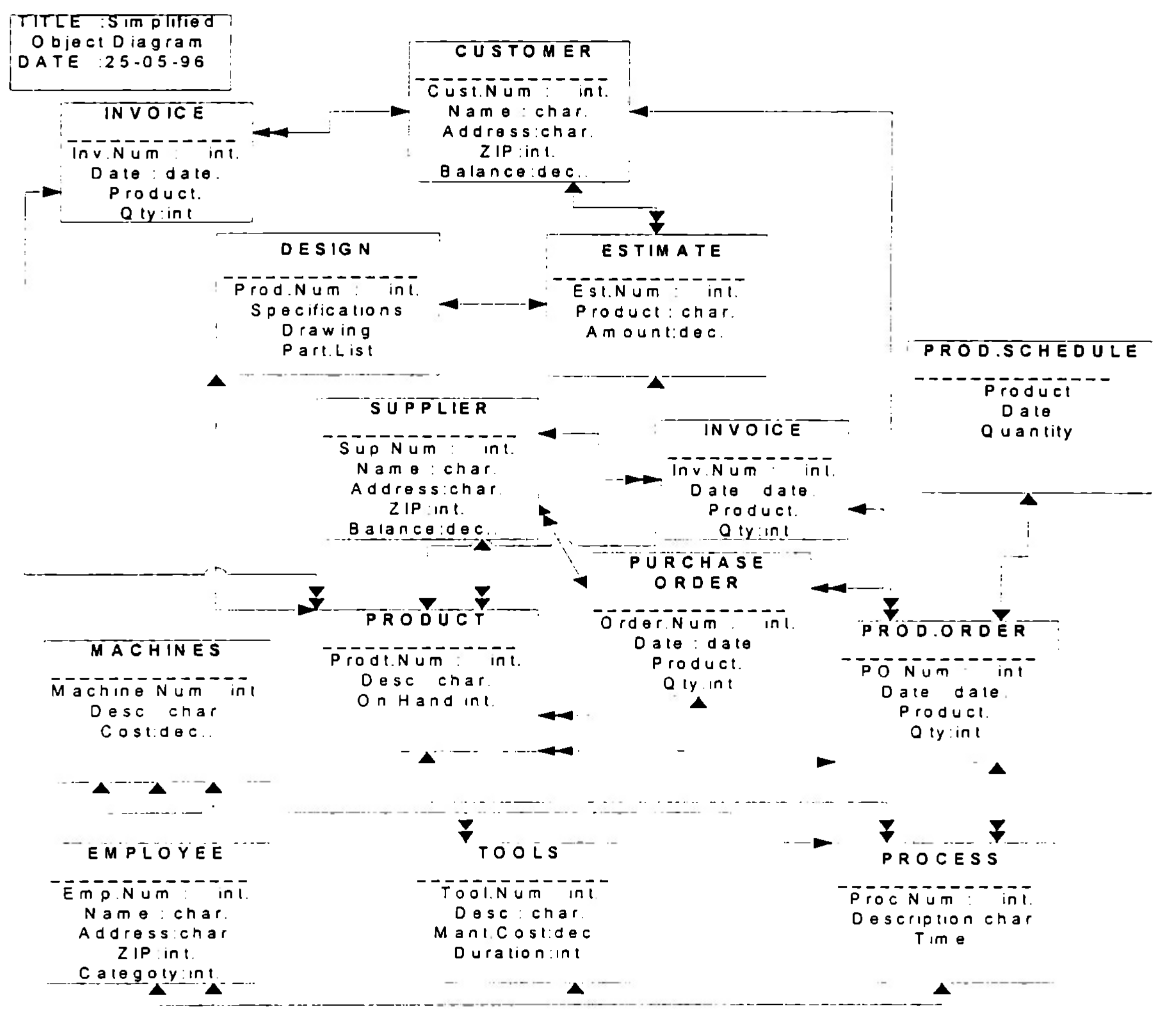



Figure 6.13. Simplified Object Diagram.

In this diagram the object pre-process disappeared because of the changes introduced in the third process diagram, also the object product and the object materials were merged into only one object named product, because the attributes were similar, as guideline number three for simplifying the object model suggests. This object model is simpler an easier to implement.

VI.3.3. INTERACTION SIMPLIFICATION.

In this case the state diagram of figure 6.10 is not very complex and could not be simplified any further with the citeria given in section V.3.3. This criteria will be useful for bigger state diagrams with more states.

After the simplification phase was applied the design phase would take these simplified models to design the information system.

VI.4. DESIGN PHASE.

In the design phase the object-oriented models from the simplification phase were combined to obtain the computer objects of the information system, then the objects were grouped to form reusable components, then these components were used to form modules.

VI.4.1. DATA DICTIONARY DESIGN.

The data dictionary was formed for a relational database according to the rules of section V.4.1. Only the new tables that were not available in the other databases were obtained here, as the customer, invoice, suppliers, employees and other tables existed in other databases of the company. The objects and relations from the object model were translated to the following tables:

CATHER: Tool catalog.

| Field name | Data type | Description |
|---|---|---|
| CLAHER | character | It is the label of the tool. |
| DESHER | Character | Description of the tool. |
| COSHER | Decimal | Cost of the tool. |
| FECHER | Date | Purchase date of the tool. |
| HORHER | Integer | Useful hours of the tool. |
| AFIHER | Decimal | Sharpening cost. |

CATMAQ: Machine catalog.

| Field name | Data type | Description |
|---|---|---|
| CLAMAQ | Character | label of the machine. |
| DESMAQ | Character | description of the machine |
| COSMAQ | Decimal | cost of the machine. |
| FECMAQ | Date | purchase date of the machine. |
| HORMAQ | Integer | utility hours of the machine. |

ARTICULOS: This file has the product and item catalog and its quantity on hand.

| Field name | Data type | Description |
|---|---|---|
| LINEA | Character | Line of the product or item. |
| CODIGO | Character | Label of the item. |
| DESCRIP | Character | Brief description of the item. |
| EXIST | Decimal | Quantity on hand at the inventory. |
| UNIDADE | Character | Unit of measurement of the product. |
| CLASIF | Character | Classification of the material. |
| ANCHO | Decimal | Width of the item. |
| LARGO | Decimal | Item Length . |
| GRUESO | Decimal | Item thickness. |

KITALM: This file is to make components products.

| Field name | Data type | Description |
|---|---|---|
| LINEA | character | Line of the product. |
| CODIGO | character | Label of the item. |
| LINKITA | character | Line of the kit product. |
| CODKITA | character | Label of the kit product. |
| CANKITA | decimal | Amount of the kit item. |

LINEAS: Product line catalog.

| Field name | Data type | Description. |
|---|---|---|
| LINEA | character | Product line. |
| NOMLIN | character | Line description . |

CATPROC: Process Catalog

| Field name | Data type | Description |
|---|---|---|
| LINEA | character | Line of the product. |
| CODIGO | character | Label of the product. |
| NUMPROC | integer | Process number |
| NOMPROC | character | Process name. |
| CLAMAQ | character | Label of the machine. |
| CLAHER | character | Tool label. |
| TIEPROC | integer | Length of the process. |
| DESPROC | character | Process Brief description. |
| NUMCATEG | integer | Category number. |

CATCATEG: Employee Category Catalog. (Versionable)

| Field name | Data type | Description |
|---|---|---|
| NUMCATEG | Integer | It referes to the category number. |
| FECCATEG | Date | Date where the salarary of the category was changed. |
| PUECATEG | Character | Category post. |
| SALCATEG | Decimal | category salary |

CATCLASIF: Material classification catalog. (Versionable)

| **Field name** | **Data type** | **Description** |
|---|---|---|
| CLASIF | Character | Code of the classification. |
| FECCLASIF | Date | Date where the cost of the product classification changed. |
| COSCLASIF | Decimal | Cost of the classification. |
| DESCLASIF | Character | Description of the product classification. |

DATORDEN: Production order.

| **Field Name** | **Data Type** | **Description** |
|---|---|---|
| NUMORDEN | Integer | Order number |
| CTA | Integer | Customer Number |
| LINEA | Character | Line of the product. |
| CODIGO | Character | Code of the product. |
| CANORDEN | Integer | Quantity ordered |
| STATORDEN | Integer | Status (Products finished) |
| FECORDEN | Date | Date of the order |

CALENPROD: Production calendar.

| Field Name | Data Type | Description |
|---|---|---|
| FECPROD | Date | Date of production. |
| LINEA | Character | Line of the product. |
| CODIGO | Character | Code of the product. |
| CANPROD | Integer | Quantity to produce |

CATMEN: Error message catalog.

| Field name | Data type | Description |
|---|---|---|
| CODMEN | Integer | number of the error message. |
| DESMEN | Character | Description of the error message. |
| FREMEN | Integer | Frequent of occurrence of the error message . |

As we had mentioned in chapter 3 one of the main problems of information systems in Mexico is the change of prices, currency exchange and salaries; one of the solutions proposed to solve this problem is the concept of versions proposed in section V.4.1. In accordance to this concept two new tables were create which are the employee category catalog (named CATCATEG above) which maintains the salary of a category of employees but maintains the versions of change of the salary of the category with dates. The other table that has versions is the material classification catalog (named CATCLASIF above) which maintains the classification of raw materials and the associated cost with the versions of the cost by date. With this two tables if the salary of the employees changes the versions of the salary would be maintained and also the changes in the cost of raw material. This is a way to respond to uncertain financial environment of Mexico.

## VI.4.2. METHOD DESIGN.

The methods (procedures) of the system were determined from the simplified process model by detecting the processes that are methods and dividing them until they can be assigned to each object, in order to encapsulate the processes with the information that they use into the objects. The following methods were determined from the simplified process models shown in table 6.7.

Table 6.7. Methods assigned to objects.

| OBJECT | METHOD |
| --- | --- |
| Product | Create Product or part.<br>Assign parts to Products.<br>Calculate Cost of Raw Material.<br>Determine raw material parts list.<br>Classify parts according to dimensions. |
| Process | Create Process.<br>Calculate Time of Processes.<br>Generate list of employees required by category. |
| Machine | Create Machine.<br>Calculate Depreciation Cost. |
| Tools | Create Tools.<br>Assign Tools to Machines.<br>Calculate Cost Of Sharpening. |
| Prod.Order. | Create Prod. Order.<br>Get Order Status. |
| Prod.Schedule | Generate Prod. Schedule.<br>Generate Work Orders. |
| Employee Category | Calculate cost of man work hours. |

These methods were determined with the guidelines of section V.4.2. From the process models and from the object models, these methods were divided until they could be assigned to an object, for example the process calculate estimate from the process diagram was divided into the methods: calculate cost of raw material, calculate time of process, calculate the cost of man work hours, calculate the depreciation cost and calculate cost of sharpening. These methods can be implemented later on an object-oriented language and associate them to graphical objects to be able to run then from the user interface as the next section explains.

### VI.4.3. OBJECT INTERACTIONS DESIGN.

The object interactions design defines the user interface that is going to be used by the users of the system to interact with the computer objects of the information system. The user interaction is designed by combining the simplified object model and the simplified interaction model by following the activities listed in section V.4.3.

The first activity of the design of object interactions is to identify the tasks of the system according to the responses of the events generated in the analysis model. The tasks generated for the production system of MYMCE are shown in table 6.8.

Table 6.8. Tasks of the system.

| TASK NUMBER | TASK DESCRIPTION |
|---|---|
| 1 | Register New Product. |
| 2 | Register machine. |
| 3 | Register tool. |
| 4 | Create process. |
| 5 | Generate estimate. |
| 6 | Plan Production. |
| 7 | Programming Production. |
| 8 | Place Production Order. |

These are the relevant tasks for the design of the production system, other tasks will be done with other information systems. For example the task "design product" will be done with the CAD system, so there is no need to consider it here.

The second activity of the interaction design is to divide the tasks into subtasks and later into actions that can be implemented by a computer object of the user interface. The subtasks and actions of the system are presented in the following tables.

Table 6.9. Subtasks and actions to register a new product.

| TASKS | SUBTASKS | ACTIONS |
|---|---|---|
| 1. Register New Product. | | |
| | 1.1. Register new product line. | |
| | | 1.1.1. Create new product line. |
| | | 1.1.1. Enter new product line data. |
| | 1.2. Register new parts. | |
| | | 1.2.1. Create new part. |
| | | 1.2.1. Enter part data. |
| | 1.3. Define product. | |
| | | 1.3.1. Create new product. |
| | | 1.3.2. Enter product data. |
| | 1.4. Assign parts as components of the product. | |
| | | 1.4.1. Create new component. |
| | | 1.4.2. Browse part data. |
| | | 1.4.3. Select part. |
| 2. Register Machine. | | |
| | | 2.1. Create new machine. |
| | | 2.1. Enter machine data. |
| 3. Register Tool. | | |
| | | 3.1. Create new tool. |
| | | 3.2. Enter tool data. |
| 4. Register process of product. | | |
| | | 4.1. Create new process. |
| | | 4.2. Enter product code. |
| | | 4.3. Enter machine code. |
| | | 4.4. Enter tool code. |
| 5. Generate Estimate. | | |
| | 5.1. Obtain product to estimate. | |
| | | 5.1.1 Browse product. |
| | | 5.1.2. Select product. |
| | 5.2. Obtain raw material cost. | . |
| | | 5.2.1. Generate part list. |
| | | 5.2.2. Calculate product cost. |
| | 5.3. Obtain process cost. | |
| | | 5.3.1. Generate process list. |
| | | 5.3.2. Calculate process time. |
| | | 5.3.3. Calculate process cost. |
| | 5.4. Obtain operation cost. | |
| | | 5.4.1.Calculate machine depreciation cost. |
| | | 5.4.2. Calculate tool sharpening. |

The second part of these tasks, divided in subtasks and actions are presented in table 6.10.

Table 6.10. Second part of subtasks and actions to register a new product.

| TASKS | SUBTASKS | ACTIONS |
|---|---|---|
| 6. Plan Production. | | |
| | 6.1. Obtain product and quantity. | |
| | | 6.1.1. Browse Product. |
| | | 6.1.2. Select Product. |
| | | 6.1.3. Enter quantity to produce. |
| | 6.2. Obtain blocks of material. | |
| | | 6.2.1 Generate block listing. |
| | | 6.2.2 Classify according to dimensions. |
| | 6.3. Obtain tables needed. | |
| | | 6.3.1. Relate blocks to tables (according to dimensions). |
| | | 6.3.2. Sort table listing (according to thickness in descending order). |
| | 6.4. Obtain processes to perform. | |
| | | 6.4.1. Analyze parts features. |
| | | 6.4.2. Analyze machines available. |
| | | 6.4.3. Assign process to machines and parts. |
| | | 6.4.4. Calculate process time. |
| | 6.5. Obtain employee requirements | |
| | | 6.5.1. Assign people to processes. |
| | | 6.5.2. List people requirements. |
| 7. Programming production. | | |
| | 7.1. Obtain production schedule. | |
| | | 7.1.1. Analyze machine load. |
| | | 7.1.2. Obtain cycle time. |
| | | 7.1.3. Generate production schedule. |
| | 7.2. Obtain work orders. | |
| | | 7.2.1. Generate work orders. |
| 8. Place Production Order. | | |
| | 8.1. Obtain product.. | |
| | | 8.1.1. Browse product.. |
| | | 8.1.2. Select product. |
| | 8.2. Register new order. | |
| | | 8.2.1. Create Production Order. |
| | | 8.2.2. Enter Order Data. |

In table 6.9. and 6.10. we can see how tasks are divided into subtasks and later into actions that can be associated to an object in the next activity or be implemented as methods that work over several objects.In task 6.2. blocks or material are mentioned. these blocks are blocks of wood from which the parts will be obtained. also these blocks are formed from wood tables of certain dimensions.

The third activity of the object interaction design is to form object action pairs, to relate clearly all the actions to their respective objects. The object action pairs for the system are shown in table 6.11.

Table 6.11. Object-Action Pairs.

| OBJECT | ACTION |
|---|---|
| Product | Create<br>Enter Data<br>Browse<br>Modify<br>Delete<br>New Component<br>Generate part list.<br>Calculate product cost. |
| Product line | Create<br>Enter Data<br>Browse<br>Modify<br>Delete |
| Machine | Create<br>Enter Data<br>Modify<br>Browse<br>Delete<br>Calculate machine depreciation cost.<br>Analyze machine load. |
| Tool | Create<br>Enter Data.<br>Modify<br>Browse<br>Delete<br>Calculate tool sharpening |
| Process | Create<br>Enter Data<br>Mofify<br>Browse<br>Delete<br>Generate process list.<br>Calculate process time.<br>Calculate process cost. |
| Production Order | Create<br>Enter Data<br>Verify Status |
| Production Schedule | Generate production schedule.<br>Generate work orders. |
| Employee category | Create<br>Enter Data<br>Modify salary<br>Browse<br>Delete |
| Material classification | Create<br>Enter Data<br>Modify<br>Browse<br>Delete |

In table 6.11 we can see the objects and the actions associated with each object. So that most of the actions have an object associated, as the concept of encapsulation which consists of gathering objects and the actions or procedures that act upon them suggests. Actions which could not be assigned directly to one objects will be added to the methods of the system because they could not be assigned to just one object.

In the fourth activity of the object interaction design it was defined how to implement the interface with the actions. In table 6.12. each action was associated to a graphical computer object of the user interface.

Table 6.12.Actions and Graphical Objects.

| OBJECT | ACTION | Graphical Object |
|---|---|---|
| Product | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Browse | Browser |
| | Modify | Button |
| | Delete | Button |
| | New Component | Button |
| | Generate part list. | Menu Item |
| | Calculate product cost | Menu Item |
| Product line | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Browse | Browser |
| | Modify | Button |
| | Delete | Button |
| Machine | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Modify | Button |
| | Browse | Browser |
| | Delete | Button |
| | Calculate machine depreciation | Menu Item |
| | Analyze machine load | Menu Item |
| Tool | Create | Button |
| | Enter Data. | Fill-In-Fields |
| | Modify | Button |
| | Browse | Browser |
| | Delete | Button |
| | Calculate tool sharpening | Menu Item |
| Process | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Mofify | Button |
| | Browse | Browser |
| | Delete | Button |
| | Generate process list. | Menu Item |
| | Calculate process time. | Menu Item |
| | Calculate process cost. | Menu Item |
| Production Order | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Verify Status | Browse |
| Production Schedule | Generate production schedule. | Menu Item |
| | Generate work orders. | Menu Item |
| Employee category | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Modify salary | Button |
| | Browse | Browser |
| | Delete | Button |
| Material classification | Create | Button |
| | Enter Data | Fill-In-Fields |
| | Modify | Button |
| | Browse | Browser |
| | Delete | Button |

In this table we can see the actions associated with a graphical computer object which will help to activate the desired action upon a certain object. Buttons are graphical buttons that can be pressed, Fill-In-Fields are fields were the user can enter data, Browsers are boxes which can be scrolled up and down to see registers of data.

The fifth activity of the object interaction design is to link actions to methods already defined in the previous step in order to be able to relate which methods will be used to implement each action (see table 6.13).

Table 6.13. Methods assigned to objects.

| OBJECT | METHOD | ACTION |
|---|---|---|
| Product | Create Product or Item.<br>Assign items to Products.<br>Calculate Cost of Raw Material.<br>Determine raw material parts list. | Create<br>New Component<br>Calculate Product Cost<br>Generate Part List |
| Process | Create Process.<br>Calculate Time of Processes. | Create<br>Calulate process time |
| Machine | Create Machine.<br>Calculate Depreciation Cost. | Create<br>Calculate Machine depreciation |
| Tools | Create Tools.<br>Assign Tools to Machines.<br>Calculate Cost Of Sharpening. | Create<br>Enter Process Data<br>Calculate tool sharpening |
| Production Order | Create Prod. Order.<br>Get Order Status. | Create<br>Verify Status |
| Production Schedule | Generate Prod.Schedule.<br>Generate Work Orders. | Generate Prod.Schedule.<br>Generate Work Orders. |
| Employee Categories | Calculate cost of man work hours | Calculate process cost |

In this table the actions of the user interface are related to the methods (procedure) of the objects that are going to implement each action. This is the point were the methods are linked to the user interface of the system. In this table there are several methods in the last row of the table which involve multiple objects and do not belong to a single object. Other trivial methods will be defined for simpler actions for example the modify product action will be implemented by a corresponding method and the same will happen for all other simple actions but these are not listed in this table for clarity.

The last activity of this step is to generate the user event lists. These user event lists inform users of exeptional events that occur in the system, the user event list for the user of the production system is shown in table 6.14.

Table 6.14. User event lists for the production system.

| **EVENT** | **TYPE OF THE EVENT** |
|---|---|
| PRODUCTION ORDER COMPLETES TODAY | OPORTUNITY |
| PRODUCTION ORDER DELAYED | PREVENT BREAK |
| PRODUCTION ORDER CANCELED | EXCEPTIONAL |
| SEND DAILY PRODUCTION REPORT | RECURRENT |
| TOOL NEEDS TO BE SHARPENED | PREVENT BREAK |

In this table we can see the user event lists for the production system. The events would appear when the user enters the information system to inform him so that he can take the correspondent actions. The first event is an opportunity to use the workers and machines for other products, the second event would inform if a production order has gone behind schedule, the third event would inform if a production order has been canceled, the fourth event would remind the user to send the daily production information, the last event would inform if a certain tool needs to be sharpened according to the useful hours. These user event lists help the users of the system to take actions fast.

This is the end of the object interactions design step. In this step the objects, actions and user event lists of the system were identified, in the next step these objects will be grouped into components.

VI.4.4. REUSABLE COMPONENT DESIGN.

Reusable components are groups of graphical objects (buttons, browsers, fill-in-fields) that help to define parts of the system that are common and can be reused (see section V.4.4). All objects would be grouped into a component with their actions and their user interface objects. But some of these objects can be reused as explained in the following paragraph.

The first step to define components is to identity common actions or subtasks from the task model obtained in the previous step. From table 6.9 and 6.10. we can identify the common actions :

- browse parts (or products).
- enter product code
- enter machine code
- enter tool code

From these common actions we can see that the objects components of the system that can be reused will be products machines and tools. So from this common actions an object component hierarchy was constructed, which is shown in figure 6.14.

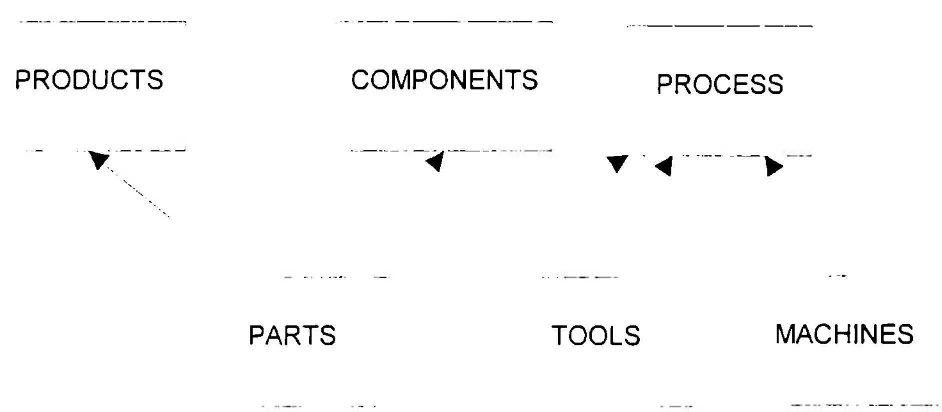



Figure 6.14. Object component hierarchy.

In figure 6.14. we can see that the reusable component parts will be used by the components products and components, also the components tools and machines will be used by the process component. In this way reusable components help to achieve faster development and contribute to the consistency of the design.

VI.4.5. SYSTEM MODULE DESIGN.

The components mentioned in the previous step were grouped in modules, the components which are closely related were put into a common module and in this way modules help to group the functionality of the system.

The first activity to identify modules is to identify the modules itself and the components and objects that belong to those modules. The production system will be divided in the following modules:

- Fabrication
- Materials
- Operations
- Planning and Programming
- Cost Estimation.

These modules will conform the production system and each of these modules is going to contain the components and objects listed in table 6.15.

Table 6.15. Modules related to components and objects.

| MODULE | COMPONENT OR OBJECT |
|---|---|
| Fabrication | Machines<br>Tools |
| Materials | Parts<br>Products<br>Components<br>Material Classification |
| Operations | Process<br>Employee Categories |
| Planning and Programming | Production Order<br>Production Schedule |
| Estimates | Uses objects of Fabrication, Materials and Operations |

In the second activity of module design the objects that will belong to a common module are identified, in this case the objects that are going to belong to the common module will be:

- months of the year.
- systems parameters.
- error messages.

This common module will contain the months of the year, system parameters and error messages. These objects are used on all the system.

In the third activity of module design the module relation diagram was constructed showing the relationships between modules. This diagram is shown in figure 6.15.

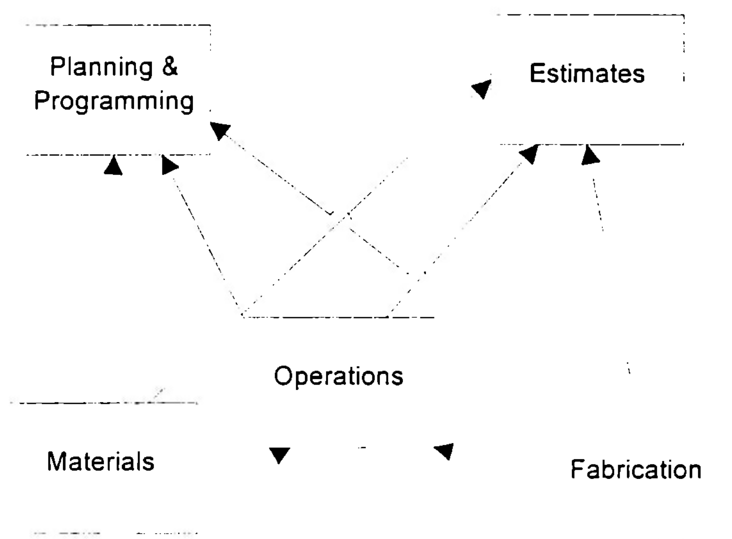



Figure 6.15. Module relation diagram.

This diagram shows how the operations module will use objects of the materials and fabrication module. Also the planning & programming module and the cost estimation module will use objects of the other three modules. The common module is not shown in this diagram for clarity because this common module will be related to all the other modules.

VI.5. INTEGRATION PHASE.

The integration phase is the final phase of the method (see section V.5). Here domains and databases are defined and in this phase the domains and databases for the complete system of MYMCE will be presented.

VI.1. ESTABLISH DOMAINS AS GROUPS OF MODULES.

In the first step of this phase the domains were identified and classified in support, value and mixed domains. The domains for MYMCE are presented in table 6.16.

Table 6.16. Domains and their types.

| DOMAIN | TYPE OF DOMAIN |
|---|---|
| Accounting | Support |
| Inventory | Support |
| Sales | Value |
| Purchasing | Value |
| Payroll | Support |
| Product Design | Value |
| Production | Value |

In this table the domains of all the information system of the company are shown. Each of these domains represents a subsystem of the whole information system. Domains of value generate direct value for the company, support domains perform support activities for the other domains and generate information to take decisions.

VI.5.2. DEFINE DOMAIN INTERCONNECTION RELATIONSHIPS.

In the next phase of the integration phase the relations between domains were identified. These relations indicate that some transfer of information occurs between domains, the domain interconnection graph is shown in figure 6.16.

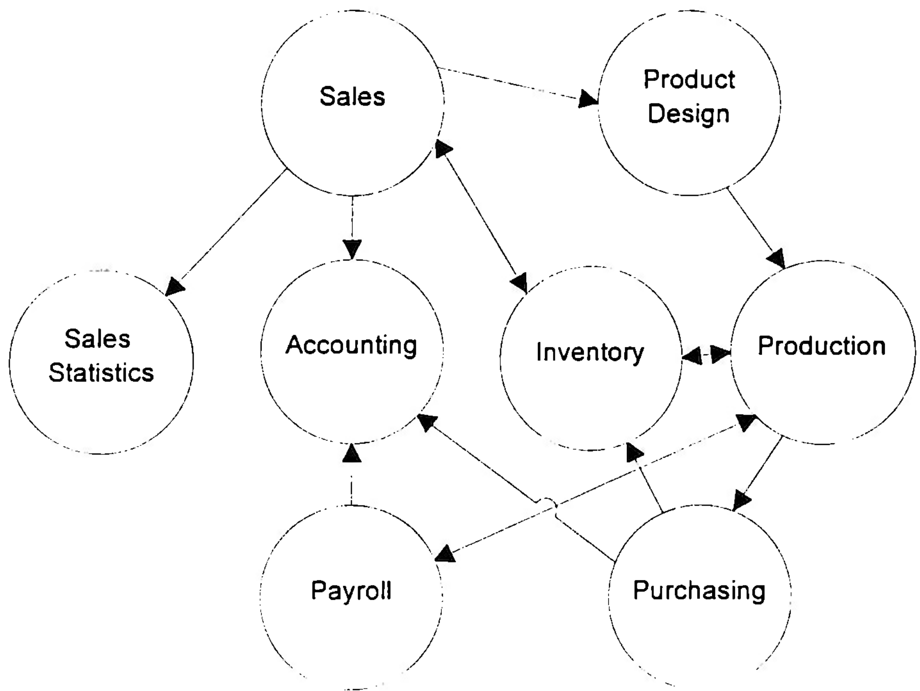



Figure 6.16. Domain Interconnection Graph.

In this figure we can see the domains and the relations to each other. Each relation means that one domain transfer information to another domain, for example the sales domain transfer information about sales to the accounting domain. The type of information that is transferred and the frequency are explained in the next step of this phase.

VI.5.3. DEFINE DOMAIN PROTOCOLS.

In the third step of the integration phase the domain protocols for the intercommunication between domains are defined. The domain protocols have three parts information to transfer, the structure of the communication and the frequency of activation of the communication.

In table 6.17. the information that is transferred between domains is presented. In this table we can see the information that is transferred between domains, these information can be transferred by a computer network or via modem from remote sites.

Table 6.17. Information transferred between domains.

| SOURCE DOMAIN | DESTINATION DOMAIN | INFORMATION |
|---|---|---|
| Sales | Sales Statistics | Sales information containing:<br>date of sale<br>customer number<br>product numbers<br>quantity of each product<br>price of each product |
| Sales | Accounting | Sales information containing:<br>date of sale<br>customer number<br>total sale |
| Sales | Inventory | Sales information containing:<br>date of sale<br>product numbers<br>quantity of each product. |
| Sales | Product Design | Description of the product that the customer wants. |
| Product Design | Production | Part list of the product containing:<br>part code<br>dimensions<br>quantity |
| Production | Inventory | Products produced containing:<br>product code<br>quantity produced. |
| Inventory | Sales | Products to sell:<br>product code<br>description<br>price |
| Inventory | Production | Inventory information:<br>part code<br>quantity available |
| Production | Purchasing | Material required:<br>material code<br>quantity |
| Purchasing | Inventory | Material purchased:<br>supplier number<br>material code<br>quantity |
| Purchasing | Accounting | Purchasing information:<br>date of purchase<br>supplier number<br>total purchase |
| Production | Payroll | People required:<br>category number<br>number of people |
| Payroll | Accounting | Concepts payed:<br>date of payment<br>number of employee<br>number of concept<br>amount of money |
| Payroll | Production | Employee Category Data:<br>category number<br>salary of category |

In table 6.17 the information that is transferred is defined. The structure of the communication in each case is presented in table 6.18, were the steps for transferring the information are defined.

Table 6.18. Structure of the communication between domains.

| SOURCE DOMAIN | DESTINATION DOMAIN | STEPS OF THE COMMUNICATION |
|---|---|---|
| Sales | Sales Statistics | 1. Online Transfer via network. |
| Sales | Accounting | 1. Generate Sale Information.<br>2. Send Sales Information by network<br>3. Verify Arrival of Sales Information.<br>4. Load Sales Information. |
| Sales | Inventory | 1. Online Transfer via network. |
| Sales | Product Design | 1. Send Product Information via fax. |
| Product Design | Production | 1. Generate Part Listing.<br>2. Send Part Listing by network.<br>3. Load Part Listing. |
| Production | Inventory | 1. Generate Product Information.<br>2. Send Product Information by modem.<br>3. Verify Product Information.<br>4. Acknowledge Arrival.<br>5. Load Product Information. |
| Inventory | Sales | 1. Online Access via network. |
| Inventory | Production | 1. Generate product availability information<br>2. Send product availability by modem.<br>3. Verify product information.<br>4. Acknowledge Arrival.<br>5. Load information. |
| Production | Purchasing | 1. Generate material required.<br>2. Send material required by modem.<br>3. Verify material Information.<br>4. Acknowledge Arrival.<br>5. Load material Information. |
| Purchasing | Inventory | 1. Online Transfer via network. |
| Purchasing | Accounting | 1. Generate Purchasing Information.<br>2. Send Purchasing Information via network.<br>3. Verify Arrival of Purchasing Information.<br>4. Load Purchasing Information. |
| Production | Payroll | 1. Generate people required.<br>2. Send information via modem.<br>3. Verify information.<br>4. Acknowledge Arrival.<br>5. Load information. |
| Payroll | Accounting | 1. Generate payroll information.<br>2. Send payroll information via network.<br>3. Verify Arrival of payroll information.<br>4. Load Payroll Information. |
| Payroll | Production | 1. Generate category information.<br>2. Send information via modem.<br>3. Verify information.<br>4. Acknowledge Arrival.<br>5. Load Information. |

In table 6.18 we can see the structure of the communication between domains, some information is updated online through databases, other information is sent via computer network, other information is transferred by modem but this requires more steps because the possibility of error is greater.

In table 6.18 we have the structure of the communication but we need to know also the frequency of the communication. In table 6.19 the frequency of the communication is presented.

Table 6.19. Frequency of the communication between domains.

| SOURCE DOMAIN | DESTINATION DOMAIN | INFORMATION | FREQUENCY OF COMMUNICATION |
|---|---|---|---|
| Sales | Sales Statistics | Sales information. | Monthly |
| Sales | Accounting | Sales information. | Daily |
| Sales | Inventory | Sales information. | Daily |
| Sales | Product Design | Description of the product that the customer wants. | When customer requests |
| Product Design | Production | Part list of the product | When a new product is designed |
| Production | Inventory | Products produced | Daily |
| Inventory | Sales | Product to sell | Seconds |
| Inventory | Production | Inventory information | Daily |
| Production | Purchasing | Material required | When planning to produce a new product. |
| Purchasing | Inventory | Material purchased | Daily |
| Purchasing | Accounting | Purchasing information | Daily |
| Production | Payroll | People required | When planning to produce a new product |
| Payroll | Accounting | Concepts pay | Weekly |
| Payroll | Production | Employee Category Data | When salary changes |

In table 6.19 the frequency of the communication between each domain is presented; some information is sent daily, other information is sent weekly, monthly or when a new product is requested. The information that is sent more frequently generally requires faster mediums of transmission, while information that is less frequent may use slower mediums of transmission.

## VI.5.4. DEFINE DATABASES AS GROUPS OF DOMAINS.

The databases contain one or more domains; the number of databases determines the number of database servers needed to share the information among users. In figure 6.17 the databases of MYMCE are shown.

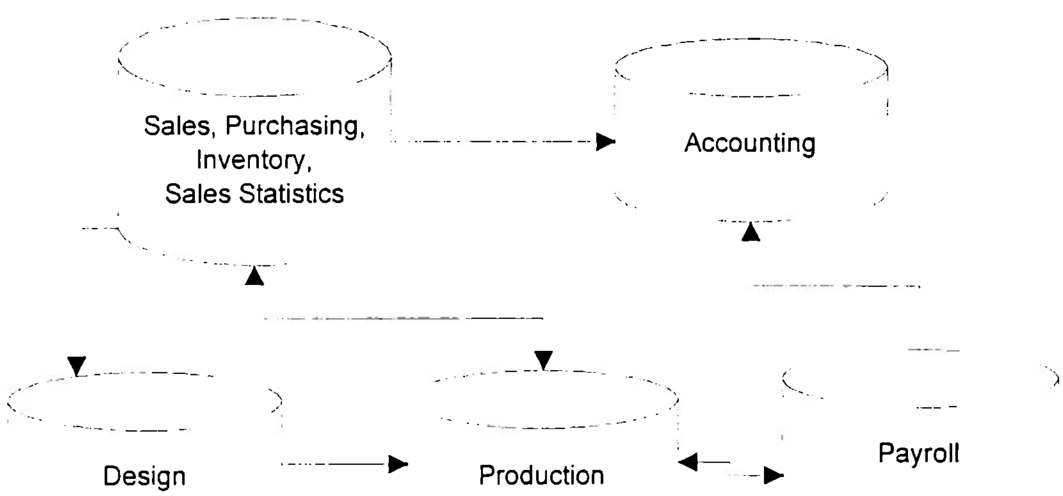



Figure 6.17. MYMCE Databases.

In this figure we can see the databases that will be used in the system. We can see that the sales, purchasing, inventory and sales statistics domains were grouped into one database. because of the frequency of the relationships between them. the rest of the domains have a separate database for each domain. because the relationships are not so frequent and the information can be administrated easier in a separate database.

VI.5.5. PREVIEW ADJUSTMENTS IN THE ORGANIZATIONAL STRUCTURE.

In this part of the method the adjustments to the organizational structure of the company will be previewed because people will be working with information systems and the time they took to perform a certain task is going to be reduced. In the case of MYMCE the organizational structure that the company had when there were no information systems is shown in figure 6.18.

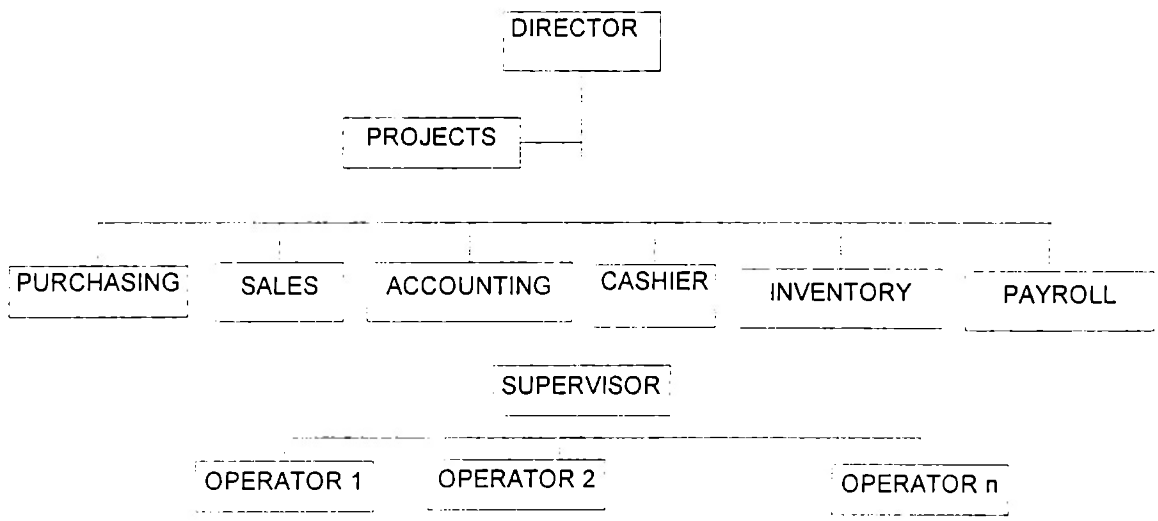



Figure 6.18. MYMCE organizational structure without information systems.

In this figure we can see that MYMCE had many people in the administrative functions, because there was one people for purchasing one for sales, accounting, etc. All this people were needed because with a manual system the people took longer time in doing their tasks.

According to the guidelines of section V.5.5 for adjusting the organizational structure, the number of people in domains with a common database should be reduced. In the case of MYMCE this was true because with the information system only one person performs the tasks of purchasing, inventory and payroll (see figure 6.19).

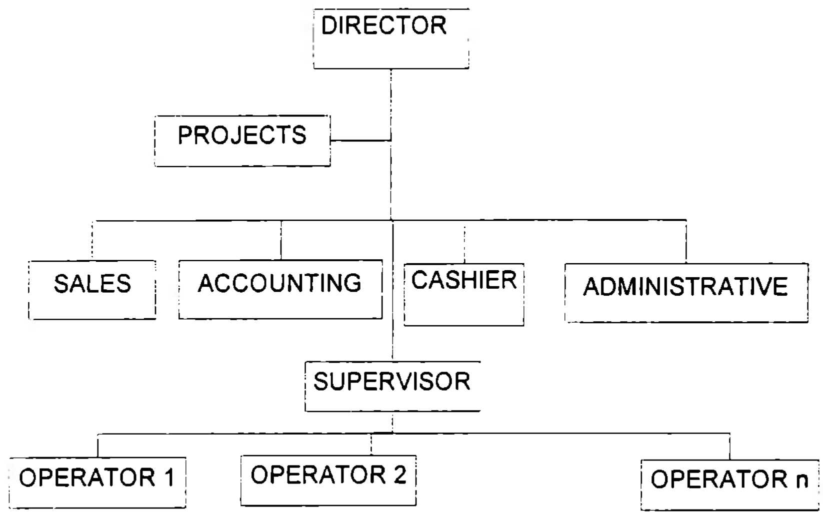



Figure 6.19. MYMCE organizational structure with stand alone information systems.

Notice here in this figure that there still was one person working in the accounting function, but after the information systems were integrated to accounting, that means that the transactions were generated automatically from the other systems to accounting. So the accounting function was transferred to the people that managed the other administrative systems, and the person that was in the support domain accounting was not needed after the integration of the other systems to accounting. The person that was in sales with the information system had free time, so the task of cashier was also assigned to the person of sales. So the organizational structure was reduced further to the one shown in figure 6.20.

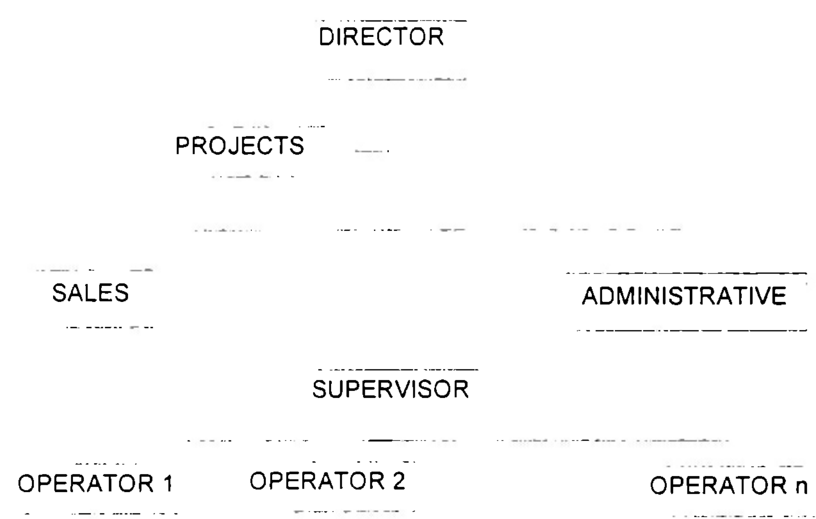



Figure 6.20. MYMCE organizational structure with integrated information systems.

Later MYMCE started to manufacture wood products for the national and export market, so the organizational structure expanded for the new manufacturing operations (which is an activity of value) and the structure of the organization is the one that was shown in figure 6.2. Since 1995 the company has maintained that organizational structure, in the beginning of 1995 they had about 40 employees, actually in December of 1996 they had about 80 employees, because more people was hired to manufacture other products like furniture. It is expected that in the beginning of 1997 the company would have around 100 employees, because of the expected increase in operations, but is also expected that the administrative personnel remains to be the same, or slightly reduced because of the use of integrated information systems.

In table 6.20 we can see a table of where the total sales of year 1995 and 1996 of MYMCE are presented. We can see that there was an increase in the sales of 1996 with respect to 1995. The number of production employees as mentioned above increased, but the administrative personnel remains the same.

Table 6.20. Indicators of MYMCE.

| YEAR | TOTAL SALES | ADMINISTRATIVE EMPLOYEES | PRODUCTION EMPLOYEES |
|---|---|---|---|
| 1995 | 6.058 million pesos. | 5 | 35 |
| 1996 | 10.338 million pesos. | 5 | 75 |

Another effect of the information systems, was the decision to buy a Numerical Controlled Machine for wood products. These machine will be using the information of the CAD system. This indicates that decision of introducing the CAD system was good and that now the company is automating part of the company to be more productive.

This is the end of the method, and we can observe that in MYMCE the efficiency of the administrative personnel increased because of the use of integrated information systems, efficiency as mentioned in the introduction of this thesis means that the company increased its operations with less administrative personnel, and that persons can do more work now with the help of the integrated information systems. We can also observe that the people in support domains (accounting, inventory, payroll) were not needed later, because the information was generated automatically from the value domains (sales, purchasing, and recently production), so the greater benefits were observed when the information systems were integrated.

# CHAPTER VII. CONCLUSIONS.

## VII.1. HOW THE HYPOTHESIS AND THE GOALS WERE ACHIEVED.

In Mexico the NAFTA agreement that started in 1994 created a new condition for the manufacturing sector. This condition brought many opportunities to sell in bigger markets but also brought many challenges to compete with international companies in price, productivity and quality. Most of the small companies in Mexico did not take into account the new opportunities of this bigger market and remained focused on the local markets (see results of the questionnaire in Appendix A2). Also small companies did not prepare their infrastructure in information systems to compete with foreign companies (see section A.2), neither their manufacturing systems (see chapter 3.2). So small mexican companies have the need to improve their information systems to compete and participate in the foreign market, but most of them do not use a method for constructing information systems (see figure 3.8). So there is a need for a method for developing information systems, but it is not convenient for mexican companies to use a foreign method (as the ones presented in chapter 4) because in Mexico the conditions of operation of information systems are different (see chapter III.3) due to the mexican environment. So this is the proof that there is a need of a new method for developing information systems for mexican companies that takes into account the characteristics of the mexican environment, which is the proof of hypothesis number 1 (see section I.9).

In chapter VI the implementation of the new method in the company MYMCE was presented. This method was implemented in MYMCE during 1995 and 1996. We can see in the results of chapter VI (see table 6.20) that the total sales in MYMCE increased 70% from 1995 to the end of 1996. We can also see in the results that the number of production employees increased 114% during the same period to produce more, because they are using manual machines now. And we can also see in the results that the administrative employees remained the same, this means that the information systems helped the company to increase its operations (sales and production) but with the same administrative employees (they could do more work with the information system). Another effect of the information systems, was that the company decided to buy a new machine with numerical control to use the information that they have available now to produce more. So this is a proof that information systems can help manufacturing companies to become more efficient and to integrate their functions, which is the proof of hypothesis number 2 (see section I.9).

In chapter V my conception of how to use object-oriented techniques for developing information systems that can be applied in manufacturing companies was presented (see general structure diagram in figure 5.1). For the analysis and design phases of the method object-oriented techniques were used because in a manufacturing company there are many different types of objects from machines, tools, invoices, orders, etc. Object-oriented techniques allow the analysis of all the areas of the company with the same object-oriented tools, this permits the construction of common models (analysis and design models) for all areas of the company. These common models allow the analysis of all the information of the company whether it is information used for controlling the machines or administrative information. These features make the object-oriented techniques suitable for implementing integrated information systems which can later evolve to CIM systems in which all the information of the company would be integrated. So this is a proof that object-oriented techniques can be used for implementing information systems for CIM, which is the proof of hypothesis number 3 (see section I.9).

Besides we can see that object-oriented techniques can be used not only in manufacturing companies but in any other type of company because the concept of object is general. So the application of the method developed in chapter V can be done in manufacturing companies, services companies (banks, insurance companies or other), etc.

## VII.2. ADVANTAGES OF THE METHOD.

In this section the advantages of the method will be discussed, and how these advantages brought benefits to the company where the pilot implementation was developed. These advantages would be discussed in the order of the phases of the method.

One of the advantages of the evaluation phase is that the strategies of the company are identified to align the information systems to these company strategies, in the case of MYMCE the information systems contributed directly to the strategies of the company (see section VI.1.2.). Another advantage of this phase is that the potential areas to improve are detected to identify the areas where there would be more benefit, in MYMCE the areas of improve were identified (see section VI.1.4) and the ones in which there would be more benefit were detected. Other advantages are that the trends in information systems are taken into account and the economic justification validates the usefulness of the projects, in the project with MYMCE this advantages brought benefits because the trends were identified (see section VI.1.3) and their introduction was justified economically.

In the analysis phase one of the main advantages is that it starts with the process analysis (other methods start with the object analysis, see chapter 4). In MYMCE starting with the process analysis facilitated the communication with the engineers because they are more accustomed to talk about processes than about objects. This also allows the identification of the real world objects and provides and introduction for the engineers to the object-oriented concept.

The simplification phase of the method has the advantage of explicitly simplify the models generated by the analysis phase, this allows the application techniques to optimize the processes, data structures and interactions. In the case of MYMCE this allowed the simplification of the process and object models (see sections VI.3.1 and VI.3.2) which later allowed a simpler design.

The design phase has the advantage of taking into account the characteristics of operation of mexican information systems, so that the design of the system can respond to these characteristics with features of the system that are introduced in the design. In the project of MYMCE these allowed the introduction of features (see section VI.4.1. and VI.4.3) that would permit the operation of the systems in uncertain conditions.

The integration phase has the advantage of guaranteeing that the systems will be integrated by analyzing the domains and their interactions. In MYMCE this allowed the new systems to interconnect to the existing information systems. This phase also has the advantage of adjusting the organizational structures to work more efficiently with the information systems. In MYMCE several adjustments to the organizational structure have been made to work with the integrated information systems (see section VI.5.5) more efficiently.

## VII.3. FUTURE DIRECTIONS.

If a company has all its information systems complete and integrated, this information could be used to produce more with the introduction of automatic machines in some areas of the company. This would permit to achieve higher levels of productivity and exploit the information available. In the project of MYMCE they are buying a numerical controlled machine for wood operations, it is expected that this machine would allow to use the information available to produce more. This indicates that in the future maybe another phase of the methodology could be added to consider the areas where automation is feasible. This would coincide with what Underwood says in his book Intelligent Manufacturing [16] that first it is necessary to Simplify then Integrate and then Automate.

Actually this method considers only the internal information of the company to make it more efficient, but a further area of investigation could be to consider external information to make the company more competitive, in a way that the external information could be integrated with the internal information to achieve better results for the company. With the extensive use of the Internet and with the products that the database companies have now for making transactions on the Internet this could be feasible in a near future.

Another area of further investigation would be to consider the integration of production chains between companies that already have their information systems complete. This would allow the integration of several companies in a production chain where all the companies know the information of the other companies to coordinate in their production effort and to make more synchronized their client-supplier relationships. This would allow to reduce inventory and to coordinate effectively with their suppliers and clients.

In the previous paragraphs some areas of further investigation in the area of integration of information systems were mentioned. but maybe further areas would appear when the communication networks of the world become faster and more reliable. because the development of computer networks and world wide networks make more information available and create more opportunities to interact with other companies. While the markets open and new trade agreements are being developed. the need for integration and cooperation increases.

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APPENDIX A. CUESTIONNAIRE.

The model of the questionnaire applied to 30 small manufacturing companies is presented below in section A.1. Later in section A.2 the method of elaborating the results is presented.

A.1. MODEL OF THE CUESTIONNAIRE.

QUESTIONNAIRE OF INFORMATION SYSTEMS.

I. COMPANY DATA:
1. NAME: ______________________
2. ADDRESS: ___________________
3. TELEPHONE: _________________
4. NUMBER OF EMPLOYEES: _____

II. DATA OF THE PERSON WHO ANSWERS THE QUESTIONARY:

NAME: ____________________________ DEPARTMENT: ___________________

| III. MAIN PRODUCT LINES OF THE COMPANY. | FOR EXPORT (X) YES |
|---|---|
| 1. ________________________________________ | ___ |
| 2. ________________________________________ | ___ |
| 3. ________________________________________ | ___ |
| 4. ________________________________________ | ___ |
| 5. ________________________________________ | ___ |

IV. INDICATE THE PERCENTAGE OF AUTOMATIZATION (COMPUTERIZATION) OF THE FOLLOWING AREAS OF THE COMPANY:

| AREAS | %COMPUTERIZED |
|---|---|
| 1. FINANCIAL ACCOUNTING | ____ |
| 2. COSTS ACCOUNTING | ____ |
| 3. PAYROLL | ____ |
| 4. HUMAN RESOURCES | ____ |
| 5. INVENTORY OF RAW MATERIAL | ____ |
| 6. INVENTORY OF PRODUCT IN PROCESS | ____ |
| 7. INVENTORY OF FINISHED PRODUCT | ____ |
| 8. INVOICING TO CUSTOMERS | ____ |
| 9. SALES STATISTICS | ____ |
| 10. PURCHASING | ____ |
| 11. PLANNING THE REQUIREMENTS OF MATERIAL | ____ |
| 12. PLANNING THE PROCESS OF MANUFACTURING | ____ |
| 13. PLANNING WORKER LOADS | ____ |
| 14. PLANNING MACHINE LOADS | ____ |
| 15. RELASE OF WORK ORDERS | ____ |
| 16. TRACKING OF WORK ORDERS | ____ |
| 17. MANTENIANCE TO EQUIPMENT | ____ |
| 18. DISTRIBUTION | ____ |
| 19. DESIGN OF PRODUCTS | ____ |
| 20. ESTIMATION OF COSTS OF MANUFACTURING | ____ |

V. PLEASE INDICATE IF YOU HAVE THE FOLLOWING HARDWARE AT YOUR COMPANY.

| | HOW MANY ? |
|---|---|
| 1. PERSONAL COMPUTERS | _______ |
| 2. LOCAL AREA NETWORKS | _______ |
| 3. MULTIUSER HOSTS | _______ |
| 4. TERMINALS | _______ |
| 5. COMMUNICATIONS BY MODEM | _______ |

VI. PLEASE INDICATE THE LANGUAGE USED TO DEVELOP YOUR SYSTEMS.

| | NAME OF THE LANGUAGE | IS FOR WINDOWS YES/NO |
|---|---|---|
| 1. COBOL/RPG/PASCAL/C | ____________________ | ______ |
| 2. DBASE/FOXPRO/CLIPPER | ____________________ | ______ |
| 3. ACCESS/PARADOX/REVELATION | ____________________ | ______ |
| 4. ORACLE/INFORMIX/PROGRESS. | ____________________ | ______ |
| 5. VISUAL BASIC/POWER BUILDER/GUPTA | ____________________ | ______ |
| WE USE ANOTHER LANGUAGE(S): | ________________________ | ______ |
| | ________________________ | ______ |
| WE USE A COMMERCIAL PACKAGE: | ________________________ | ______ |
| | ________________________ | ______ |
| | ________________________ | ______ |

VII. INDICATE THE PERCENTAGE OF MACHINES THAT USE WINDOWS ___%

VIII. INDICATE HOW MUCH HAS THE COMPANY INVESTED IN COMPUTERS:

| | HARDWARE | SOFTWARE |
|---|---|---|
| 1991. | __________ | _____________ |
| 1992. | __________ | _____________ |
| 1993. | __________ | _____________ |
| 1994. | __________ | _____________ |
| 1995. | __________ | _____________ |
| 1996. | __________ | _____________ |

IX. DO YOU USE ANY OF THE FOLLOWING METHODOLOGY TO DEVELOP YOUR SYSTEMS:

____ STRUCTURED ANALYSIS AND DESIGN.
____ DEVELOPMENT BY PROPTOTYPES.
____ OBJECT-ORIENTED ANALYSIS AND DESIGN
____ WE DO NOT USE ANY METHODOLOGY

INDICATE THE NAME OF THE METHODOLOGY : ___________________________

X. WHICH ARE THE MAIN ELEMENTS OF THE MEXICAN ENVIRONMENT THAT HAVE AFFECTED THE OPERATION OF YOUR INFORMATION SYSTEMS SINCE LAST YEAR:

| | 1 NOTHING <--> 5 MUCH | | | | |
|---|---|---|---|---|---|
| 1. THE CHANGE OF PRICES OF SUPPLIERS | 1 | 2 | 3 | 4 | 5 |
| 2. THE EXCHANGE RATE OF THE DOLLAR | 1 | 2 | 3 | 4 | 5 |
| 3. THE SCARCITY OF RAW MATERIALS | 1 | 2 | 3 | 4 | 5 |
| 4. THE CANCELATION OF ORDERS BY CUSTOMERS | 1 | 2 | 3 | 4 | 5 |
| 5. THE VARIATION IN INTEREST RATES | 1 | 2 | 3 | 4 | 5 |
| 6. SUPPLIERS DO NOT SEND THE RIGHT PRODUCTS THEY MAKE MISTAKES | 1 | 2 | 3 | 4 | 5 |
| 7. CHANGE IN FISCAL LAWS IVA/ISR/ETC | 1 | 2 | 3 | 4 | 5 |
| 8. CHANGE IN WORKER LAWS IMSS/SAR/ETC | 1 | 2 | 3 | 4 | 5 |
| 9. PRODUCTS OF SUPPLIERS DO NOT ARRIVE ON TIME | 1 | 2 | 3 | 4 | 5 |
| 10. CUSTOMERS DO NOT PAY ON TIME | 1 | 2 | 3 | 4 | 5 |

OTHER PROBLEM OF THE MEXICAN ENVIRONMENT THAT HAVE AFFECTED:

| | | | | | |
|---|---|---|---|---|---|
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |

XI. INTERNALLY WHICH ARE THE FACTORS THAT HAVE AFFECTED THE CORRECT OPERATION OF THE INFORMATION SYSTEMS.

| | 1 NOTHING <--> 5 MUCH | | | | |
|---|---|---|---|---|---|
| 1. PEOPLE DO NOT ENTER THE INFORMATION CORRECTLY | 1 | 2 | 3 | 4 | 5 |
| 2. USERS DO NOT FINISH PROCESSES ON TIME | 1 | 2 | 3 | 4 | 5 |
| 3. USERS DO NOT INFORMS OF CANCELATION OF ORDERS, INVOICES, ETC TO OTHER USERS. | 1 | 2 | 3 | 4 | 5 |
| 4. LACK OF COORDINATION BETWEEN DEPARTMENTS. | 1 | 2 | 3 | 4 | 5 |
| 5. OTHER DEPARTMENTS DO NOT HANDLE INFORMATION ON TIME. | 1 | 2 | 3 | 4 | 5 |
| 6. THE INFORMATION CHANGED IN THE SYSTEM BUT NOT EVERYBODY NOTICED IT. | 1 | 2 | 3 | 4 | 5 |
| 7. THE INFORMATION IS NOT UP TO DATE BY THE PEOPLE RESPONSIBLE. | 1 | 2 | 3 | 4 | 5 |
| 8. USERS FORGET TO EXECUTE CERTAIN OPTIONS OF THE SYSTEM. | 1 | 2 | 3 | 4 | 5 |
| 9. USERS OF THE SYSTEM DO NOT KNOW HOW TO OPERATE THE SYSTEM CORRECTLY. | 1 | 2 | 3 | 4 | 5 |
| 10. THERE ARE NO STANDARDS TO PUT THE INFORMATION IN THE SYSTEM. | 1 | 2 | 3 | 4 | 5 |

OTHER INTERNAL PROBLEMS THAT HAVE AFFECTED US ARE

| | | | | | |
|---|---|---|---|---|---|
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |
| ____________________ | 1 | 2 | 3 | 4 | 5 |

A.2. METHOD OF ELABORATING THE RESULSTS.

Questions number 1 and 2 just provide information about the company and about the person who answered the questionnaire.

In question number 3 the average of the percentage of product lines which are for export were determined, to get an idea of the participation of the small companies in exports. The average of the percentage of product lines which are for export calculated was 14%.

In question number 4 the first 10 areas are for administrative systems and the last 10 areas are for production and manufacturing support systems. The objective of this question was to determine the percentage of completeness of administrative systems and the percentage of completeness of production systems, so the average of the first 10 areas was calculated and the average of the last 10 areas was also calculated (see table A.1).

Table A.1. Completeness of Information Systems

| **TYPE OF SYSTEMS** | **PERCENTAGE OF COMPLETENESS** |
|---|---|
| ADMINISTRATIVE SYSTEMS | 62 % |
| PRODUCTION SYSTEMS | 30% |

In question number 5 the average of the number of hardware technologies that the companies have was calculated to determine which are the predominant hardware technologies that companies have (see table A.2).

Table A.2. Number of hardware computer technology

| HARDWARE COMPUTER TECHNOLOGY | AVERAGE NUMBER |
|---|---|
| PERSONAL COMPUTERS | 7.06 |
| LOCAL NETWORKS | 0.84 |
| MULTIUSER SYSTEMS | 0.59 |
| MODEM COMUNICATIONS | 1.65 |
| BAR CODE READERS | 1.28 |

In question number 6 the objective was to determine which are the predominant software development technologies that small companies use, so the average use of each of the technology were calculated to determine which are the most important technologies used.

Table A.3. Use of software development technology.

| SOFTWARE DEVELOPMENT TECHNOLOGY | AVERAGE USE OF EACH TECHNOLOGY |
|---|---|
| 3GLs :COBOL/RPG/PASCAL/C | 28% |
| XBASE :(DBASE,FOXPRO, ETC) | 40% |
| SIMPLE DATABASES : ACCESS/PARADOX | 25% |
| 4GLs : ORACLE/INFORMIX/PROGRESS | 9% |
| RAD : VISUAL BASIC/POWER BUILDER | 9% |
| COMERCIAL PACKAGES | 81% |

In question number 7 the average of the percentage of machines that use windows was calculated, to determine the average use of graphical user interface systems. The result was that 79% of the machines that the companies have use windows.

Question number 8 was intended to determine the average investment in Hardware and Software but very few companies answered this question, maybe because they did not wanted to put amounts, so it was not possible to determine these data accurately.

In question number 9 the objective was to determine if companies use a methodology or if they do not use a methodology. So the average use of an specific methodology was calculated and also the average do not use a methodology. This results are presented in table A.4.

Table A.4. Use of methodologies.

| METHODOLOGY | AVERAGE OF COMPANIES THAT USE IT |
|---|---|
| STRUCTURED ANALYSIS | 20% |
| PROTOTYPING | 0% |
| OBJECT-ORIENTED ANALYSIS | 7% |
| NO METHODOLOGY | 73% |

In question number 10 the objective was to determine which external factors affected more the operation of the information systems of the companies, so the degree of importance that each company selected was totaled for each factor to determine which were the most important factors (see table A.5).

Table A.5. Influence of external factors.

| EXTERNAL FACTOR | TOTAL OF POINTS |
|---|---|
| CHANGE OF PRICES OF SUPPLIERS | 104 |
| EXCHANGE RATE OF THE DOLLAR | 114 |
| SCARCITY OF RAW MATERIALS | 62 |
| CANCELATION OF CUSTOMER ORDERS | 74 |
| VARIATION IN INTEREST RATES | 94 |
| SUPPLIERS DO NOT SEND THE RIGHT PRODUCTS | 63 |
| CHANGE IN FISCAL LAWS | 100 |
| CHANGE IN WORKER LAWS | 90 |
| PRODUCTS OF SUPPLIERS DO NOT ARRIVE ON TIME | 81 |
| CUSTOMERS DO NOT PAY ON TIME | 94 |

In question number 11 the objective was to determine which internal factors affected more the operation of the information systems of the companies, so the degree of importance that each company selected was totaled for each factor to determine which were the most important factors (see table A.6).

Table A.6. Influence of internal factors.

| INTERNAL FACTOR | TOTAL OF POINTS |
|---|---|
| PEOPLE DO NOT ENTER INFORMATION CORRECTLY | 110 |
| USERS DO NOT FINISH PROCESSES ON TIME | 98 |
| USERS DO NOT INFORM OF CANCELATION OF ORDERS, INVOICES, ETC. | 94 |
| LACK OF COORDINATION BETWEEN DEPARTMENTS | 91 |
| OTHER DEPARTMENTS DO NOT HANDLE INFORMATION ON TIME | 100 |
| THE INFORMATION CHANGED IN THE SYSTEM BUT NOBODY NOTICED IT. | 83 |
| THE INFORMATION IS NOT UP TO DATE | 88 |
| USERS FORGET TO EXECUTE CERTAIN OPTIONS OF THE SYSTEM | 86 |
| USERS DO NOT KNOW HOW TO OPERATE THE SYSTEM | 95 |
| THE ARE NO STANDARDS TO PUT THE INFORMATION IN THE SYSTEM | 93 |

APPENDIX B. QUESTIONNAIRE ANSWERED BY MYMCE.

QUESTIONNAIRE OF INFORMATION SYSTEMS.

I. COMPANY DATA:

1. NAME: Maderas y Materiales del Centro SA de CV. (MYMCE)
2. ADDRESS:KM 1. CARR. SAN LUIS-RIOVERDE
3. TELEPHONE:_222083__________
4. NUMBER OF EMPLOYEES:_40__

II. DATA OF THE PERSON WHO ANSWERS THE QUESTIONARY:

NAME:_JOSE ANTONIO CONTRERAS____ DEPARTMENT:_GERENTE DE PROYECTOS

III. MAIN PRODUCT LINES OF THE COMPANY.

| | FOR EXPORT (X)YES |
|---|---|
| 1. BASES PARA LEISER | ___ |
| 2. TARIMAS ROCKWELL | ___ |
| 3. ADORNOS PARA CASA | _X_ |
| 4. MUEBLES | _X_ |
| 5. | ___ |

IV. INDICATE THE PERCENTAGE OF AUTOMATIZATION (COMPUTERIZATION) OF THE FOLLOWING AREAS OF THE COMPANY:

| AREAS | %COMPUTERIZED |
|---|---|
| 1. FINANCIAL ACCOUNTING | _100 |
| 2. COSTS ACCOUNTING | ___0 |
| 3. PAYROLL | _100 |
| 4. HUMAN RESOURCES | ___0 |
| 5. INVENTORY OF RAW MATERIAL | _100 |
| 6. INVENTORY OF PRODUCT IN PROCESS | ___0 |
| 7. INVENTORY OF FINISHED PRODUCT | _100 |
| 8. INVOICING TO CUSTOMERS | _100 |
| 9. SALES STATISTICS | _100 |
| 10. PURCHASING | _100 |
| 11. PLANNING THE REQUIREMENTS OF MATERIAL | ___0 |
| 12. PLANNING THE PROCESS OF MANUFACTURING | ___0 |
| 13. PLANNING WORKER LOADS | ___0 |
| 14. PLANNING MACHINE LOADS | ___0 |
| 15. RELASE OF WORK ORDERS | ___0 |
| 16. TRACKING OF WORK ORDERS | ___0 |
| 17. MANTENIANCE TO EQUIPMENT | ___0 |
| 18. DISTRIBUTION | ___0 |
| 19. DESIGN OF PRODUCTS | ___0 |
| 20. ESTIMATION OF COSTS OF MANUFACTURING | ___0 |

V. PLEASE INDICATE IF YOU HAVE THE FOLLOWING HARDWARE AT YOUR COMPANY.

| | HOW MANY ? |
|---|---|
| 1. PERSONAL COMPUTERS | ______5 |
| 2. LOCAL AREA NETWORKS | ______1 |
| 3. MULTIUSER HOSTS | _______ |
| 4. TERMINALS | _______ |
| 5. COMMUNICATIONS BY MODEM | ______2 |

VI. PLEASE INDICATE THE LANGUAGE USED TO DEVELOP YOUR SYSTEMS.

| | NAME OF THE LANGUAGE | IS FOR WINDOWS YES/NO |
|---|---|---|
| 1. COBOL/RPG/PASCAL/C | ___________________ | ______ |
| 2. DBASE/FOXPRO/CLIPPER | ___________________ | ______ |
| 3. ACCESS/PARADOX/REVELATION | ___________________ | ______ |
| 4. ORACLE/INFORMIX/PROGRESS. | ___PROGRESS________ | __YES_ |
| 5. VISUAL BASIC/POWER BUILDER/GUPTA | ___________________ | ______ |
| WE USE ANOTHER LANGUAGE(S): | ________________________ | ______ |
| | ________________________ | ______ |
| WE USE A COMMERCIAL PACKAGE: | ________________________ | ______ |
| | ________________________ | ______ |
| | ________________________ | ______ |

VII. INDICATE THE PERCENTAGE OF MACHINES THAT USE WINDOWS _50%

VIII. INDICATE HOW MUCH HAS THE COMPANY INVESTED IN COMPUTERS:

| | HARDWARE | SOFTWARE |
|---|---|---|
| 1991. | ___1,400__ | ____1,500____ |
| 1992. | ___1,400__ | ____3,000____ |
| 1993. | ___7,000__ | ____1,500____ |
| 1994. | __________ | ____1,500____ |
| 1995. | __________ | ______800____ |
| 1996. | ___1,100__ | ____1,500____ |

IX. DO YOU USE ANY OF THE FOLLOWING METHODOLOGY TO DEVELOP YOUR SYSTEMS:

____ STRUCTURED ANALYSIS AND DESIGN.
____ DEVELOPMENT BY PROPTOTYPES.
____ OBJECT-ORIENTED ANALYSIS AND DESIGN
__X_ WE DO NOT USE ANY METHODOLOGY

INDICATE THE NAME OF THE METHODOLOGY : ____________________________

X. WHICH ARE THE MAIN ELEMENTS OF THE MEXICAN ENVIRONMENT THAT HAVE AFFECTED THE OPERATION OF YOUR INFORMATION SYSTEMS SINCE LAST YEAR:

1 NOTHING <--> 5 MUCH

| | | | | | |
|---|---|---|---|---|---|
| 1. THE CHANGE OF PRICES OF SUPPLIERS | 1 | 2 | X | 4 | 5 |
| 2. THE EXCHANGE RATE OF THE DOLLAR | 1 | 2 | 3 | 4 | X |
| 3. THE SCARCITY OF RAW MATERIALS | 1 | 2 | 3 | X | 5 |
| 4. THE CANCELATION OF ORDERS BY CUSTOMERS | X | 2 | 3 | 4 | 5 |
| 5. THE VARIATION IN INTEREST RATES | 1 | 2 | 3 | X | 5 |
| 6. SUPPLIERS DO NOT SEND THE RIGHT PRODUCTS THEY MAKE MISTAKES | 1 | 2 | 3 | 4 | 5 |
| 7. CHANGE IN FISCAL LAWS IVA/ISR/ETC | 1 | 2 | 3 | 4 | X |
| 8. CHANGE IN WORKER LAWS IMSS/SAR/ETC | 1 | 2 | 3 | 4 | X |
| 9. PRODUCTS OF SUPPLIERS DO NOT ARRIVE ON TIME | 1 | 2 | X | 4 | 5 |
| 10. CUSTOMERS DO NOT PAY ON TIME | 1 | 2 | 3 | X | 5 |

OTHER PROBLEM OF THE MEXICAN ENVIRONMENT THAT HAVE AFFECTED:

| | | | | | |
|---|---|---|---|---|---|
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |

XI. INTERNALLY WHICH ARE THE FACTORS THAT HAVE AFFECTED THE CORRECT OPERATION OF THE INFORMATION SYSTEMS.

1 NOTHING <--> 5 MUCH

| | | | | | |
|---|---|---|---|---|---|
| 1. PEOPLE DO NOT ENTER THE INFORMATION CORRECTLY | 1 | 2 | 3 | 4 | X |
| 2. USERS DO NOT FINISH PROCESSES ON TIME | 1 | 2 | 3 | X | 5 |
| 3. USERS DO NOT INFORMS OF CANCELATION OF ORDERS, INVOICES, ETC TO OTHER USERS. | 1 | 2 | 3 | X | 5 |
| 4. LACK OF COORDINATION BETWEEN DEPARTMENTS. | 1 | 2 | X | 4 | 5 |
| 5. OTHER DEPARTMENTS DO NOT HANDLE INFORMATION ON TIME. | 1 | 2 | 3 | 4 | X |
| 6. THE INFORMATION CHANGED IN THE SYSTEM BUT NOT EVERYBODY NOTICED IT. | 1 | 2 | X | 4 | 5 |
| 7. THE INFORMATION IS NOT UP TO DATE BY THE PEOPLE RESPONSIBLE. | 1 | 2 | X | 4 | 5 |
| 8. USERS FORGET TO EXECUTE CERTAIN OPTIONS OF THE SYSTEM. | 1 | 2 | 3 | X | 5 |
| 9. USERS OF THE SYSTEM DO NOT KNOW HOW TO OPERATE THE SYSTEM CORRECTLY. | 1 | 2 | 3 | 4 | X |
| 10. THERE ARE NO STANDARDS TO PUT THE INFORMATION IN THE SYSTEM. | 1 | 2 | X | 4 | 5 |

OTHER INTERNAL PROBLEMS THAT HAVE AFFECTED US ARE

| | | | | | |
|---|---|---|---|---|---|
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |
| ________________ | 1 | 2 | 3 | 4 | 5 |

## APPENDIX C. BASIS OF THE METHOD OF ECONOMIC JUSTIFICATION.

The method of economic justification is based in reference 36 and 37, this appendix is a summary of references 36 and it is presented to clarify the basis of the method of economic justification.

The adoption of new manufacturing technologies which include computers, machines, computer networks and software normally requires high investments, nevertheless companies are forced to adopt these technologies to compete in a global economy, so the correct economic evaluation of the benefits of these technologies is important.

But the decision of adopting new technologies, which involve many components, which will be implemented in a large period of time in several phases involve many uncertain factors, among them the uncertainty of the cash flows of the project due to the varying economical conditions, market fluctuations, production variations and also because there is limited sample information that does not permit to assume a prior distribution of the cash flow. Because of this uncertain components of the decision it is safer to adopt a discrete decision process in which the decisions to implement a project in several phases will be evaluated in the beginning of each phase depending on the results of the previous phases.

The general assumptions of this discrete decision approach are presented in this paragraph. First the net present value (NPV) , which is a discounted sum of a series of cash flows, normally is presented in new projects with three values : optimistic, most-likely and pessimistic. The second assumption is that in this projects there is a high degree of uncertainty in the points of cash flow occurrences, but that these projects have a stable behavior in the operating portion of the implemented system, because when the system is working you can predict easier its behavior. The third assumption is that as there are generally very few observations of the cash flow, the distribution of periodic cash flows can be modeled using a discrete approximation.

The first part of the decision method would be to calculate and estimate the NPV of the cash flows of each period with the three ranges of optimistic, most-likely and pessimistic values. The NPV of the cash flow will be discounted at the minimum attractive rate of return (MARR) for the company. After that a decision tree is developed to specify the decision points and alternatives of each decision. Then the NPV of the cash flows with the three points are used to fit a distribution (in the case of this method a triangular distribution). Then the expected value of the sum of the cash flow is calculated, to finally take an initial decision based on these results.

After the initial decision is taken the first phase of the project is implemented, when this project is finished the data from this project will be used to refine the decision process and adjust the expected values of the NPV, so that the decision of going on to the next phase can be evaluated based on the results of the first project, this permits a "pay as you go" approach, in which the risk is minimized because the decisions are being revised after each phase.