Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 10, Issue, 09, pp. 39816-39831, September, 2020
https://doi.org/10.37118/ijdr.19289.09.2020

RESEARCH ARTICLE **OPEN ACCESS**

APPLICATION OF A SYSTEMS ENGINEERING APPROACH TO INTEGRATED PRODUCT DEVELOPMENT: A PEDAGOGICAL ROADMAP

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ARTICLE INFO

Article History:

Received 11th June 2020
Received in revised form
29th July 2020
Accepted 07th August 2020
Published online 23rd September 2020

Key Words:

Systems Engineering, Product Integrated Development, Video surveillance system, Pedagogical Roadmap.

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ABSTRACT

This article describes the approach of the systems engineering to develop a Video Surveillance System. It used the concepts of integrated development and total vision framework as lines of direction for concept of the related system. The approach adopted the analysis of the interactions between product, process and organization during all the life cycle. It is consensus the continuous success of a development organization now is determined by its capacity continuously to shorten the time of the development cycle, to reduce cost, to manage risks and, at the same time, to improve the performance of the product. In the case specific of an organization that offers monitoring services can be emphasized one of the more excellent competitive advantages is the quality of the customer's attendance as much as in emergency situations and in common occurrence of accidents or situation as maintenance, contract support, acquisition and contract rescission. The approach of systems engineering can provide then a methodology capable to separate, to simplify and to prioritize the main interests in question, in order to maximize the benefits of all the stakeholders.

Citation: ***Herlandí de Souza Andrade, Laerte José Fernandes, Evandro Sinisgalli, Antonio Iacono et al. 2020.*** "Application of a Systems Engineering approach to integrated product development: a pedagogical roadmap*", International Journal of Development Research*, 10, (09), 39816-39831.

INTRODUCTION

The continued success of an organization focused on new product development is determined by its ability to continuously shorten the development cycle time, reduce costs, manage risks and, at the same time, improve product performance. Achieving these goals is highly dependent on the organization's ability to deal with changes and the complexity that can result from them. This involves identifying the elements that are likely to change and the interactions between them, early in the development of the product's life cycle, at its conceptual stage. These elements are not only of the product, but also part of the product lifecycle processes and the organizations that perform them. Traditional development approaches provide only a partial view of these elements and their interactions. Integrated product development is the process from which information about the market is transformed into the information and goods necessary for the production of a product for commercial purposes (Clark and Fujimoto, 1991). This is a systematic activity necessary from the identification of the market and the needs of users to the sale of products capable of meeting these needs. These activities are involved with the product, processes, people and organization (Pugh, 1996). Thus, this paper aims to show the application of an integrated development process using a systems engineering approach, considering the Total View Framework (TVF), developed by Loureiro (1999), in order to find a balanced solution throughout the cycle of life to satisfy the stakeholders of a video monitoring system. The TVF, according to Loureiro (1999) is a modeling that integrates the product, its life cycle processes and the organizations that perform them, through the analysis of requirements, functional and physical, at all levels of the product hierarchy, deriving attributes as properties emerging from a fully integrated system. The application of the framework will be demonstrated through an integrated development project for a video monitoring system, as previously described. The growth of the national and international market, in the area of surveillance and monitoring, has been driven by the increase in the crime rate, by the growth of asymmetric threats such as terrorism (Lipton, 2004), by the evolution of the technologies involved in the production of electronic components and mainly due to the growing need for security on the part of society. According to ABESE (2020). in 2018, the electronic security sector had revenues of approximately R$ 6.52 billion in Brazil. An increase of 8%, taking into account the previous year.

> “Currently, there are about 815 thousand properties with electronic security systems in the country. Among the main requests are video surveillance and wired and wireless alarm systems. IP video surveillance cameras are the best-selling products in the public security and property sector. According to the survey, IP cameras represent 36% of the best-selling products - topping the list. However, analog cameras still represent a good share of sales in Brazil, approximately 30%. Even so, among the companies that serve the video surveillance sector, 82% work with IP products and services, while 72% still work with analog solutions. The security market is optimistic for the coming years. For the next three years, the main bets in the segment are: the use of security applications on mobile devices with 94%, a cloud platform for integrating hardware and software systems with 84%, home automation integrated with the alarm system with 81%, IoT with 80%, self-monitoring services with 64%, artificial intelligence with 63%, remote ordinance with 60%, applied intelligence systems for behavior analysis with 55% and audio monitoring with 27%. About 95% of the industry intends to launch new products” (ABESE, 2020).

There are some discrepancies between the objective and the results achieved by the installation of the current video surveillance systems today:

1. They work under the research paradigm instead of the prevention paradigm and provide an infrastructure only for capturing, storing and displaying videos, leaving the task of detecting threats to human operators only (Hampapur, 2003);
2. Studies reveal that human beings have a low capacity to retain attention, at acceptable levels, to identify specific events on video monitors (Green, 1999); and;
3. Today's systems are, on a large scale, completely analog. They have several limitations and operating difficulties inherent to these platforms, such as difficulties in recovering parts of video of interest, low quality of the recorded image and low storage capacity.

The characteristics indicated above, on the current systems, impose a very low effectiveness in the identification of events of interest and high costs of a posteriori investigation. Great academic efforts have been made to develop systems that provide automation in video surveillance systems (Loureiro, 1999; Naylor, 2003; Collins et al., 2000). The main area of knowledge involved is known as Computer Vision. Despite recent advances in academic research in this area, there are still no commercial products to track its results in recent years. Many technologies dominated today and available academically have not yet been incorporated into commercial products, for example, techniques for recognizing human behavior, tracking people, identifying people and vehicles.

A recent and prominent trend is the digitization of all collected information, automation of monitoring and video search through the use of computer vision algorithms and development of shared systems architectures, leaving systems centralized only for applications with a reduced number of cameras. We can see that the available and really effective technologies for the monitoring and surveillance systems have been disseminated, leaving room for differentiation and innovation, basically in the model adopted by the organization. For this, it is possible to use systems engineering as a tool to define what the organization should offer as a product and service, along with the various solution alternatives, including characteristics such as partnership benefits and a product value proposal.

Integrated development using a Systems Engineering approach, through the Total View Framework: Systems Engineering is a collaborative approach of inter and multidisciplinary engineering to derive, evolve and verify a balanced solution / system, throughout the life cycle, that meets the expectations of the interested parties (Loureiro, 1999). Systems engineering is used mainly for the development of complex products (Andrade, 2008). According to Andrade and Loureiro (20018A, 2018B, 2018C and 2017) systems engineering consists of two important disciplines: the domain of technical knowledge in which the engineering system operates and the management of systems engineering. For the application of the Systems Engineering concepts, the TVF, developed by Loureiro (1999), will be adopted in this work. The TVF aims to help manage the complexity associated not only with the product itself, but also with the interactions between the product, its life cycle processes and attributes of the organization. Figure 1 shows TVF.

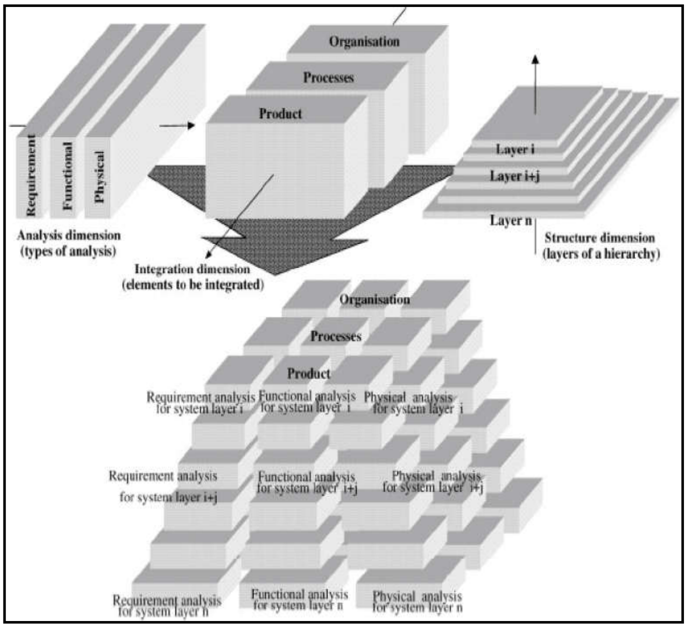

Figure 1. Estrutura da Visão Total (Loureiro, 1999)

The TVF is a modeling structure that integrates the product, its life cycle processes and its executing organizations along the requirements, functional and physical analysis processes, at all levels of the product hierarchy, deriving attributes as emerging properties from all over an integrated system. The total visualization structure applies the systems engineering process to the simultaneous engineering of products, processes and organization (Loureiro, 1999).

The TVF, according to Loureiro (1999) aims to identify the attributes, not only of the product, but also of its life cycle processes and its executing organizations and the relationships between these attributes. These attributes are identified by mirroring a system engineering process through three analysis processes: requirements, functional and physical analysis. The analysis processes are applied at all levels of the product detailing structure. The analysis processes start by capturing and analyzing the requirements of products, processes and organization, simultaneously, from the beginning. The analysis continues through the simultaneous functional and physical analysis of the product, process and organization. Therefore, the system, object of the analysis, is composed not only by the product itself, but also by the life cycle processes and their performing organizations.

According Loureiro (1999):

- The product element refers mainly to the final products. The end products perform the operations function and are delivered to an end user. The product element can also include product activation, depending on the scope of the development project. Product models capture information about the interactions between product functions and components.
- The elements of the process refer to the life cycle processes of the final product. In general, a process is a set of interrelated activities, actions or tasks that together transform inputs into products. IEEE-Std-1220-1994 defines eight essential life cycle processes: development, manufacturing, testing, distribution, operations, support, training and disposal. Process models capture information about the interactions between activities, actions or tasks in the processes.
- The organization element refers to organizations that implement life cycle processes. An organization is a structured set of resources that can play a role in carrying out a particular class of tasks. These resources can be human (people) or technological (machines, applications, etc.). Organization models capture information about the interactions between these resources to carry out a process. Process elements refer to a product's life cycle processes. The organization element refers to the organization that performs these life cycle processes. Often, the organization is configured to perform a certain process in the life cycle of many products. For example: a production organization can be set up to produce 1000 different products per day; a service station is configured to support many different types of cars.
- The analysis dimension defines the different types of analysis that are performed to simultaneously identify the requirements and attributes of the elements of the product, process and organization of the system. They are requirements analysis, functional analysis and physical analysis.
  - The requirements analysis aims to establish what the system should do (functional requirements), how well it should be done (performance requirements) and under what conditions it should be done. It also governs, as appropriate, the logical and physical characteristics of the system.
  - Functional analysis aims to derive a functional architecture and describe it by identifying the functional attributes associated with its elements. It describes the problem defined by the requirements in more detail. This must be achieved by translating the validated set of technical requirements into a functional architecture. A first set of functions is derived from requirements. The functional architecture describes these functions and their interactions and their breakdown into subfunctions.
  - Physical analysis aims to derive a physical architecture and describe it by identifying the physical attributes associated with its elements. It models the physical architecture resulting from the synthesis sub-process, as, for example, defined by the IEEE-Std-1220-1994 standard.

METHODOLOGY

The methodology used for this research is the case study, which will be applied considering the specification of requirements for the development of products, through the requirements, processes of functional and physical analysis. The requirements analysis process consists of identifying an initial set of requirements for poorly defined stakeholders and transforming them into a complete and consistent set of technical requirements. The set of technical requirements contains conditions, functional and performance requirements for the final products, their life cycle process and their performing organizations. An indication of whether it can be compensated or not is assigned to each requirement in the requirements set. The resulting set of technical requirements must be traceable to the initial requirements and other identified requirements of the interested parties, to any assumptions made by the developers and to any established objective of the development organization.

Functional analysis aims to identify the functional boundary of the system, the functions provided by the boundary, the functional architecture and the characteristics of the elements of the functional architecture. The basic sources of functionality are technical requirements, collected from stakeholder requirements. An analysis of the behavior of each function allows to identify inputs and outputs and how the functions are interrelated. The stakeholder analysis, considering Andrade (2008) and Deglane et al. (2007A, 2017B) is important to identify your needs and expectations, so that they stop providing the product, process or organization with characteristics that meet those needs or expectations. A functional architecture is obtained so that we can have an image of the system's functions and their interactions. Each architectural function is described using functional characteristics. We seek to adapt functional analysis to the simultaneous and integrated development of the product, its life cycle processes and the organizations that carry them out. Functional analysis begins by defining what is within and outside the scope of the system. Thus, the main functions of the system are defined and the elements of the environment that interact with the systems are identified. The main functions include the product's mission/objective, the life cycle processes and their scenarios, as well as the business processes that implement the life cycle processes. The physical analysis proposed in this work is essentially a model for the activity. It aims to identify the elements that make up the physical architecture of a product, its life cycle processes and the organizations that carry them out, the interaction between these elements and the characteristics. The physical analysis can be understood, therefore, as the analysis for the implementation of the product, processes and organizations that form the system. Products, processes and organizations are analyzed interactively.

Development: In this section, the development stage of this study will be presented, aiming to provide a pedagogical guide for the application of TVF.

Stakeholder analysis and requirements analysis: The requirements analysis consisted of identifying an initial set of stakeholder requirements and transforming them into a set of technical requirements. This set of technical requirements contains performance, functional and product condition requirements, their life cycle processes and the organizations that perform them. We tried to adapt the requirements analysis with the simultaneous and integrated development of the product, its life cycle processes and the organizations that perform them. Figure 2 provides a complete view of the requirements analysis.

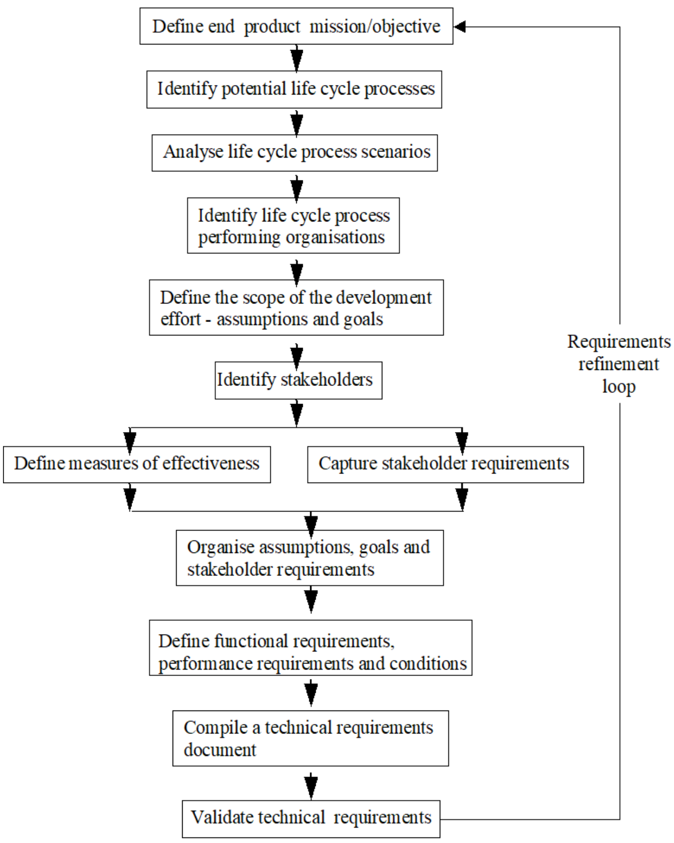

Figure 2: Requirements Analysis Roadmap (Loureiro, 1999)

Definition of the mission/objective of the product: The mission of the video surveillance system, its purpose and reason for existing, is to provide automated electronic surveillance for industrial warehouses.

Identification of potential life cycle processes: Considering the nature of the product, whether it is software, hardware, electronic, mechanical or mechatronic, the main non-operational functions have been identified. These non-operational functions are the subject of product lifecycle processes. The processes for the system are: Development; Marketing, Sales and After-Sales; Assembly; Distribution; Installation; and Support.

Analysis of life cycle process scenarios: The scenarios refer to the functions identified in the life cycle processes. The Development and Marketing, Sales and After-Sales processes were chosen to illustrate the scenarios.

- Development
  - Identifying stakeholder needs
  - System design
  - Componentsuppliers
  - Making prototypes
  - Validationandtesting
- Marketing, Sales and After Sales
  - Map the target market
  - Productpositioning
  - Sales plan
  - Customersatisfaction assessment
  - Evaluationofsuggestions
  - Advertising
  - Feedback for development
  - Sales

Identification of organizations that perform the life cycle processes: For strategic reasons the company's core business is Product Development and Marketing, Sales and After-Sales. Assembly, Distribution, Installation and Support processes will be entrusted to other companies.

Defining the scope of the development effort - assumptions and goals: Product development processes and marketing, sales and after-sales are part of the company's development effort. The assembly, distribution, installation and support processes carried out by third parties are outside the company's development scope. However, the requirements of these organizations that affect the product and the life cycle processes will be considered when solving the system.

A hypothesis and two goals are also proposed by the company.

- Goal: 95% availability of the system in operation.
- Goal: company to reach 10% market share in two years.
- Hypothesis: demand for a security system will grow more and more.

Stakeholder identification: The people and organizations that are affected and affect the product, the processes of their life cycle and the organizations that perform them were identified, according to the following sub-items.

Product: To identify product stakeholders, we analyze people or organizations that have direct interaction with the monitoring system during its potential life cycles, as shown in Figure 3.

Interests of Product Stakeholders:

- Customers: security;
- Supplier: offeringtechnology;
- Assembler: sales predictability, scale and technical knowledge of the product;
- Distributor: exclusivity, transport security, profitability;
- Support: exclusivityandprofitability.

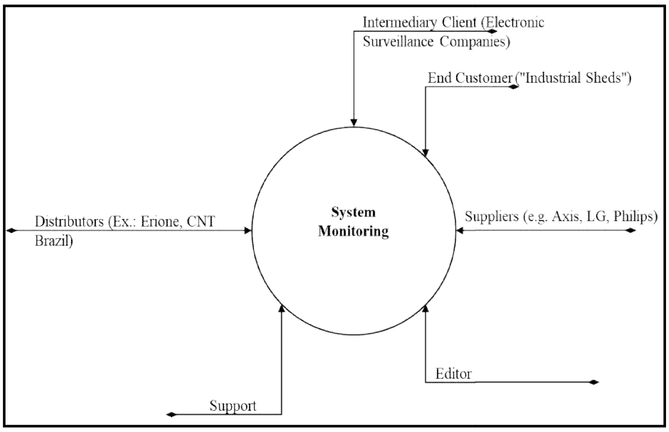

Figure 3. Product Stakeholders - Monitoring System

Process: For the identification of the stakeholders of the processes, we analyze the people or organizations that have direct interaction with the different processes of the life cycle, as indicated in Figure 4, 5, 6, 7, 8 and 9.

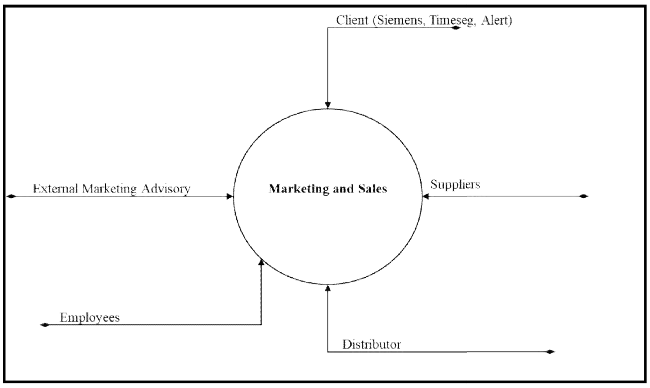

Figure 1. Process Stakeholders - Marketing, Sales and After Sales

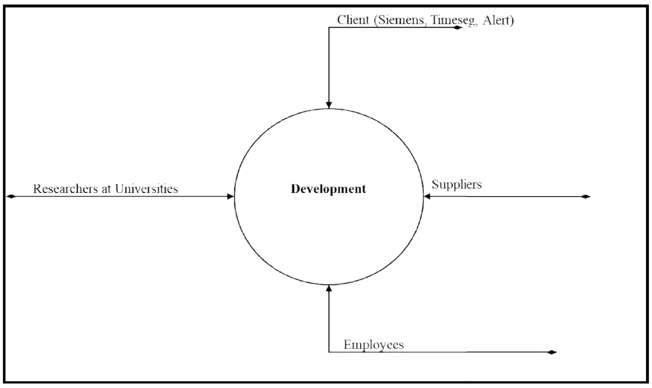

Figure 5. Process Stakeholders – Development

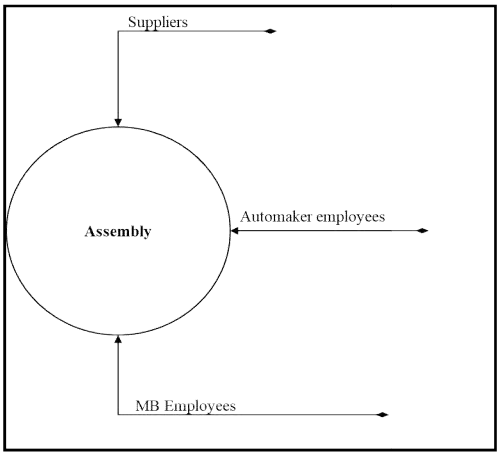

Figure 6. Process Stakeholders - Assembly

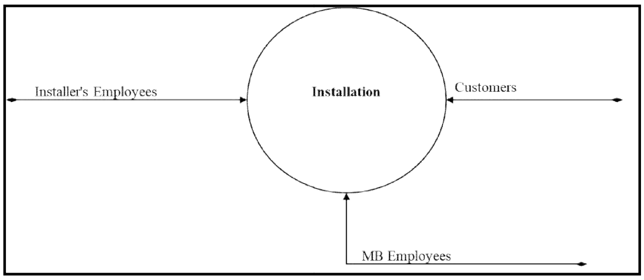

Figure 7. Process Stakeholders – Installation

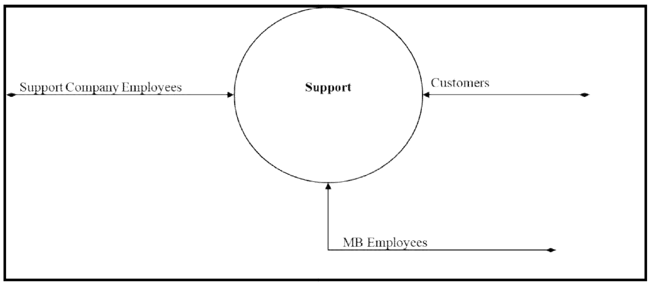

Figure 8. Process Stakeholders – Support

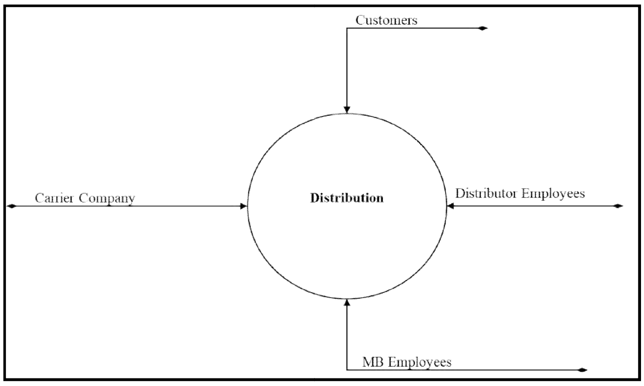

Figure 9. Process Stakeholders – Distribution

Interests of Process Stakeholders:

- Development:
  - Employees: knowtechnology;
  - Customers: meeting theirneeds;
  - Suppliers: providetechnology;
  - Researchers: applyingtheirknowledge;
  - Development Manager: deadline, risk and cost.
- Assembly:
  - Suppliers: predictability and scale;
  - Employees: know how the system works.
- Marketing, Sales and After Sales:
  - Customer: technical knowledge of the seller;
  - Distributor: productattractiveness;
  - Supplier: predictability;
  - Advisory: know the market;
  - Employee: training.
- Distribution:
  - Client: support, proximity and delivery time;
  - Carriers: optimization of logistics;
  - Employee: training;
  - Employee MB: delivery information.
- Support:
  - Employee: training;
  - Employee MB: information about problems;
  - Customers: servisse.
- Installation:

- Employee: training;
- Customer: servisse;
- MB Employee.

Organization: In this case, to identify the organization's stakeholders, we analyze people or organizations outside the business and who may have some relationship with the business, as shown in Figure 10.

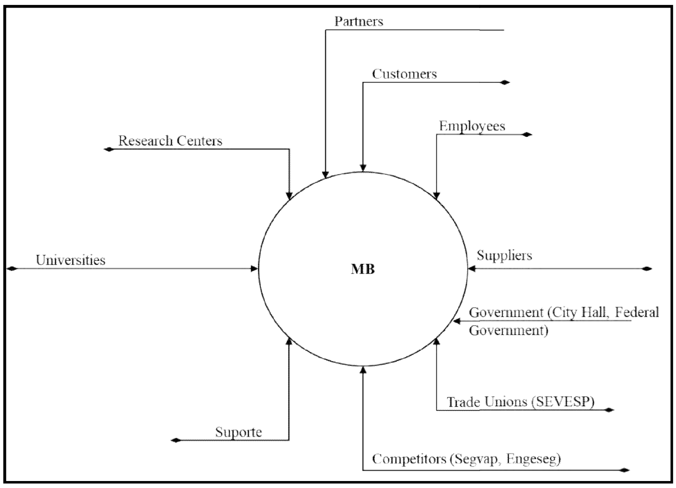

Figure 10. Organization Stakeholders – MB

Interests of the Organization's Stakeholders:

- Partners: returnoninvestment;
- Customers: security, meeting needs;
- Employees: careerdevelopment;
- Suppliers: long-termpartnership;
- Competitors: benchmark;
- Government: taxcollection;
- Unions: wages.

Definition of effectiveness measures: Effectiveness measures are the metrics by which stakeholders will measure their satisfaction with the system's solution, a consequence of the development effort. In order to identify them, the various interests of the stakeholders in relation to the product, processes and organization were considered. The metrics defined in this work are listed in sub-item 4.1.8.

Identification of stakeholder requirements and preparation of the technical requirements document: Considering the definitions previously made, the identification of stakeholder requirements is described in Tables 1, 2, 3, 4, 5, 6, 7, 8 and 9.

CA - Support waiting time must be less than or equal to 24 hours and punctuality must be equal to or less than 30 minutes before the delivery deadline.
CB - The storage device must have the capacity to store compressed digital video for 20 days, at a rate of 5 FPS and a resolution of 720 x 680 pixels/inch.
CC - The system must transmit and store encrypted videos so that only system administrators have access to the content.
CD - The seller must have experience greater than or equal to 2 years in the industry.
CE - The data link must be able to support the provision of videos in real time, with a resolution of 320 x 280 pixels / inch at a rate of 15 FPS.
CF - The system should provide search for video clips by events and desired date / time.
FA - The supplier requires that the payment term be less than or equal to 20 working days after the delivery of the component.
FB - The supplier requests to receive the product purchase and delivery forecast 20 days in advance.
FC - The supplier wants to have a long-term partnership, for a period greater than or equal to 2 years.
DA - The distributor requires exclusivity in distribution, obtaining a 15% net margin.
DB - The distributor needs the complete specification to transport the product, so as not to cause damage.
DC - The distributor wants the product to be highly liquid, with a maximum turnover of 30 days.
MA - The assembly company requires 40 hours / semester training for its employees, in order to learn about the operation and installation of the product and the improvement of its personnel.
MB - The assembly company needs to have the sales portfolio of the future month to balance the staff and schedule its purchases.
FA - Employees want to have an access plan with a 10-year vision.
PA - Researchers at universities and research centers want to apply their technical knowledge through 24 consultations/year.
GA - The city hall and the federal government must collect taxes in accordance with the company's tax framework.
S.A - Partners must obtain 25% return on investments (ROI)
GDA - The development manager establishes that the risk of system failure must be low.
GDB - The development manager determines that the project's completion period should not exceed six months.
GDC - The development manager encourages that the real cost of the project should not exceed 5% of the total budgeted cost.

Organization of stakeholder requirements: The requirements identified with the stakeholders are organized and classified in Table 10.

Requirements Classification Legend:

- Type (condition, function, performance or interface)
- Compliance (mandatory, desirable or optional)
- Status: to be defined (def), to be reviewed (revised), to be approved (apr), to be deleted (del) and to be verified (see).
- Allocation-ppo: for the product, process and organization
- Constraint: yes / no

Validation of technical requirements

It ensured that the technical requirements are consistent and complete with respect to the requirements of the stakeholders, goals, hypotheses and restrictions identified. After this stage, a loop was performed to refine the requirements, returning to the first stage, defining the mission/objective of the product.

Table 1. Customer requirements

Item	Customer	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
CA	Delivery time/Proximity						X
CB	Store	X					
CC	Restricted Access	X					
CD	Trained seller					X	
CE	Real-time video broadcast	X					
CF	Search	X					

Table 2. Supplier requirements

Item	Supplier	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
FA	Payment deadline	X					
FB	Demand			X	X		

Table 3. Distributor/support requirements

Item	Distribuidor/Suporte	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
DA	Exclusivity/Profitability	X					
DB	Avoid losses	X					
DC	Product turnover				X		

Table 4. Assembler requirements

Item	Fitter	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
MA	Training	X					
MB	Sales portfolio	X					

Table 5. Employee requirements

Item	Employee	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
FA	Career plan						X

Table 6. Researcher's requirement

Item	Researcher	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
PA	Knowledge		X				

Table 7. Government requirements

Item	Government	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
GA	Taxes						X

Table 8. Membership requirement

Item	Shareholder	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
SA	Return on investment						X

Table 9. Development manager requirements

Item	Development Manager	Product	Process				Organization
			Development	Assembly	Marketing/Sales	Distribution	
DA	Risk of system failure		X				
DB	Deadline for completion		X				
DC	Actual project cost		X				

Table 10. Classification of Requirements

Number	Text	Concern	Type	Compliance	Status	PPO	Constraint
Customer							
CA	Delivery time/Proximity	Punctuality	P	M	def	prod	y
CB	Store	Documentation	F	M	apr	prod	y
CC	Restricted Access	Secrecy	C	M	apr	prod	y
CD	Trained seller	Credibility	C	D	def	org	y
CE	Real-time video broadcast	Surveillance	F	D	apr	prod	n
CF	Search	Search	F	M	apr	prod	y
Supplier							
FA	Payment deadline	Working capital reduction	C	D	ver	org	n
FB	Demand	Predictability	P	D	ver	proc	n
Distribuidor/Suporte							
DA	Exclusivity/Profitability	Exclusivity	I	D	revi	org	n
DB	Avoid losses	Security	C	D	def	proc	n
DC	Product turnover	financial liquidity	P	D	revi	org	n
Fitter							
MA	Training	Knowledge	C	D	revi	org	n
MB	Sales portfolio	Forecast	I	D	revi	org	n
Employee							
FA	Career plan	Career evolution	C	D	ver	org	n
Researcher							
PA	Knowledge	Consulting	P	D	revi	org	n
Government							
GA	Taxes	Contribution	C	M	def	org	y
Shareholder							
SA	Return on investment	Profit	P	D	def	org	y
Development Manager							
DA	Risk of system failure	Minimize risk	F	M	rev	proc	y
DB	Deadline for completion	Shortest term	P	D	def	proc	n
DC	Actual project cost	Low cost	P	D	def	proc	n

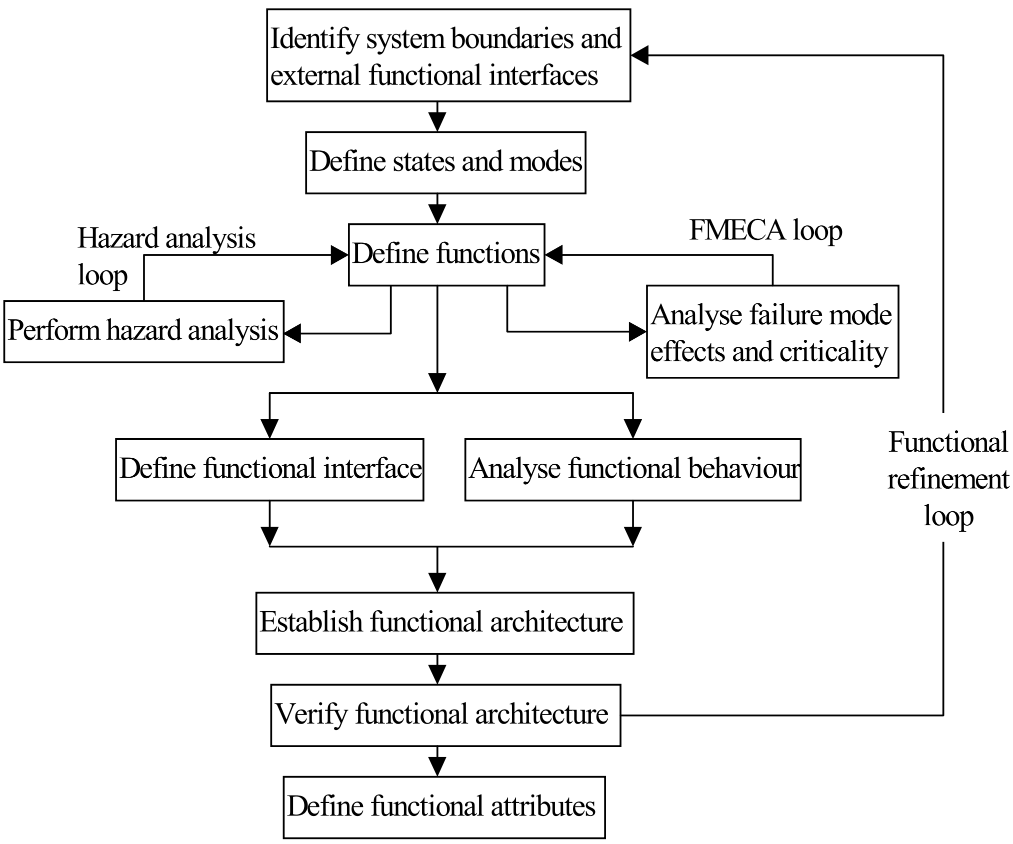

Figure 11. Functional analysis roadmap(Loreiro, 1999)

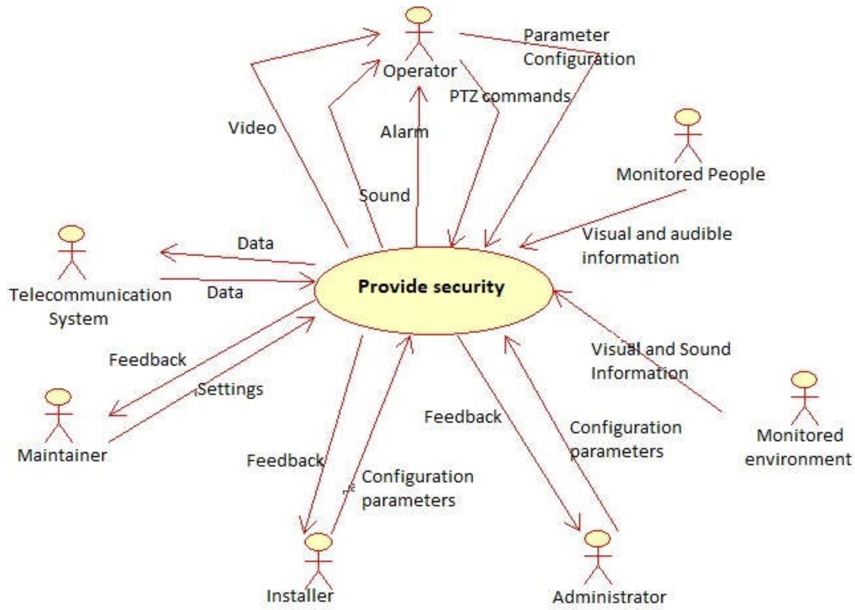

Figure 12. Video surveillance system context diagram

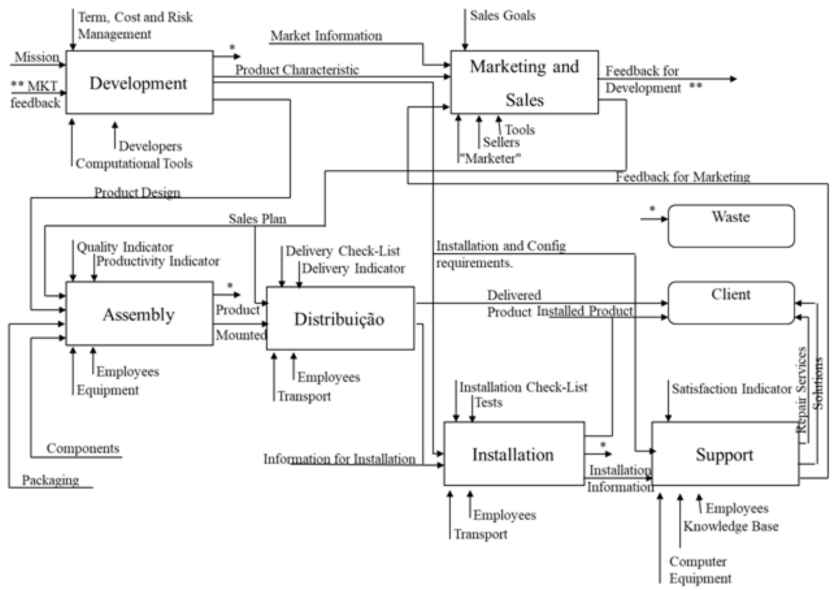

Figure 13. Process - Diagram of behavior with functional analysis of a video surveillance system

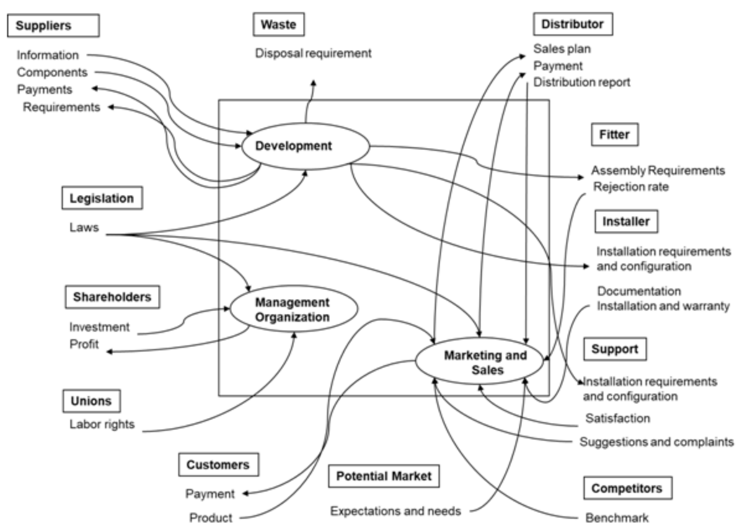

Figure 14. Organization - Use-Case Diagram (DCU) with an organization's interfaces with its environment

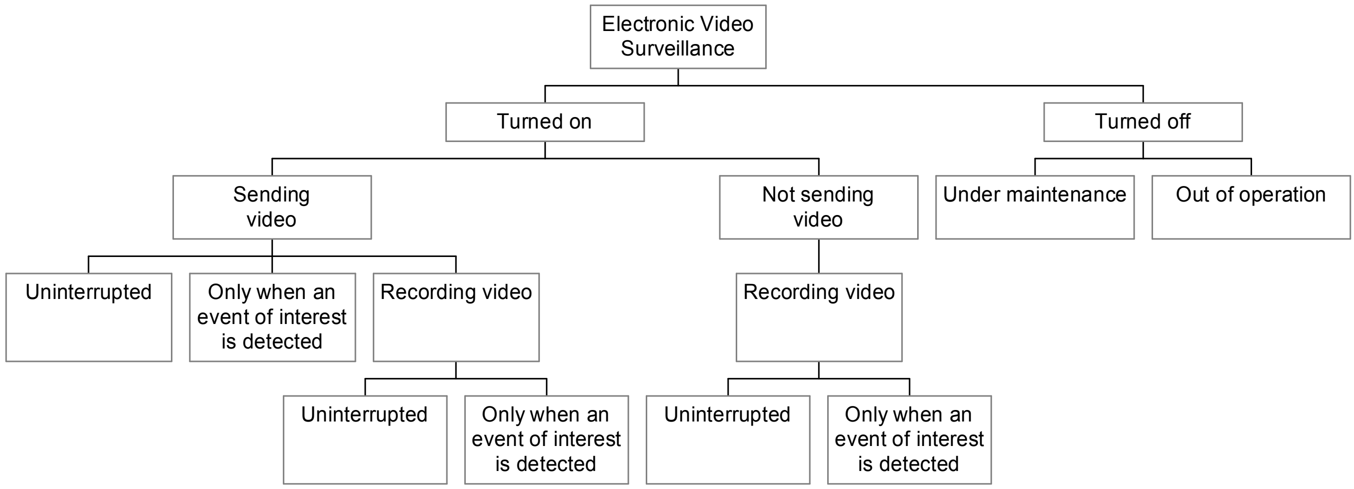

Figure 15. Possible states for the Video Surveillance System

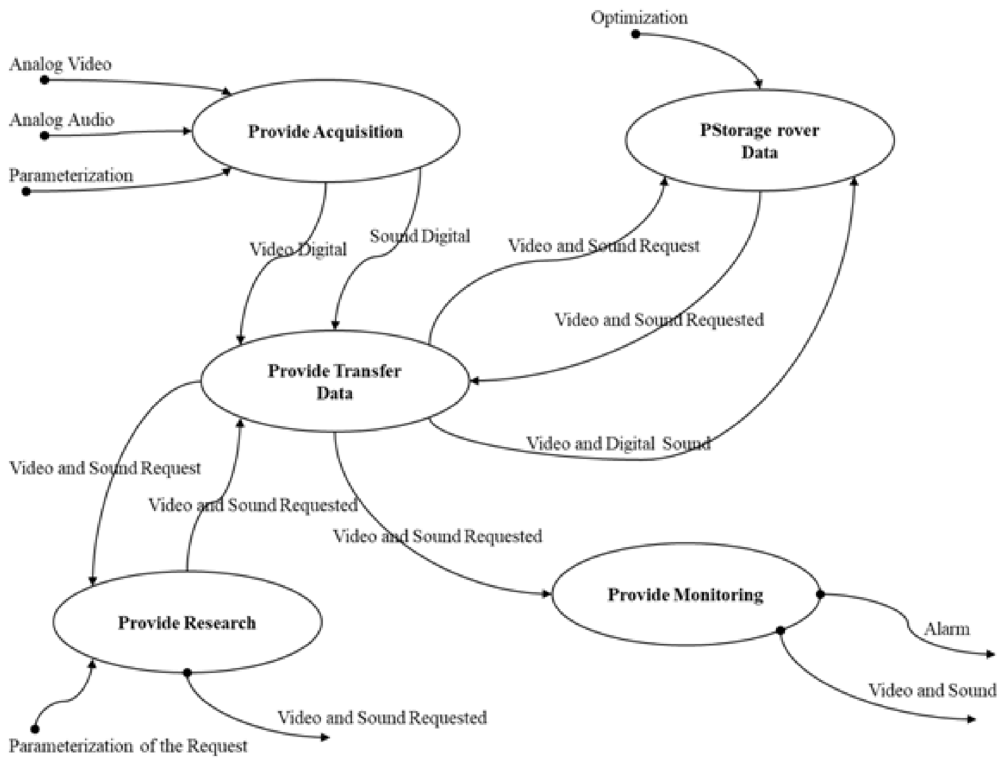

Figure 16. Product - Functional decomposition of the video surveillance system

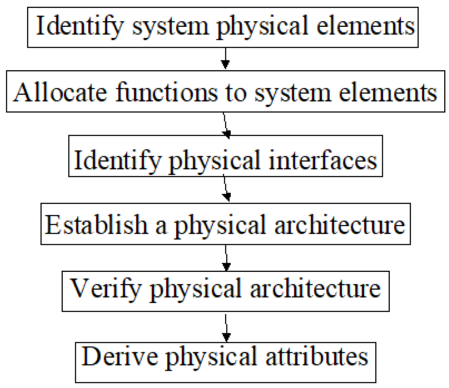

Figure 17: Physical analysis roadmap (Loureiro, 1999)

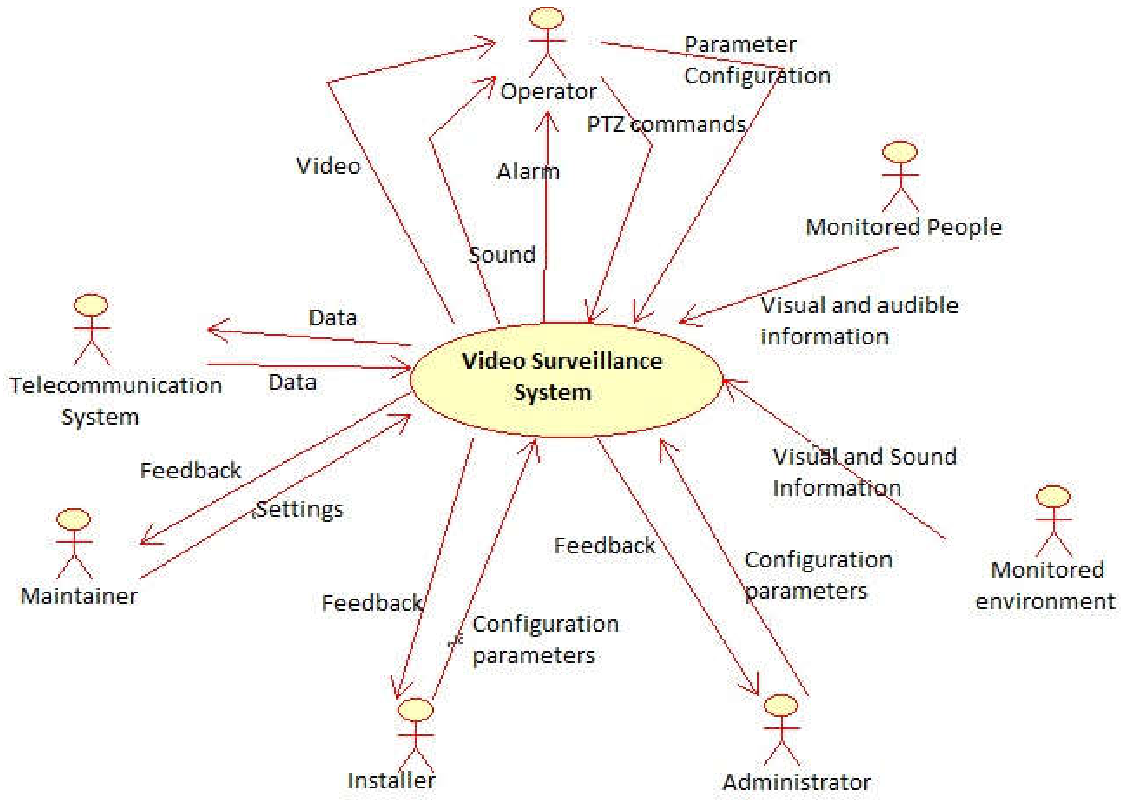

Figure 18. Product - DFD representing the video surveillance system and its relationship with the environment

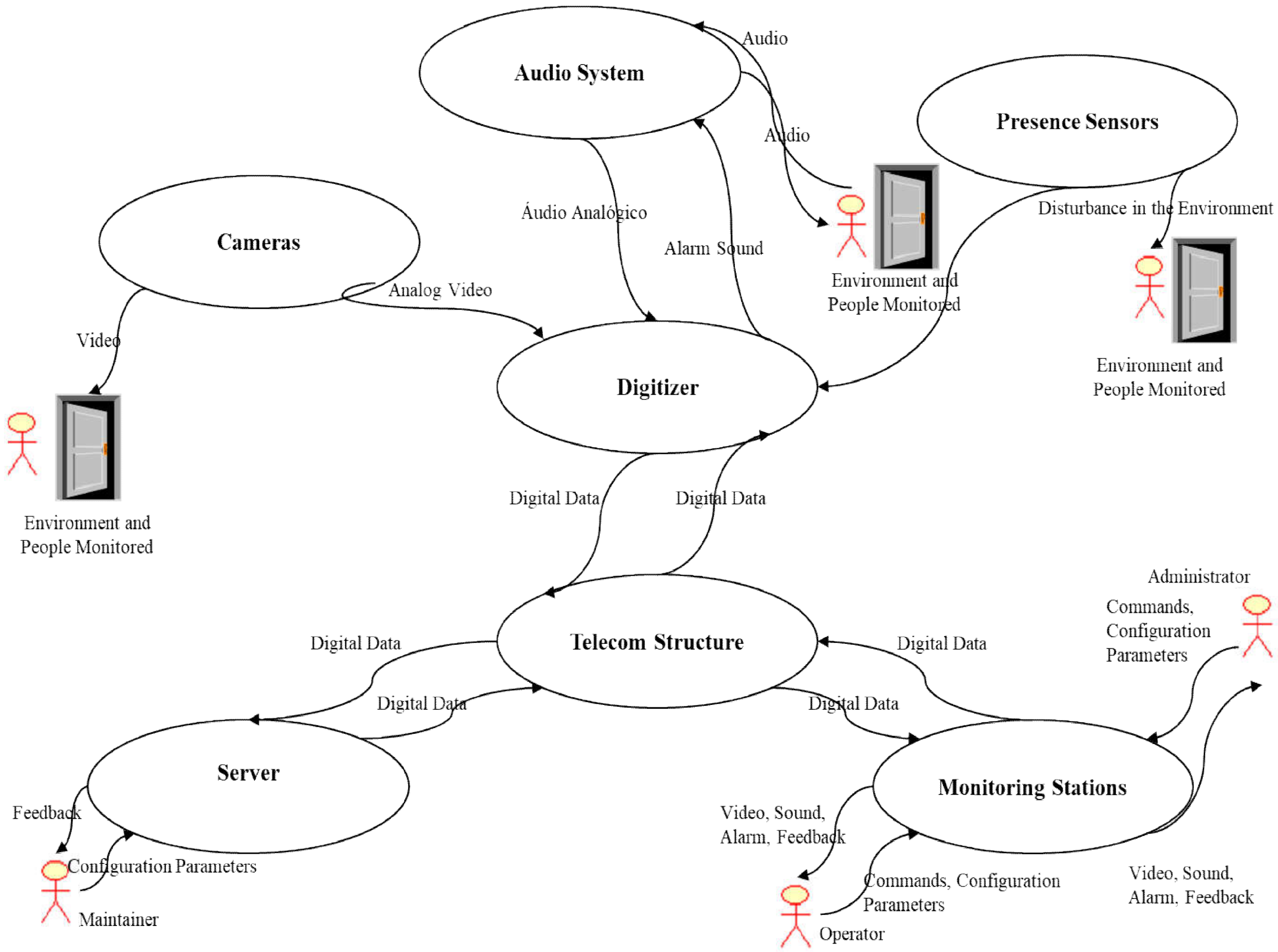

Figure 19. Product - Architecture flow diagram of the video surveillance system

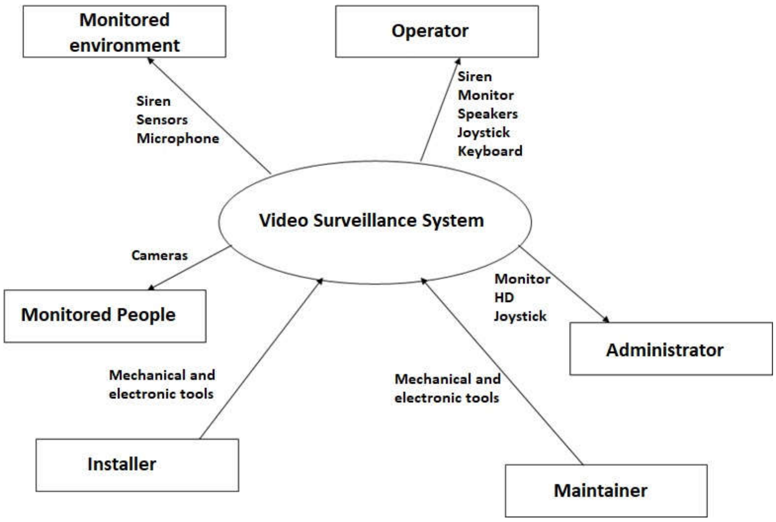

Figure 20. Product - FBD representing a monitoring system and its physical interfaces with the environment

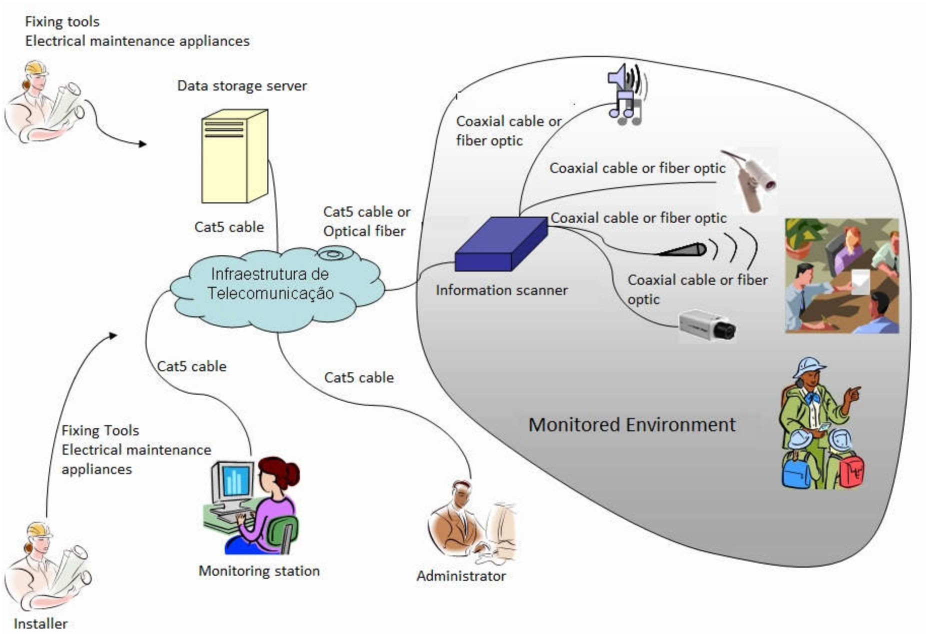

Figure 21. Product - FBD architecture interconnection diagram for a video surveillance system

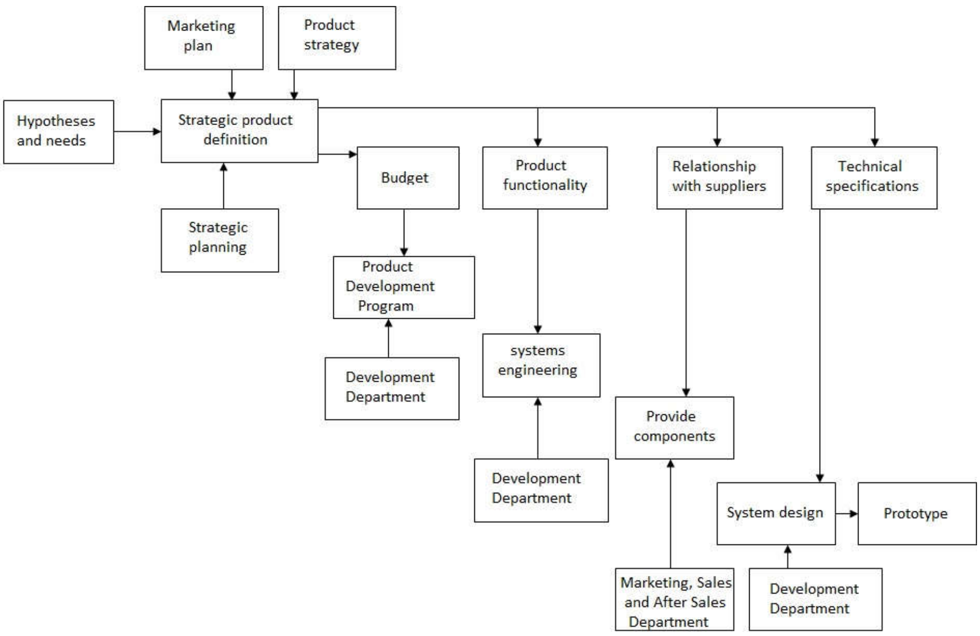

Figure 22: Processes - Physical model of the development process

Functional analysis: Functional analysis aims to identify the functional boundary of the system, the functions provided by the boundary, the functional architecture and the attributes of the elements of the functional architecture. The basic sources of functionality are technical requirements, a result of stakeholder requirements. An analysis of the behavior of each function allows the identification of inputs and outputs and how the functions interrelate. A functional architecture is obtained in order to have a photograph of the system's functions and their interactions. Each function in the system architecture is described through the use of functional attributes. We tried to adapt the functional analysis with the simultaneous and integrated development of the product, its life cycle processes and the organizations that perform them.

System Boundaries and Their External Functional Interfaces: Functional analysis begins by defining what is within the scope of the system and what is outside. Thus, the main functions of the system are defined and the elements in the environment interacting with the system are identified. The primary functions include the product's mission / objective, the life cycle processes and their scenarios, and the business processes that implement the life cycle processes. Figure 12, a context diagram, shows in the central circle the mission / objective of the video surveillance system and the interactions with the different elements of its environment (operator, monitored people, monitored environment, administrator, installer, maintainer and monitoring system). telecommunications). For example, the operator element sends PTZ commands, a configuration parameter to the video surveillance system and it returns the video, sound and alarm to the operator. Figure 13, a behavioral diagram, depicts the six life cycle processes of the video surveillance system. The rectangles represent the functions of the process and the arrows represent the inputs, outputs, controls and mechanisms depending on whether they are positioned to the left, right, above and below the central rectangle, respectively. Figure 14, a use-case diagram, depicts in the square the organization with its three business processes and its interactions with the various actors (people, things and organizations) outside the organization. For example, the marketing and sales process sends the sales and payment plan to the distributors and it returns the distribution report.

Definition of states and modes: Eight states and their respective modes of operation have been defined as shown in Figure 15. The states are:

- On, sendingvideocontinuously;
- On, sending video only when an event of interest is detected;
- On, videostorageuninterrupted;
- On, video storage only when event of interest;
- On, notsendingvideo;
- Off;
- Undermaintenance;
- Out ofoperation.

From the possible states identified for the system, the corresponding operating modes were defined, which are described in Table 11.

Definition of Functions: We tried to identify the functions of the system and investigate its interactions since the beginning of the product development process. Figure 16 shows the five functions (providing acquisition, providing data storage, providing data transfer, providing research and providing monitoring) identified in the video surveillance system and the inputs and outputs of each function. It is a child diagram of the context diagram of Figure 12 (Context Diagram of the video surveillance system). Figure **12. Video surveillance system context diagram**

Analysis of performance hazards: Two events were identified in the environment that can negatively affect the functions of the system and the degree of risk for each of them was estimated. Table 12depictsthisanalysis.

Analysis of functional behavior: Referring to Figure 11, functions resulting from some events (stimulus and response) were identified, listed in Table 13.

Definitionoffunctional interfaces: Figure 16 also represents the functional decomposition of a video surveillance system with the functional interfaces defined by the flow of information, material and energy between the functions. For example, the functional interfaces between the functions "provide data transfer" and "provide research" are: "request for video and sound" and "sound and video requested".

Functional architecture: The functions and functional interfaces identified earlier make up a functional architecture. Figure 16 illustrates the functional architecture of a video surveillance system.

Verification of functional architecture: It was found that the functional architecture is complete, as it meets the technical requirements. The elements of the functional architecture were tracked to validate the technical requirements.

Definition of functional attributes: In this work, attributes are defined as properties and characteristics possessed by a product, a process or an organization, which are intended to meet the requirements of stakeholders. Eleven functional attributes were highlighted, of which five refer to the product, 2 to the processes and four to the organization. Examples of functional attributes corresponding to the functions in the models in Figure 12, Figure 13 and Figure 14, provided in Table 14.

Architecture Analysis: The physical analysis proposed in this work is essentially an activity modeling. It aims to identify the elements that make up a product's physical architecture, its life cycle processes and the organizations that perform them, the interaction between these elements and the attributes. The physical analysis can be understood, therefore, as the analysis of implementation of the product, processes and the organizations that constitute the system. Product, processes and organizations are analyzed in an interactive way.

Identification of the physical elements of the system

Listof system elements

- Server
- Monitoringstation
- Teleconinfrastructure

- Videodigitizer
- Loudspeaker

- Microphones

Table 11: Matrix of States x Modes

		States				
		On, sendingvideocontinuously.	On, sending video only when an event of interest is detected.	On, not sending video and recording.	Off, undermaintenance.	Off, out ofoperation.
Modes	Sending and generating video continuously	X				
	Always sending the video and recording only when an event of interest is detected	X	X			
	Sending and recording video when an event of interest is detected		X	X		
	Sending and recording video with maximum spatial reduction	X				
	Sending and recording video with minimal spatial reduction	X				
	No video upload and no recording				X	X

Table 12: Hazard Analysis

Hazard	Failure	Efect	Sev.	Prob.	Risk
Invasionoftheenvironment	Monitoringinterruption	Do notgeneratealarm	3	2	6
	Do notdetectmovement		3	1	3
	Camerastopsworking		3	1	3
	Data link down	Do not store images and sounds	3	2	6
	HD defect		3	1	3
Strong wind	Cameralosefit	Blurred image or incorrect image direction	2	1	2

Legend: Severity: 1 - Low; 2- Medium; 3 – High; Probability: 1 - Low; 2- Medium; 3 – High; Risk: 1 - Low; from 2 to 4 - Medium; 5 to 9 - High

Table 13. Stimulusand Response

	Stimulus	Response	Function
Operator	Movement	Alarm	Generate an alarm when motion is detected in the scene of a monitored environment.
Operator	PTZ commands	Cameramovement	Generatedesiredimage.
Operator	Date and time, camera	Desiredimage	Finddesiredimage.
Instalator	Parameters	Operating feedback	Adjust the monitored area system.

Table 14: Functional attributes vs elements of the functional model

			Functional Model Element							
			Product					Process	Organization	
			Provide monitoring			Provide research				
			Alarm	Sound	Video Digital	Video Requested	Requisition parameter	System Development	System Development	Organization management
Functional Attributes	Product	Spatial video resolution			1					
		Transfer rate		1	1					
		Date/time of the video					1			
		Type of claim				1				
		Alarm mechanism	1	1						
	Process	Development time						1		
		Cost of development						1		
	Organization	Return on investment								1
		Investment risk								1
		Market share								1

• Resources: Legal advice, product specifications, assembly specifications and user manual.

identify which functions, in the functional architecture of the product, processes and organizations, are performed by which

Table 15: Functional allocation for subsystems

		Subsystems						
		Cameras	Audio system	Presencesensors	Scanner	Telecommunicationequipm	Server	Monitoringstation
Functio	Provideacquisition							
	Provide data storage							
	Provide data transfer							
	Providesearch							
	Providemonitoring							

			Product											Process				Organization		
			Server		Monitoring Station		Video digitizer		Sirens	Camera		Microphone	Sensors	Strategic Product Definition						
			HD	Network Interface	Monitor	Joystick	Output Interface	Analog video input interface	Sound Generator	CCD	Lenses	Power supply interface	Power supply interface	Hypotheses/Needs	Budget	System Functionality	Suppliers List	System Engineering	Department of Development	Marketing/Sales/After-Sales Department
Physical Attributes	Product	Storage Capacity (in days)	X																	
		Storage Capacity (in GB)	X																	
		Number of Monitoring Stations			X	X														
		IP communication		X			X													
		Analog video standard						X												
		Siren Power							X											
		Sensor size								X										
		Number of cameras								X	X									
		Expansion rate									X									
		Required Power										X	X							
		24-hour uninterrupted Video Surveillance												X						
	Process / Organization	Total HR investments													X					
		Provide quick action in case of accident														X				
		Value offer															X			X
		Test Plan Steps																X		
		Number of Developer Employees																	X	

Table 16. Physical attributes X Elements of the physical model

Life Cycle Process:

Selection

- Department: Development
- Resources: Equipment tests and specific technical documentation.

Acquisition outsourcing management

- Department: Marketing, Sales, After Sales.
- Resources: Legal advice and product specifications

Installation outsourcing management

- Department: Marketing, Sales, After Sales.
- Resources: Legal advice, product specifications, assembly specifications and user manual.

Maintenance outsourcing management

- Department: Marketing, Sales, After Sales.

Figure 18, a data flow diagram, shows a video surveillance system and its functional interactions with the different elements (operator, monitored people, monitored environment, administrator, installer, maintainer and telecommunication system) in your environment. Figure 19, an architectural flow diagram, shows how functional flows are allocated to each physical element of the video surveillance system. The physical elements are: cameras, audio system, presence sensors, digitizer, server, monitoring stations and telecommunication structure. To compare the inputs and outputs of the product elements in Figure 19 with those functions in Figure 16, the functional decomposition of a video surveillance system, the relationships between functions and physical elements can be identified as shown in Table 15.

Identification of physical interfaces: The physical interfaces of the product are the physical connections through which the flows of energy, material and information, identified in the functional analysis, are exchanged between two physical elements. Figure 20, a function block diagram, represents a video surveillance system and its physical interfaces with the environment

Physical architecture: The physical architecture describes the

them. Figure 21, a function block diagram, shows the architecture of a video surveillance system, that is, its subsystems and physical connections. Figure 22, a behavioral diagram, describes the development process adopted by the MB-294 company. The development subprocesses are described diagonally in figure 22. They are: strategic product definition, product development program, systems engineering, providing components and system design.

Verification of physical architecture

Physical verification is done for the purpose of:

- Ensure that the lowest level elements of the physical architecture are traceable to the functional architecture;
- Ensure that the elements of the physical architecture meet the validated technical requirements.

Derivation of physical attributes: Sixteen physical attributes were highlighted, of which eleven refer to the product and five refer to the processes and organization. Table 16 shows the relationships between the elements of the physical model and their physical attributes.

Final considerations: This work used the full vision framework, according to LOUREIRO (1999), for the integrated development of a video surveillance system. This integrated development takes into account not only the product, but also its life cycle processes and the organizations that perform them. Thus, a balanced solution was sought for the attributes of the organization, processes and product as emerging properties of a fully integrated system. The main benefit of applying the full vision framework for the integrated development of the video surveillance system is the ability to investigate, at the beginning of the product development, the interactions between product requirements and attributes and the stakeholders involved. A good example in this context is to define your target customers as soon as possible and determine which occurrences should be detected and stored. It was noticed by the authors of this work that the objective of the search for a balanced solution was favored by the separation of the functional analysis from the analysis of the physical architecture. Because, with the most important functions (monitoring, storage and search), the benefits of physical allocation options can be balanced in the system architecture. An example was the allocation of the monitoring function and the storage function, which are centralized and each located in different places. In general, it can be said that the system designed satisfies an important subset of the needs of all stakeholders and that these needs are tracked along the various stages of the system design. The presentation of the results in the form of a pedagogical script allows the replication of these systems engineering tools, using TVF, in other product development projects.

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