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Workflow Management analysis through the Petri-net system and resources

The case of Amavido GmbH

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Introduction

This dissertation explores in details the concepts of workflow management (WFM) and business process management (BPM) and provides some analytical tools that are used when these implement frameworks. The aim of the thesis is to analyze the methods of representation of EPC, Petri nets and PERT in order to compare the results obtained from these analytical tools whit the scope of an optimization of a selected process of a company, specifically, we will study a German startup named Amavido. We will discuss if the results that appear from these types of representation could be combined in order to improve the business process.

This thesis is developed in four chapters: first of all, a theoretical framework is defined in order to provide the definitions and some historical references of the Workflow management and the Business Process Management. Then three analytical tools are illustrated: the EPC, the Petri Nets and the PERT. After this description, the business process of the German startup is displayed through the use of these analytical tools. At the end the representations obtained from the use of these different tools are compared in order to understand how combine all the information and for improving the process of the startup.

The first chapter presents the Workflow Management by giving a definition and outlining the main elements that compose it. The four key elements of Workflow Management are identified and analyzed: for each of them a definition is given focusing on their main characteristics.

The second chapter deals with the Business process Management: it is defined and a summary of its development from its birth until today are reported. Then the relationship between Workflow Management and Business Process Management is explained.

In the third chapter the three different analytical tools, EPC, Petri nets and PERT are examined. These instruments are used for designing and projecting processes. Each tool is defined and the rules for mapping a process are established.

The fourth chapter illustrates the application of these analytical tools to a real case, the Amavido start up. The Amavido's process is analyzed and represented from the various points of view that are given by the three different tools. Then the advantages and criticalities of these tools are taken into consideration thanks to the SWOT analysis. At the end the comparisons and the interweaving of the information are explored in order to improve the process of a company.

A final scheme with the conclusions will close the thesis.

FIRST PART: Theoretical framework

1. Workflow Management

1.1 Definition of Workflow Management

“[…] information technology has made huge leaps forward in recent years, resulting in the creation of completely new ways of organizing business processes. The development of generic software packages for managing business processes - so-called WorkFlow Management Systems (WFMS) - is particularly important in this respect” (van der Aalst & van Hee, 2001, p. 5).

The Workflow Management Coalition (WfMC), a global organization of adopters, developers, consultants, analysts, as well as university and research groups engaged in workflow and BPM founded in 1993, defines workflow as: “The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules” (Lawrence, 1997). A Workflow Management System (WFMS) is defined as: “A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications” (Lawrence, 1997). Both definitions emphasize the focus on enactment, i.e., the use of software to support the execution of operational processes. In the last couple of years, many researchers and practitioners started to realize that the traditional focus on enactment is too restrictive. As a result, new terms like BPM have been coined (van der Aalst W. , 2004, p. 3).

It is evident that the management, the analysis, the revision of processes through the Workflow representation are fundamental and determining for the company.

In these first chapters we will study the key elements of the Workflow Management and three of the analytical tools that a company could use for improving a business process.

1.2 Perspectives of Workflow Management

Workflow management can be modelled using five different perspectives (Tick, 2006, p. 330). The adoption of these five different points of view will make it possible to adopt different models to represent process. A model is a linked and direct graph that has elements and rules defined that are used to represent and analyze a process (Halpin, et al., 2010, p. 232). Below is a description of the five different perspectives that can be adopted to analyse a process.

- *Control flow or process perspectives*: it presents the static structure of workflow. It considers the activities that compose the process and how they are related. The control flow determines what time dependencies exist among certain elements. It focuses on the operation and it points out the sequential and parallel branches. Control workflow determines the description of the entire routine valid for the workflow model.
- *Resource or organization perspective*: it determines the type and the quantity of the resources available for the execution of the tasks. It is composed by the organisational structure that determines the roles of the functionality aspect, the groups, and of the organisation aspect, and at the end, the responsibility and the availability linked to these. There are two important things in this perspectives, the human and device resource allocations to the roles and groups.
- *Data or information perspective* is accountable for describing the data that is necessary for the workflow and route operation. The production information includes such data, tables and documents that are significant characteristics of the production but are not strictly linked to workflow management though.
- *Task or function perspective*: it is focused on the elementary operations execute by the resources while performing a task.
- *Operation or application perspective*: it is focused on the elementary actions using specifies applications. The applications used cover mainly general programs such as text editor or spreadsheet editor.

After outlining from which perspectives workflow management can be influenced, it is easier to outline a definition of workflow management as a discipline.

1.2.1 Key elements of Workflow Management

After the definition of Workflow, it is possible to understand the key elements that compose it. Below there are the definitions of case, task, process, routing, and enactment, made by Workflow Management Coalition, organisation that creates and contributes to process related standards, educates the market on related issues, and is the only one that concentrates purely on process:

- Task

The task is one of the most important concepts of the workflow. By identifying tasks, it is possible to structure workflows (van der Aalst & van Hee, 2001, p. 38). A task is a logical unit of work that is indivisible and is always carried out in full. When something goes wrong during the performance of a task, then it must be return to the beginning of the entire task: this process is called rollback. The indivisible property of a task depends upon the context within which it is defined. A task can be described as 'atomic' when it is not possible to unbundle it into a smaller one. There are three different types of tasks: manual, automatic and semi-automatic tasks (van der Aalst & van Hee, 2001, p. 38). A manual task is performed by one or more people, without any use of an application. By contrast, automatic task is performed without any intervention by people, so it is performed by a computer program entirely based upon previously recorded data. In a semi-automatic task, a person and an application are involved.

- Case

The case is the primary objective of a workflow system (van der Aalst & van Hee, 2001, p. 37). A case can be considered as an unexpected or frequent event, as an insurance claim, a mortgage application, a tax return or an order to buy something, which starts a process with the aim of finding a solution and solving the problem. Each case has a unique identity and it has a limited lifetime, in fact it begins and finishes. Similar cases belong to the same case type, so cases dealt with in the same way. Into the workflow system the case has a particular state, that consists of three elements: the values of the relevant case attributes; the condition which have been fulfilled; and the content of the case. Each case is characterized by attributes. Attributes represent pieces of information that further describe case (Carkenord, 2009, p. 222) and they are used to manage it. Thanks to the attributes it is possible to indicate that a task may – under certain conditions– be omitted. A condition is a requirement or need for a specific situation necessary for the process to be able to resolve the request received and thus achieve a result. The value of a case attribute may change as the case progresses. The case attribute is not helpful to understand how far a case has progressed. To do this, it is better to use conditions. They are used to determine which tasks have been carried out, and which still remain to be performed. Examples of conditions include 'order accepted', 'application refused' and 'under consideration'. Condition can be also a requirement which must be met before a particular task may be carried out. It is clear which conditions a task have to be met and which not. A workflow system contains only the attributes and the conditions of the case. The content of the case is contained in documents, files, archives and/or databases.

- Activity

It is a description of a piece of work that forms one logical step within a process (Tick, 2006, p. 331). The task can be considered as the result of combining the execution of a general task that is started with the occurrence of an external event. Tasks can be either manual, which means that they are performed by an employee specific to that type of task, such as a restorer, or a mechanic; or they can be automated and therefore require the support of a computer or automated machine. The process needs the support of activities carried out by men and machines in order to proceed with its execution.

- Work item

Using the term task referring to the performance of an activity for one specific case is not correct. In fact, a task refers to a generic piece of work. To avoid the confusion between the task itself and the performance of that task as part of case it is better to use work item. (van der Aalst & van Hee, 2001, p. 38). A work item is the combination of a case and a task which is just about to be carried out. Below, the Figure 1 explains the relationship between the term task, case, work item and activity.

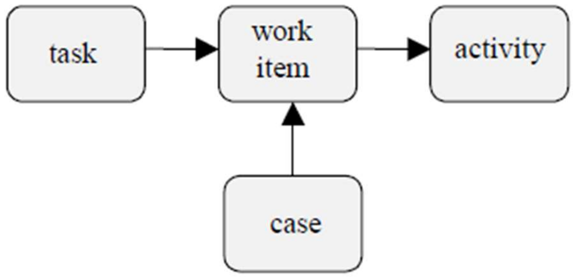


Figure 1. The relationship between the term task, case, work item and activity (van der Aalst & van Hee, 2001, p. 39)

As the Figure 1 shows, the activity is the result of the combination of performing a general task for a specific case.

- Process

The process indicates which tasks need to be carried out and it shows the order in which this should be done (van der Aalst & van Hee, 2001, p. 39). It can be also considered as a procedure for a case type. The process is influenced by the attributes of a certain case, in fact the tasks that compose the process are performed in different way based on case needs. Therefore, a process is constructed from tasks and conditions. Moreover, it is possible that a process can be a part of another process. So, a process can be constructed by tasks and conditions and subprocesses. These subprocesses are made of tasks, conditions and may be made by other subprocesses. Using subprocesses allow to define the relation between the processes and this create a hierarchical structure that establishes which process is on the top and which processes are below. The process consists of a network of activities and their relationships, which aim to indicate the beginning and end of the process and highlight information about individual activities, such as participants, associated IT applications and data, etc.

- Workflow orientation

Workflow orientation can be described as the control-flow of the Workflow model. Models are made by a co-ordinated set of activities that are connected in order to achieve a common goal. There is a word to describe this method: "routing". The definition of routing is: 'it determines which activities need to be performed and in which order' (van der Aalst & van Hee, 2001, p. 39).

Routing varies from case to case, but the Workflow Management Coalition had defined four basic concepts for routing:

- Sequential routing: it is the simplest form. 'The tasks have to be carried out sequentially, one after the other' (Tick, 2006, p. 331). There is usually also a clear dependency between them. This means that the result of one task is necessary to the next.

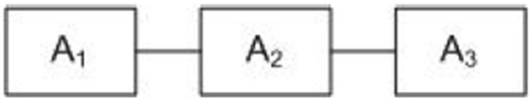


Figure 2. Sequential routing using the WfMC's standardised notation (Tick, 2006, p. 331)

- Parallel routing: this model appears when more than one process activities can be carried out at the same time (Tick, 2006, p. 332). The tasks are initiated using an AND-split, to split the control, and later resynchronized using an AND-join. Figure 3 below shows an example of parallel routing. After the execution of A_1, the following activities A_2, A_3 and A_4 could be carried out at the same time but it is not necessary. An example of this model could be the process of ordering a menu in a fast food restaurant. The customer proceeds to the order choosing which sandwich he wants, which drink he wants and if he wants chips or a dessert. The preparation of these products can be done simultaneously by three different operators, one prepares the sandwich, one the drink and one the chips or dessert. Obviously, if there are not enough operators to carry out the three preparations at the same time, one or two operators will carry them out. If there is only one, he will carry out the three activities individually at different times, while if there are two, two activities can be carried out at the same time and then one will complete the third. The only condition to be met is that in order to deliver the tray with the order, all three previous operations must be ready. The strict condition on A_5 of Figure 3 to start to execute is that all of the parallel activities (A_2 and A_3 and A_4) must be ready.

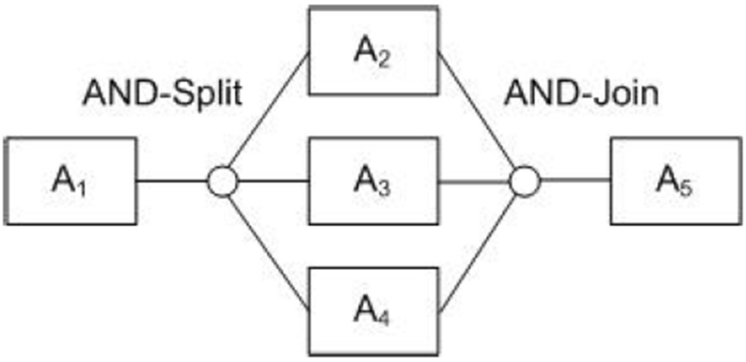


Figure 3. Parallel routing using the WfMC's standardised notation (Tick, 2006, p. 332)

- Selective routing: this model appears when there is a choice between two or more tasks (van der Aalst & van Hee, 2001, p. 40). To execute selective routing at beginning we must use an OR-split to split the control and an OR-join to collect it at the end. The OR-join means that the precondition for the activity after the OR-join to start to execute is that one of the parallel activities, as Figure 4 shows, must be ready. An example to better understand this model is that of a bodywork that receives a car with a damage. Once the damage has been assessed, the coachbuilder can perform one or more different operations to resolve it. He must therefore make a choice between different methods to solve the damage, depending on its severity. He can simply fix a bump by not having to worry about painting the bumpy part, or if the bodywork is damaged, he must proceed to fix it and repaint it. Or you could opt to replace the entire damaged part. Once the method has been decided and the problem solved, the car can be returned to the owner, as the other options do not have to be carried out. The Figure 4 below shows the selective routing. Graphically it is the same as the previous model, what changes are the two conjunctions, with which the process begins and ends. Unlike the previous one, we find the ORs, which force you to make a choice on which of the following tasks to perform in order to get a result and complete the process.

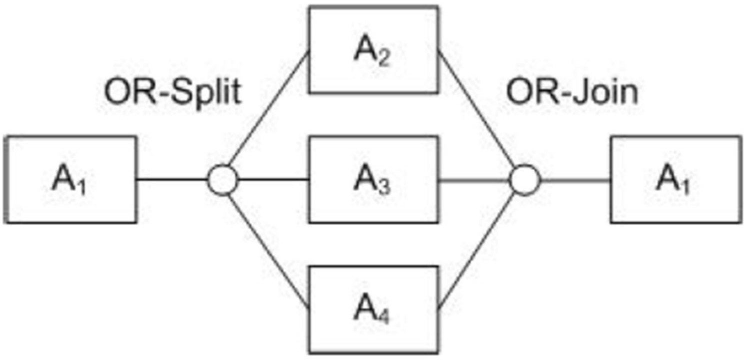


Figure 4. Selective routing using the WfMC's standardised notation (Tick, 2006, p. 332)

- Iterative routing: this routing form defines a workflow activity cycle involving the repetitive execution of one or more activity(s) until the condition is met (Tick, 2006, p. 333). An example of such a model could be the process of boarding an aircraft. In fact, once the aircraft is ready to welcome passengers, the company's staff starts boarding the customers. The boarding process is nothing more than a document and ticket control operation repeated for the number of passengers. Only when this operation is completed and the necessary condition to continue the process is reached, can you move on to the next step of allowing people to board the aircraft. Figure 5 below graphically expresses the process just explained. The arrow graphically shows the repetition of activity A_2 until the condition to continue with activity A_3 is reached.

Figure 5. Iterative routing using the WfMC's standardised notation (Tick, 2006, p. 333)

- Enactment

Enactment can be considered as the input that starts the process and continues it. Often, in order to start or continue the process, a person's intervention is necessary. The work item is only carried out once the employee has taken the initiative. There are three different types of triggers: 1) the initiative of a resource; 2) an external event and 3) a time signal. All the elements that follow a continuous flow, which therefore do not need the intervention of a resource or an external event, do not have any kind of trigger along the process.

We have verified that the Workflow Management is essential for a company because it could improve a business process through a graphic representation focused on tasks, resources, operations, data and control flows.

In the next chapter we will study the Business Process Management in a detailed way with the aim of understanding the relationship between Workflow Management and Business Process Management.

2. Business Process Management

2.1 Definition of Business Process Management

Business Process Management "supports business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information" (van der Aalst W. , 2013, p. 1). It can be considered a discipline that combines from information technology and knowledge from management sciences and applies this to operational business process.

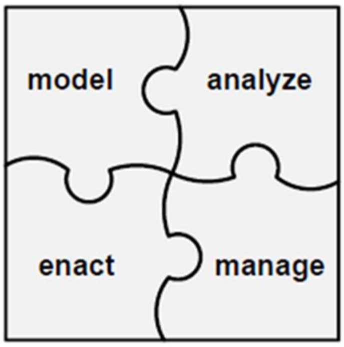


Figure 6. The four key activities of BPM (van der Aalst W. , 2013, p. 4)

The Figure 6 shows graphically the definition of business process management. The four pieces are the key activities that compose the BPM:

- model stands for creating a process model to be used for analysis;
- enact stands for using a process model to control and support concrete cases;
- analyze stands for analyzing a process using a process model;
- manage stands for all other activities, like reallocating resources, adjusting the process.

As business process management deals with people and organization on the one hand and process software on the other hand. Starting from this point it is possible to formulate a definition of business process management system: “a generic software system that is driven by explicit process designs to enact and manage operational business processes” (van der Aalst W. , 2004, p. 1). Considering the definition, it is possible to understand that business process management systems is composed by some ongoing trends, as Figure 6 shows.

The Figure 6 shows the main four layers that compose information systems (van der Aalst W. , 2004, p. 1). The center is formed by operating system, an example can be the software that makes the hardware work. The second layer consist of generic applications that can be used in a wide range of enterprise, examples can be a database management system, a text editor, and a spreadsheet program. The third layer consists of domain specific applications. These applications are used within specific types of enterprise and department. Examples can be call center software, and human resource management software. The fourth layer consists of tailor-made applications, examples can be applications that are developed for specific organizations. The four layers explained before show the business process management development. Each process starts from a general operating system, a common thing that it can be found in every enterprise. Then the process passes through generic applications that are specific for a group of enterprise, and in the end the process uses applications that are more specific for some type of department and for specific organization.

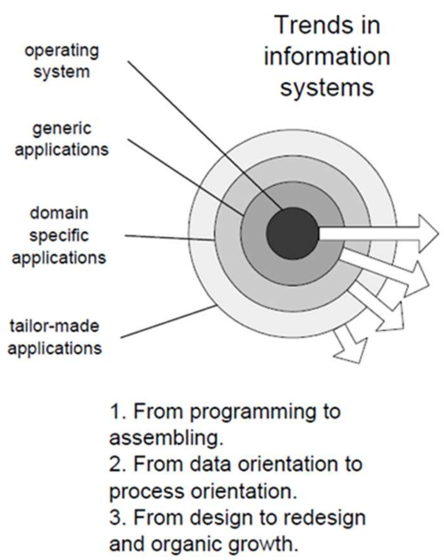


Figure 7. Trends relevant for business process management (van der Aalst W. , 2004, p. 2)

2.2 History of Business Process Management (BPM)

It is difficult to define when the Business Process Management started, it was influenced by the computer science and the management science (van der Aalst W. , 2013, p. 4). Since the Industrialization the organizations and the management implement technical innovations, improvements on the organization of work, and the use of the information technology in order to increase the productivity and the efficiency. Business process management is influenced by ideas that were developed during the Industrialization, as the advantages of the division of labor showed by Adam Smith (1723-1790), as the initial principles of scientific management introduced by Frederick Taylor (1856-1915), as the production line for the mass production of "black T-Fords" introduced by Henry Ford (1863-1947). A side-effect of the ideas of Taylor and his contemporaries was the appearance of an altogether new class of professionals, that of managers (Dumas, La Rosa, Mendling , & Reijers , 2013, p. 9). This new class of professionals has the task of supervising the production and the groups of workers who are involved in the production process. Their aim is to make all workers aware of the objectives to be achieved and to make sure that they are achieved. With the birth of this new management class, the structures of the organizations also change, they are now developing according to a structure based on the division of labor. This allowed the emergence of the functional structure that dominated from the Second Industrial Revolution until much of the 20th century. Towards the end of 1980 some large American companies realized that all efforts to optimize the functional structure created inefficiencies in operations and thus affected their competitiveness. Around 1950 computers and digital communication started to influence business process. This was a big change and the organizations found new ways for doing business and for organizing the work. An important event that can be considered as the beginning of Business Process Management was the acquisition of a financial stake in Mazda by the American Ford during the 1980s. With this acquisition, Ford's managers realized that Mazda's production units employed far fewer workers than Ford's own units. The main problem was that Ford took over and solved the problems it encountered along the production process one by one, while Mazda avoided discrepancies in first place. This was possible thanks to the use of databases where all production information was entered. This was also possible thanks to the implementation of new computers and new technologies that were more powerful than the previous ones. Changes were made to the entire production process and the processes directly involved in it, such as the warehouse, the purchasing department and even the sales process. The changes made are on several fronts such as information exchange, technologies (databases and terminals) and structural (controls and policies). This example can be considered as the beginning of the implementation of Business Process Management, which brought out a process management concept called Business Process Redesign or Business Process Re-engineering, abbreviated to BPR. Many companies around the world began to form new teams to analyze and redesign their processes. However, this enthusiasm began to decline in the late 1990s. In fact, companies began to have doubts about the effectiveness of this new way of doing things. One of the reasons was that the redesign of the process had to be radical, as Michael Hammers argued in one of his early writings on BPR. In one of these he wrote: "Don't automate, Obliterate". While for some processes a radical change approach could be justified, in many others a more gradual and incremental approach was needed. In addition, companies were faced with the problem of technologies that were not up to the task of supporting change because they were not powerful or even unavailable. These reasons influenced the use of BPR but laid the foundation for the birth of Business Process Management (BPM). This has been possible mainly thanks to technological development. New types of IT systems have emerged, among which the best known are Enterprise Resource Planning (ERP) systems and Workglow Management Systems (WfMSs). ERP systems are essentially systems that store all data related to the business operations of a company in a consistent manner, so that all stakeholders who need access to these data can gain such access (Dumas, La Rosa, Mendling , & Reijers , 2013, p. 13). WfMSs on the other hand are systems that distribute work to various actors in a company on the basis of process models (Dumas, La Rosa, Mendling , & Reijers , 2013, p. 13). Originally, WfMSs were concerned mainly with routing work between human actors. Later, these systems were little by little extended with modules to monitor and analyze the execution of business processes. Over the years WfMs have become completer and more sophisticated, increasing integration with business systems and this leads to the birth of a new type of process management called Business Process Management (BPM). The key idea of BPM is to focus on processes when organizing and managing work in an organization. In the first decade of the 21st century the organizations' focus is on the innovation in computing and communication: these two focal points are become the main drivers behind the changes on business processes. Nowadays information systems need to be configured and driven in precise instructions because there are more cross-organizational processes than before, and they can only run properly if there is a common agreement on the required interactions. There are different languages and different types of Database Management (DBM) system: organizations and managers had consensus on the fundamental concepts for the information centric view and on the other side the process-centric view on information systems was characterized by "divergency". This situation explains the reason why today organizations have a large amount of systems and languages as BPMN (Business Process Modeling Notation), EPCs (Event-Driven Process Chains), BPL (Business Process Execution Language) and UML (Unified Modeling Language). Today and especially for the future, Business Process Management is and will be influenced by the increased importance that the "Internet of Things" (IoT) is acquiring. The IoT utility is changing the way of interpreting the business process management inside and outside the firms as well as innovation processes connected to products and services (Del Giudice, 2016). The IoT increases the ability to connect people, assets and operations through a global network. The revolution that is driving the IoT is creating a new management technology landscape that is composed of products with electrical and mechanical parts that become intelligent systems that combine hardware, software, control sensors, data storage and connectivity in infinite ways. This allows and will enable BPM to improve its process management process, sharing large data flows between large companies, increasing productivity and reducing marginal costs. In addition, the development of business process management through the implementation of the IoT can lead to a greater understanding of the process, increase innovation and competitiveness of the company. Today, several megatrends are relevant for the business process management within the modern factories: the globalization, the progressing technological evolution, the dynamism of product life cycles, and the shortage of resources. Likewise, other relevant key factors seem to be the acceleration of innovation cycles and the increasing customer demand for individualized mass productions with highest quality expectations (Del Giudice, 2016).

2.3 BPM as an extension of Workflow Management

Business Process Management "can be seen as an extension of Workflow Management (WFM). WFM primarily focuses on the automation of business processes, whereas BPM has a broader scope: from process automation and process analysis to operations management and the organization of work." (van der Aalst W. , 2013, p. 1). The BPM could be associated to two different ways to act: on one side it has the scope to improve the operational business processes without using new technologies, "for example by modeling a business process and analyzing it using simulation, management may get ideas on how to reduce costs while improving service levels" (van der Aalst W. , 2013, p. 1); on the other side it has a deep connection with software in order to manage, control, and support operational processes. Improving operational business processes with the use of new technologies is the initial focus of the WFM but without considering human factors and management supports.

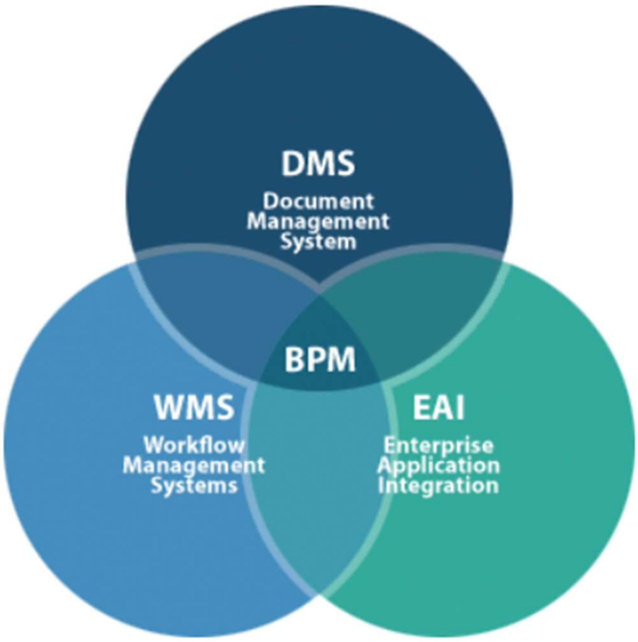


Figure 8. BPM positioned against other classes of business software (Antipodes, 2011)

Figure 8 shows the relationship between WFM and BPM. BPM extends the traditional WFM approach by support for the diagnosis phase and allowing for new ways to support operational processes (van der Aalst W. , 2004, p. 5). BPM clearly includes Workflow Management (WFM).

The lifecycle of BPM describes the various phases in support of operational business processes, and it consists of:

1. (re)design phase: the process model is (re)designed.

2. implementation/configuration phase: design is implemented by configuring a process aware information system. This point is very important because here the process is transformed into a running system.

3. run & adjust phase: in this phase the process starts, and it could be adjusted when needed. In this phase the process is just adapted and there is no possibility to redesign or to create new software.

4. diagnosis phase: while the system is running, even data are collected. The operational processes are analysed in order to identify problems and in order to find things that can be improved. This is an input for the redesign phase. Furthermore, it could be possible use two models to collect data and analyse processes and discover problems: model-based analysis and data-based analysis, as showed in the Figure 8:

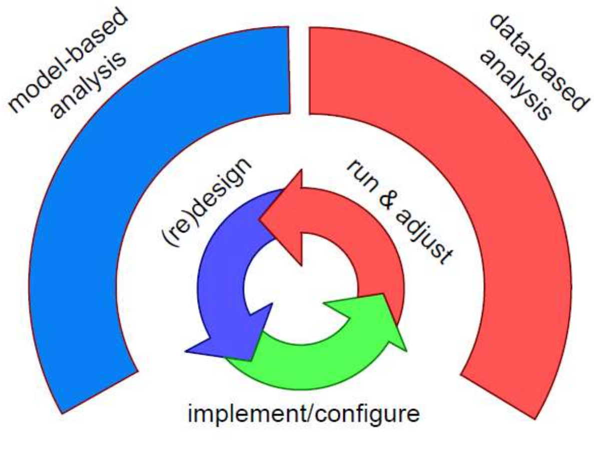


Figure 9. The BPM life-cycle and the two models to collect data (van der Aalst W. , 2013, p. 8)

2.3.1 Business Process Classification

Business process can be classified into human-centric and system-centric. To be more precisely it could be classified into Person-to-Person (P2P), Person-to-Application (P2A) and Application-to-Application (A2A) process.

Person-to-Person (P2P) processes are focuses on people and their tasks (van der Aalst W. , 2013, p. 8). Task, as described in Chapter 1, is a logical unit of work that is indivisible and is always carried out in full. An example can be things that we do in everyday life to achieve some certain purpose (Chen, 2014, p. 8079). All the activities around people are designed to support P2P processes like job tracking, project management, and groupware tools. One characteristic of tools used in this type of processes is that they tend to create interactions between computers and people, because the activities of the processes are not composed of fully automated activities. (project tracking servers, e-mail clients, video-conferencing tools, etc.)

Person-to-Application (P2A) processes involve both human activities and interactions between people, and activities and interactions involving applications which act without human intervention (van der Aalst W. , 2013, p. 8).

Application-to-Application (A2A) processes are those that involve activities performed by software systems (van der Aalst W. , 2013, p. 8). These types of systems don't need human involvement, as transaction processing systems, EAI platforms, and Web-based integration servers.

It's difficult to see a clear boundary between these categories because exist a continuum of processes, techniques, and tools covering the spectrum from P2P to A2A. These processes could be classified into unframed, ad hoc framed, loosely framed, and tightly framed by the position that they acquired in the following scheme (Figure 9).

Unframed: a process is named unframed when there is no explicit process model associated with it. It is the case of collaborative processes that do not offer the possibility of defining process models.

Ad hoc framed: this is the case when a process model is chosen before, but it run one or a small number of times before the management decides to change it. This is the case in project management environments when a process model is used once.

Loosely framed: this situation exists when there is a-priori defined process model and a set of constraints, such describing the way hot the model runs and does things and allowing the actual executions of the process to deviate from this model.

Tightly framed: when a process follows an a-priori defined process model.

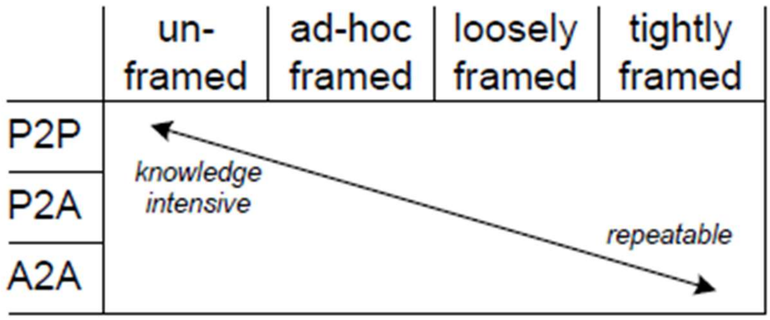


Figure 10. Classification of processes (van der Aalst W. , 2013, p. 9)

As Figure 10 shows, the degree of framing of the underlying processes (unframed, ad hoc, loosely, or tightly framed), and the nature of the process participants (P2P, P2A, and A2A) are correlated. Most processes are found around the diagonal. Knowledge intensive processes tend to be less framed and more people centric. Highly repeatable processes tend to be tightly framed and automated.

The category that the BPM systems used most is the P2A. In fact, organizations prefer to use systems that allow people and applications to work in an integrated manner.

3. Analytical tools to represent and to study processes

Process modeling is widely used within organizations as a method to increase awareness and knowledge of business processes, and to deconstruct organizational complexity (Bandara, Gable, & Rosemann, 2005). It is an approach for describing how businesses conduct their operations and typically includes graphical depictions of at least the activities, events/states, and control flow logic that constitute a business process (Curtis, Kellner, & Over, 1992). The representation phase of the business process can be divided into two categories: the first one uses an intuitive graphical modeling technique using a tool called Event Driven Process (EPC). This tool is used for its easy reading and to understand the business requirements and the improvements to be made in the process. The second uses another tool, the Petri networks, which is based on mathematical paradigms. This tool is mainly used to represent the execution and analysis of the process. An important aspect to take into consideration when deciding which technique to use is the difference in the way processes are articulated by the different tools. In fact, these analytical tools tend to analyze and emphasize different aspects of the processes, such as the sequencing of activities, resource allocation, communication or organizational responsibilities. Below there is the analysis of tools and the explanation of the rules to follow in order to model a process.

3.1 Improve processes using analytical tools

There are signs that show the evidence of a workflow is not working properly. If management observes one of these symptoms, it may exist a problem along the process that reduce the flexibility and the proper operation of the process. Exist three types of systems:

- Number of cases in progress (too) large.

If there are many cases in progress, this can indicate a problem. This problem can be caused by a lack of flexibility or the supply of cases is large, and the process is not able to manage that large numbers. The process may contain too many steps that need to be process sequentially and this can create a execution problem.

- Completion time(too) long compared with actual processing time

It is a problem that it is caused because sometimes the time of the processing time is just a small part of the total time. There are some possibilities for reducing the completion time.

- Level of service (too) low

The level of service is a measure that indicates the degree to which the organization is able to complete cases within a certain deadline. When a process doesn't respect the deadline and the completion time fluctuates widely, the level of service is low. It is very difficult to assign and to guarantee a completion time. This problem happens also when there are many 'no sales' occurring. This is the consequence of the inability to take on a potential case due to the long waiting times. When the client knows that it will take a long time to complete a case, it will approach another company. This problem also shows a lack of flexibility, a poorly designed process or a structural lack of capacity.

These symptoms are very useful because, if they are on a workflow process it is very important to tackle their causes and not to limit the symptoms by using emergency measures. To find these problems, it is important to use performance indicators. Exist two groups of performance indicators:

1. External performance indicators (case-oriented)

These types of indicators focus on the external aspects which influence and are important for the environment of the workflow. Examples are the indicators of the average completion time and reliability of the completion time.

2. Internal performance indicators (resource-oriented)

The internal performance indicators show what efforts are required to achieve the external performance. Examples are the number of cases in progress, the rate of turnover, etc. It is important to understand that, in many cases it is possible to improve external performance of a workflow without allocating additional resources. By using a better allocation strategy of resources or restructuring the workflow the improvement can be achieved. The problems could be resolved if management focus on the causes of problems and on the flexibility of the processes.

According to W. van der Aalst and K. van Hee, and their thesis on the Workflow Management book, exist number of rules of best practice for the design or redesign of workflow. There are a series of transitions that management could follow to achieve the result of find a better allocation of activities to process design.

Three analytical tools will be described below, which are used more to represent and study the processes in order to understand the points to be improved and to find greater efficiency and effectiveness along the process.

3.2 Petri nets

Petri nets are a tool for the study of systems: it helps visualizing, validating and simulating the dynamics of a distributed systems and any complex discrete systems (Peterson, 1981). Petri net theory allows a system to be modeled as a mathematical representation. Analysis of the Petri net can then reveal important information about the structure and dynamic behavior of the model system (Peterson, 1981, p. 1).

3.2.1 History of Petri nets

Petri nets originate from the early work of Carl Adam Petri: in his doctoral dissertation, "*Communication with Automa*" (Kommunikation mit Automaten, 1962), he formulated the basis for a theory of communication between asynchronous components of a computer system. He focused his attention on the description of the causal relationship between events. In the following years, A. W. Holt and others of the Information System Theory of Applied Data Research Inc. (ADR) decided to study the work of Petri. Much of the early theory, notation, and representation of Petri nets was developed from the work of Information System Theory Project. Moreover, they wrote a report titled "*Events and Conditions*" (Holt & Commoner, 1970) where they showed how Petri nets could be applied to the modeling and analysis of systems of concurrent components (Peterson, 1981, p. 4). Petri's work was also studied by Project MAC at the Massachusetts Institute of Technology (MIT) where Petri nets are used as a model of parallel computation to illustrate the problems of determinacy and communication between processes (Dennis, 1972). Other approaches in Petri net theory were developed during two important conferences on Petri nets: the first one was the Project MAC Conference on Concurrent Systems and Parallel Computation in 1970 at Woods Hole and the second one was the Conference on Petri Nets and Related Methods in 1975 at MIT.

Recently the use and the study of Petri nets has been studied and adopted widely. This has allowed to organize a workshop on Petri nets in Paris in 1977 and an advanced course on General Net Theory in Hamburg in 1979. Furthermore, a special interested group, called The Petri Net Newsletter, was formed in Bonn (Germany) in order to become a medium for the rapid distribution of any information on Petri Nets and related system models all over the world.

3.2.2 Structure of Petri Nets

Petri nets are a basic model of parallel and distributed system. The idea is to describe state changes in a system with transitions.

A Petri net is composed of four parts (Petri, 1976, p. 134):

- Tokens are the resources of the process, they can be of any kind, but they have to be countable items. They often indicate objects, sometimes they represent the people or the robot needed to work the project.
- State elements (S) or Places (P) if they can contain more than just one token. They can be identified as the representation of a specified position along the process. They usually represent a medium, buffer, geographical location, (sub)state, phase or condition.
- Transitions (T) are the actions of changing from one state to another, they can be seen as alterations in the holdings of conditions. They often represent an event, an operation, a transformation or a transportation.
- Flow relation (F) are the relation between a state and a transition, they might be read ‘from … to …’.

After identifying the four parts that composed the Petri nets, it is possible to give a definition of this tool.

Definition: A Petri net is a triple (P, T, F) (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 12):

- P is a finite set of places
- T is a finite set of transitions ($P \cap T = \emptyset$)
- $F \subseteq (P \times T) \cup (T \times P)$ is a set of arcs (flow relation)

Although based on a graph, Petri nets proposed by Carl Adam Petri have a solid mathematical basis. This means that, compared to many other schematic techniques, it has become more common because it is based on a fully formalized language allowing you to model complex processes in an accessible way. Below there is the description of a graphical representation of a Petri nets structure.

A Petri net graph uses circles to represent places (states) and bars or rectangles to represent transitions (events) (Choi, 1994, p. 12). There are relationships between places and transitions, and they are represented as direct arcs. If an arc is directed from a place to a transition, this means that the place is considered an input of the transitions. If the arc is direct from a transition to a place, this means that the place is an output of the transitions. Petri net is a multigraph since it allows multiple input and output. They are represented by multiple arcs. The arcs need to respect one rule: each arc has to direct from an element of one set, a place or a transition, to an element of the other set, transition or place.

The greater diffusion and the increasing use of this instrument has allowed an improvement from the one theorized by Carl Adam Petri. It has gone from a simpler and more basic structure, called Classical Petri Nets, to a much more complex and detailed one thanks to the addition of extensions with the aim of being able to model those complex situations in a structured and accessible way and to which the Classical Petri net could not respond. This second type of tool has been called High-Level Petri nets.

3.2.3 Classical Petri Nets

"The classical Petri net is a directed bipartite graph with two node types called places and transitions. The nodes are connected via directed arcs. Connections between two nodes of the same type are not allowed" (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 11).

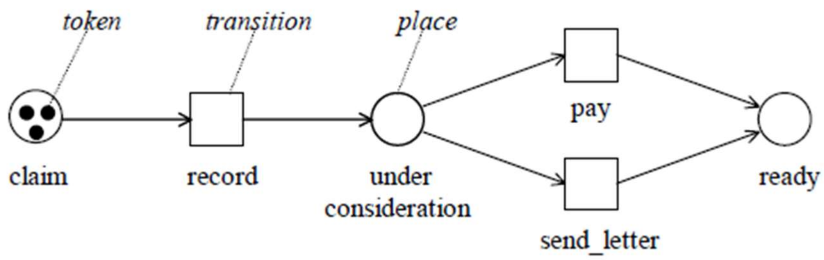


Figure 11. A classic Petri net (van der Aalst & van Hee, 2001, p. 42)

Figure 11 above is an example of a graph of Classic Petri net. It is composed of three rectangles that stand for transitions, and of three circles that are three places. The three places are claim, under consideration and ready; the three transitions are record, pay, and send letter. The graph represents the process for dealing with an insurance. The claim is the starting point, where and when the process begins. After the claim arrived, it is recorded after which a payment is made or a letter sent explaining the reasons for rejection.

As explained before, places and transitions are linked by means of a direct arc that is represented graphically as an arrow. The direction of arrows allows you to understand the direction of the process and its development (the ways that tokens can take) and the input and the output of each transitions. In fact, there are two types of arcs (arrows), those which run from a place to a transition and vice versa. A place P is considered an input when it has an arrow that runs from itself to a transition. The same rule exists for the output. A place P is considered an output when there is a running arrow from a transition to a place. In figure 10 it is possible to see that each transition has at least one input and one output.

As Figure 10 shows, there are three black dots inside the first place. They are the tokens, as described before, they are the resources of the process. They are the only part of a Petri net that can change, in fact the structure is fixed but the distribution of the tokens can change. This situation is named marking, it is a distribution of tokens on the places of a net and corresponds to the 'state' of the Petri net (Desel & Esparza, 1995, p. 2). The initial situation when the process can be started by an external input is called initial marking. The marking can change if a transition is enabled to fire, it is the action to remove one token from each of the input places of the transition, and ads one token to each of its output places (Desel & Esparza, 1995, p. 2). Transition must respect only one rule, at least one token must be present in each input of the transition.

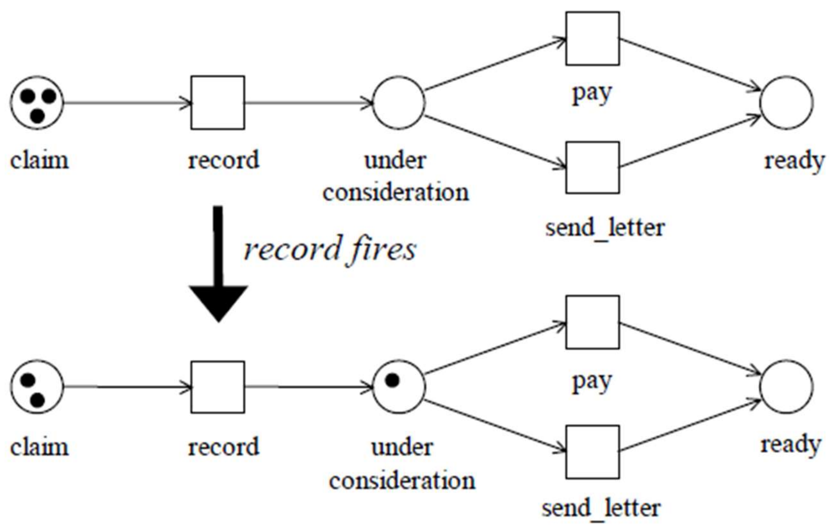


Figure 12. State before and after the transition fires (van der Aalst & van Hee, 2001, p. 43)

The Figure 12 shows the representation of the state before and after the transition fires. The transition 'record' is enabled to fire because its input has three tokens. The next state has two tokens inside the first place, 'claim', and one inside the second one, ' under consideration'. The first state illustrated in Figure 11 can be also described using the vector (3,0,0). It means that there are three tokens in claim, none in 'under_consideration' and none in ready. The second state can be described with a new vector (2,1,0). Now there is one token in the place 'under_consideration', so it is possible that one situation between pay or 'send_letter' runs. In this situation, it is not possible to define which transition will fire first. If the transition 'pay' fires, the token moves from the place ‘under_consideration’ to the place ‘ready’. The new state is described by vector (2,0,1). After the transition ‘pay’ fires, there is no more tokens in the place ‘under_consideration’, so the transition ‘send_letter’ is no longer enabled. Below the Figure 13 illustrates the new state of the net, after the firing of transition ‘pay’. Now the transition ‘record’ is still enabled because there are two tokens in the fist place. When the transitions fire for six time, all the tokens will be in the last place, ‘ready’ and the process will be over.

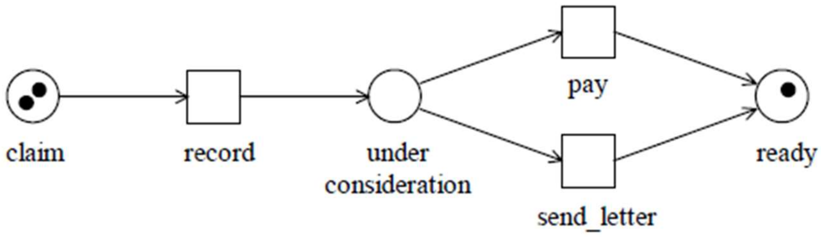


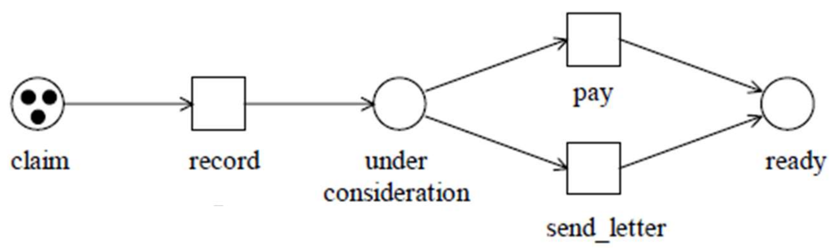
Figure 13. State after ‘pay’ fires (van der Aalst & van Hee, 2001, p. 43)

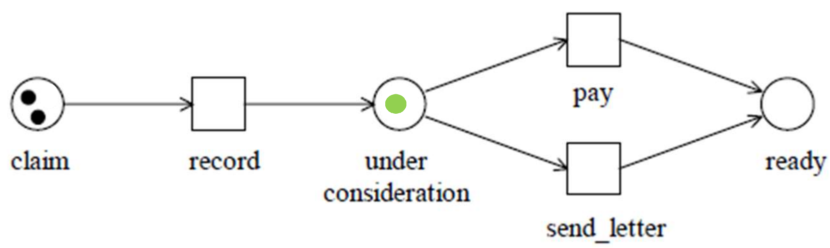
3.2.4 High-level Petri Nets

Petri nets describing real processes tend to be complex and extremely large (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 13). In fact, the classical Petri net described above does not allow for modelling the time and data. In order to overcome these limitations, there are some extensions concern the qualitative aspects of the models that increase the expressive power or the modelling capabilities of the Petri nets (Baldan, Cocco , Marin , & Simeoni, 2010, p. 13). Extension allow to model complex situations in a structured and accessible way that it is easier to use. Petri nets that adopt these extensions acquire a new name, they are called high-level Petri nets. The three main important extension existing of the basic Petri net model are (1) the extension with color to model data, (2) the extension with time, and (3) the extension with hierarchy to structure large models (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 13).

1) The color extension

Tokens are the representation of the objects in the classical Petri net, but they are indistinguishable. In fact, they are all blacks and it is not possible to understand the difference. This extension allows tokens to acquire a color, with the result that each token will have a value. The tokens will become different from one each other. The tokens that have the same characteristics, properties, values, etc. can be colored by the same color. Petri nets with color extension have to respect more rules than the classical one. For example, the firing transitions produces tokens which are based upon the values of those consumed during firing (van der Aalst & van Hee, 2001, p. 46). This means that the value of a produced token may therefore depend upon those of consumed ones. Another difference from the classical Petri net, it is that the number of tokens produced can be variable. The value of the tokens consumed can determine the number of tokens produced, now that tokens are different and therefore have different properties. Furthermore, it is possible to set preconditions to synchronize tokens, this means that a transition can fire only if a combination of tokens is ready.





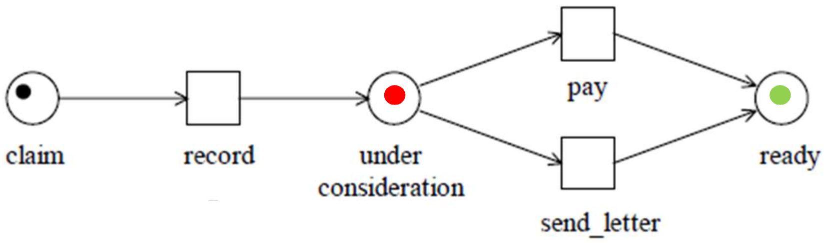


Figure 14. The color extension process (van der Aalst & van Hee, 2001, p. 43)

Figure 14 illustrates the development of a Petri nets that use a color extension. In the start marking there are three tokens in the first place. The second state shows the firing of the first transition, one token moves from the first place to the second place 'under consideration'. In the second place the token can acquire a color: if it will become green it can move through transition 'pay', otherwise if the token will become red it can move though transition 'send_letter'. The second state shows a green token in the second place, this means that the token has acquired a value after the transition 'record', it respects the characteristics in order to allow a payment, for this reason the token can acquire the color green. In the second state, a second token moves from the first to the second place through the transition 'record', but in this case it does not have the properties to acquire the green color but it has different characteristics so it can acquire a different value and a different color, red. This token will be moves from 'under_consideration' to 'ready' through the transition 'send_letter'. The color extension allows to understand which directions the tokens can take.

2) The time extension

Modeling a process, often managers want to know the expected completion time and the capacity required. The classical Petri nets do not have pertinent information to answer requests about timing of a process the model. For this reason, there is the time extension. Tokens receive a timestamp as well as a value (van der Aalst & van Hee, 2001, p. 49).Each token has a timestamp which models the time the token becomes available for consumption (van der Aalst, van Hee, & Houben, 2000, p. 18). A transition is only enabled at the moment when each of the tokens to be consumed has a timestamp equal o prior to the current time. This means that the enabling time of a transition is the time when the input place or input places contain enough tokens to enable the transition. The tokens are used according to a certain time, so there will be tokens used before others. Surely the tokens that enter the transitions first are also the first to exit. In this way the tokens must follow an order of both entry/exit and time. It may happen that there are transitions that have the same time of enabling as first, in this case it is not specified which transaction will start first. Obviously, the transition firing will affect the moment of enabling the others. Once a transition has the input to proceed it produces tokens that have the same timestamp as the transition or with a delay. The delay is added to the transition time. The delay may depend on the value of the tokens consumed or may be arbitrarily decided before the process starts. Firing itself is instant and takes no time.

Below there is an example to explain the time extension. The example illustrates a case where the time it is very important.

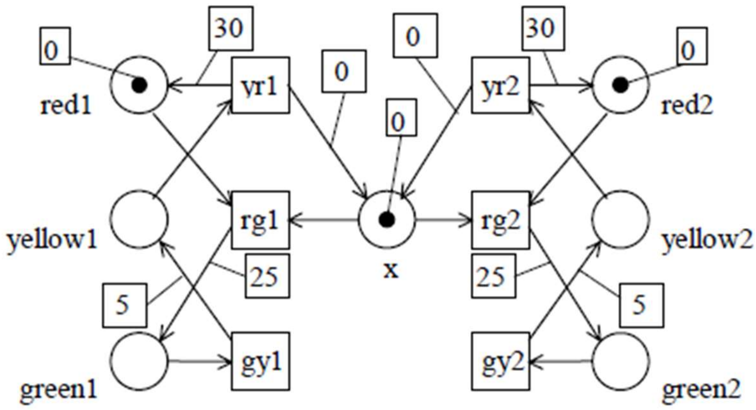


Figure 15. The two sets of traffic lights with time (van der Aalst & van Hee, 2001, p. 49)

Figure 15 illustrates the case of the two sets of traffic lights which must not simultaneously be at green or yellow. As in the figure, at time 0 both sets are at red. In this moment the timestamp of red1, x and red2 are 0. The enabling time of the transitions rg1 and rg2 is 0, so it is not specified which transition can fire first, but the firing of one transition can affect the time of the other one. If rg2 fires, it consumes two tokens from the input places, and it produces one token for the place green2 with a delay of 25-time units. After this move, there is a token in green2 with a timestamp of 25, and there is only one transaction that is enabled, gy2. At the time 25, the gy2 fires and it creates a token at yellow 2 with a timestamp equal to 25 + 5 = 30. At the moment 30 the transition yr2 can fire and it produce two tokens, one for the place red2 and one for the place x. The token to the place red2 has a delay of 30 while the token to the place x has not delay. The result of the firing is that rg2 has an enabling time of 60 and rg1 an enabling time of 30. After yr2 will fire, the rg1 transition can fire and the process can continue it. The time extension of the model has decided the timing of the various phases but also it has forced the traffic lights to change alternately.

3.2.5 Applying Petri Nets Theory

It is important to note that the fact that if a task can be executed for a specific case, then this does not mean that the task is executed directly (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 22). This means that a task does not only need the presence of material resources, represented with tokens, but new elements take action. For example, there are tasks that must be performed by a resource (operator), who if he is sick or absent, the task cannot be performed. But there are also other elements that are external vectors to the company but still affect the process. The same customers can influence the outcome of the process, having to perform some operations to be able to continue the process, such as to request a refund of a product the customer must first fill out a special form. If this is not done, the activity cannot be carried out. These examples show that there are additional conditions that must be fulfilled in order to perform certain types of tasks. Furthermore, these tasks cannot be forced by the workflow management system. At this point it is essential to clarify the two terms: enabling and execution. The first does not imply that the task is executed immediately, while the second implies that all executions must be in place in order to execute a task. Execution therefore introduces the concept of triggering. A trigger is an external condition which leads to the execution of an enabled task (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 22). The execution of a task starts the moment the task instance is triggered. It is possible to distinguish four types of tasks:

Automatic: a task is triggered the moment it is enabled. These tasks don’t need human interaction and they are executed by an application.

User: a task is triggered by a human participant, i.e., a user enables task instance to be executed. In a workflow management system, each user has a so-called 'in-basket', it contains tasks instance that are enable and may be executed by the user.

Message: when an external event triggers an enabled task instance. Examples of this type of external event are telephone-calls, fax message, e-mails or EDI messages.

Time: an enabled task instance is triggered by a clock, i.e., the task has a predefine executing time, an example can be the traffic lights explained before.

Only for the first type of the task, the enabling and the actual start of the execution coincide.

These types of triggered tasks can be represented differently in the process, through the use of symbols that help to understand which events are necessary to start. The most commonly used symbols to represent these triggered tasks are for example an arrow, an envelope or a clock as the Figure 16 below illustrates. The symbol depends which type of triggerings is used.

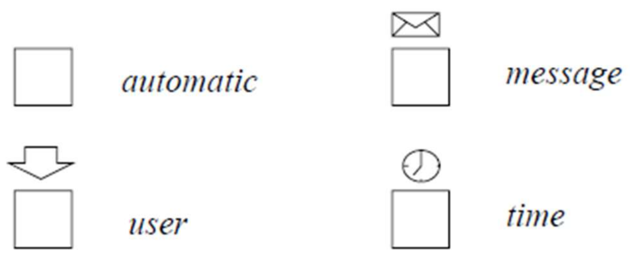


Figure 16. Four types of triggering (van der Aalst W. , The application of Petri nets to workflow management, 1998, p. 23)

3.3 Event-driven process chains (EPC)

Event-driven process chains are an intuitive graphical business process description language introduced by Keller, Nüttgens and Scheer in 1992 (van der Aalst W. , 1998, p. 642). The language is targeted to describe processes on the level of their business logic, not necessarily on the formal specification level, and to be easy to understand and use by management. The name of this tool derived from its diagram picture.

3.3.1 The structure

The figure 17 shows an example. Its aim is to illustrates a diagram that represents a process as a chain of events and functions.

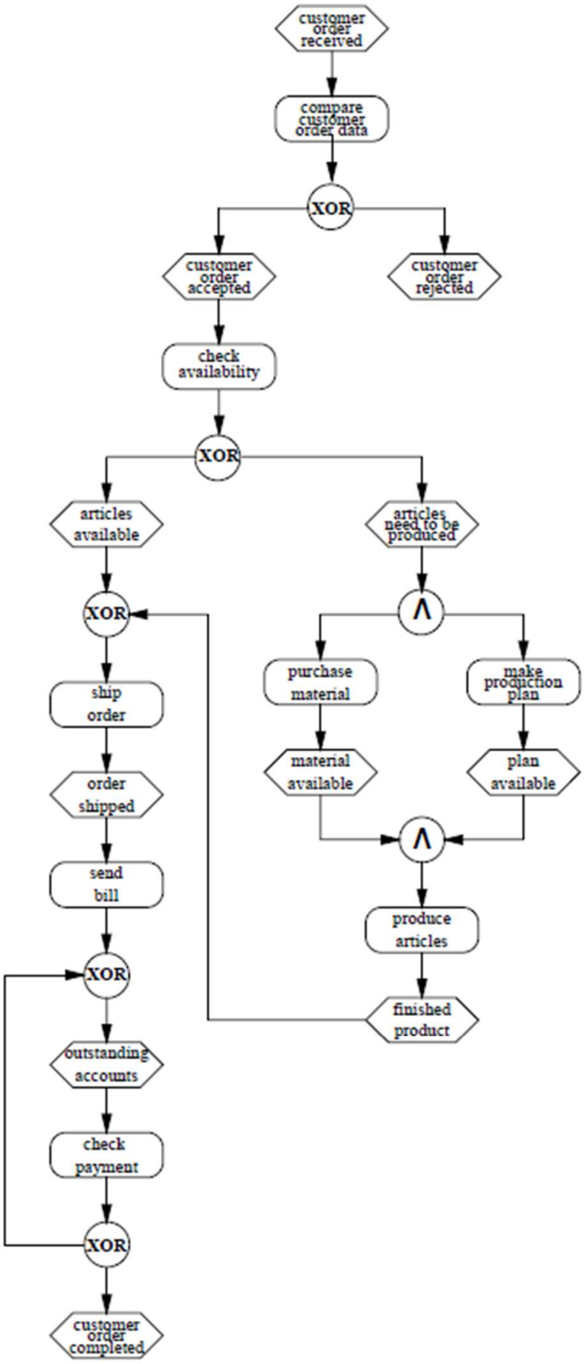


Figure 17. Modelling of a business process, using event-driven process chains (van der Aalst W. , 1998, p. 643)

Figure 17 illustrates an example of a business process that is modeled by event-driven process chains. It is possible to understand which the main elements of this tool are.

The key elements are:

Functions: they are the basic elements of this tool. They are represented like blocks, and they are activities (task, process step) which need to be executed. From Figure 17 examples of this element are ‘compare computer order data’, ‘check availability’, ‘ship order’ and others.

Events: its scope is to link functions between them. They describe the situation before and/or after a function is executed, they can be considered as preconditions and postconditions. They are represented graphically by a figure that is like a diamond. Examples of events in Figure 17 are ‘customer order received’, ‘customer order accepted’, ‘customer order reject’, and others.

Logical connectors: they are used to connect events and activities. They are also the tools used to regulate the flow of the process. There are three types of connectors and they are represented with three different symbols:

Λ it means AND

XOR it means EXCLUSIVE OR

V it means OR

The example of Figure 18 shows just two types of these logical connectors. Their meanings are different, and they are used to describe the flow process. The reason why there are three different connectors is that depending on how you want the process to go, you have to use different connectors. The first one, which means E, is used to indicate how the process at that point divides and takes different paths. This allows a process that has only one direction to take two that can operate simultaneously. The second connector used in the EPC has XOR as its symbol. This connector is used when the process has to make a choice, at that point the process has to decide which direction to take. Therefore, the process is divided into two directions and taking one precludes the other, they cannot be run at the same time. The last connector, used with the meaning of OR is more complex to explain and to understand, because it is difficult to give a formal meaning. In fact, when this is used, as in Figure 18 below, there are three possibilities of interpretation. If event X holds, function A or B needs to be executed. There are three possibilities: (1) function A, (2) function B, or (3) function A and function B are executed (van der Aalst W. , 1998, p. 21). Even with this definition it is difficult to determine what the exact definition of this connector is and whether it should be synchronized. A proposed solution to control this problem is to improve the event-driven process chain by replacing all these connectors with E and XOR connectors. This solution, however, has as a result to make the event-driven process chain much more complex and larger, going to greatly increase the possible combinations.

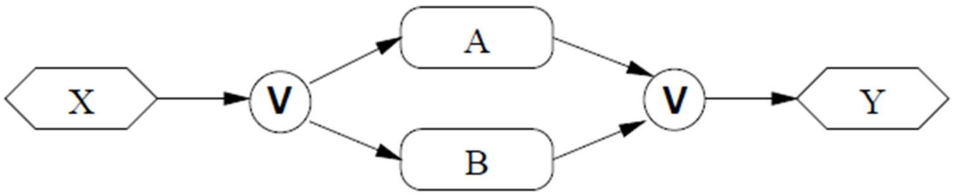


Figure 18. An event-driven process chain showing the use of V connectors (van der Aalst W. , 1998, p. 659)

3.3.2 Mapping EPCs onto Petri nets

Petri nets have formal semantics, this helps to specify the behavior unambiguously of the event-driven process chains (van der Aalst W. , 1998, p. 9). In the early stages of the (re)design of a business process it is not needed a precise and detailed diagram. A formal semantics could be ignored in the first stages of the (re)design process. It is more important to specify the behavior unambiguously if the event-driven process chains are used as a starting point for analysis. Using Petri nets to map the event-driven process chains can reduce the unclear nodes of the process. Events are changed with the places of the Petri nets, and the functions are represented by transitions.

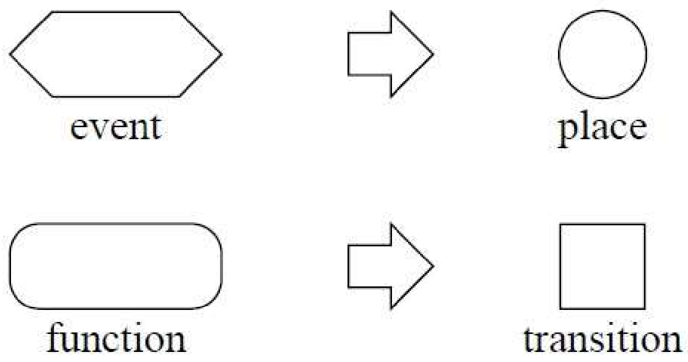


Figure 19. Mapping of events and functions to places and transitions (van der Aalst W. , 1998, p. 648)

The translation of connectors is much more complex. A connector may correspond to a number of arcs in the Petri net or to a small network of places and transitions (van der Aalst W. , 1998, p. 648). There are rules to transform an event-driven process chain to a Petri net. When events are directly connected to functions or vice versa, it is possible to map the in-between arc onto a flow relation (La Rosa, 2009, p. 60). If there are connectors, they need to be transformed in Petri net to re-build their splitting or joining behavior. A connector of type Λ between a set of events and one function, it corresponds to the places in the function's preset. Otherwise, if the Λ connector is between a set of functions and one event, the Petri nets need to add two places and one transition to capture the synchronizing behavior. If there is a XOR-join between a set of functions and one event is directly mapped to the merging behavior of the place corresponding to the event, with the functions corresponding to the transitions in the place's preset. Otherwise, if the XOR-join is between a set of events and one function, we need to add two silent transitions and one silent place to capture the merging behavior. These rules are the same for the split connectors. The figure 20 shows the several examples of the transition of connectors onto Petri nets. The figure a represents the transition of an AND-join between a set of events and one function. The figure b illustrates an AND-join to a Petri nets between a set of functions and one event. The figure c corresponds the transition of XOR-join between a set of events and one function. Figure d illustrates the transition of XOR-join between a set of functions and one event. The figure e, f, g and h represent the transitions of split connectors.

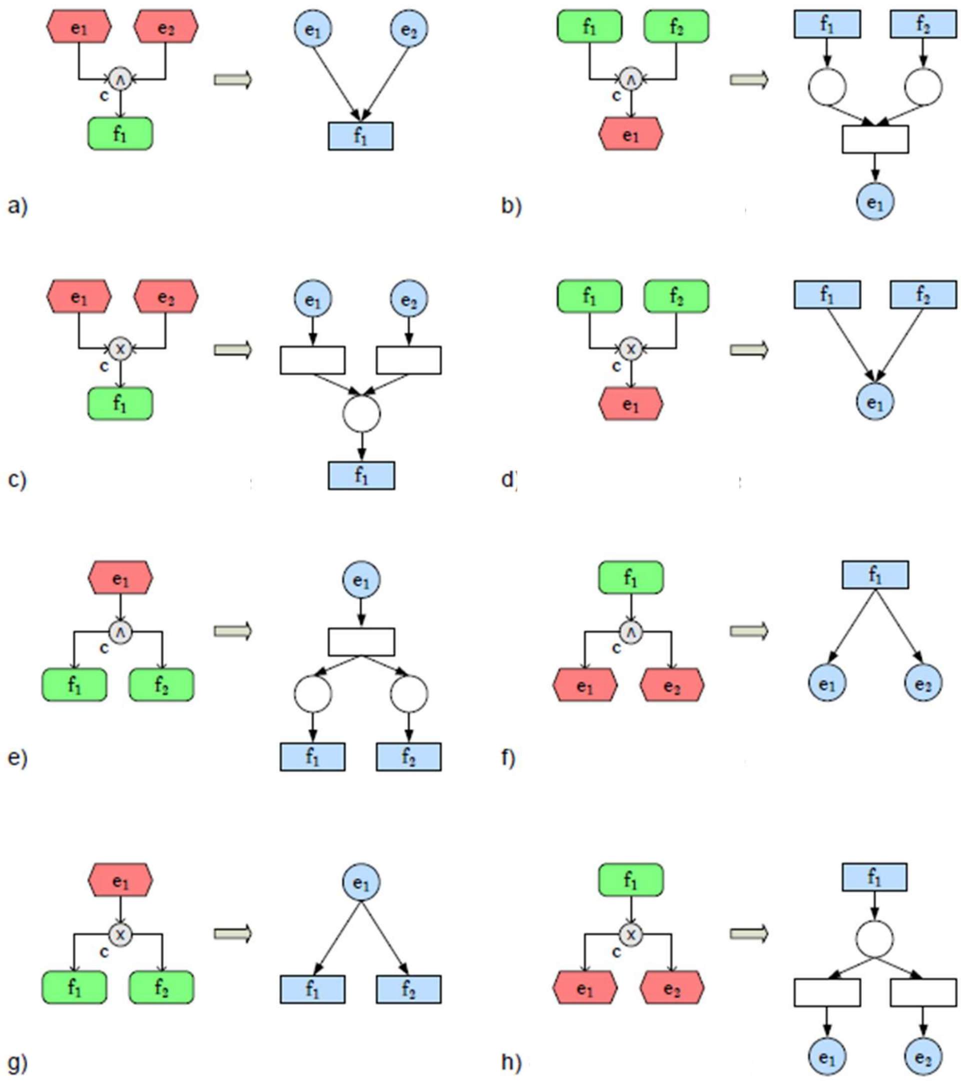


Figure 20. Mapping EPC connectors to Petri net places, transitions and arcs (La Rosa, 2009, p. 61)

The figure 21 below is an example of the translation of an event-driven process chain to a Petri net. Starting from the first chart it is possible to see how connectors and arcs are transformed. The arc between the XOR-join and the AND-join is replaced by function X and event X and three arcs. Petri net is more detailed on the representation of the process and it is also more specific than the event-driven process because it is possible to see all events and functions of the process and it is also possible to add some level to describe specific portion of the process.

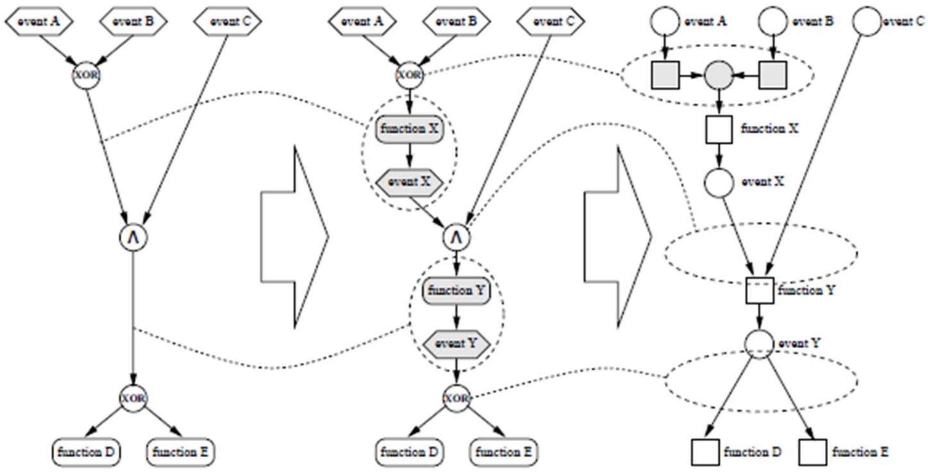


Figure 21. The phases of the transformation of a EPC into Petri nets (van der Aalst W. , 1998, p. 651)

3.4 PERT chart

The main objective of PERT is to facilitate decision making and to reduce both the time and cost required to complete a project. PERT is intended for very large-scale, one-time, non-routine, complex projects with a high degree of intertask dependency, projects which require a series of activities, some of which must be performed sequentially and others that can be performed in parallel with other activities.

3.4.1 Definition of PERT

PERT, the Project Evaluation and Review Technique, is a network based and for planning scheduling the many interrelated tasks in a large and complex project (Chinneck, 2015, Cap 11. p. 1). This tool was developed during the design and construction of the Polaris submarine in the USA in 1950, which was one of the most complex activities ever carried out until then. Today it is a tool used daily in the design of very complex projects such as the creation of software or the construction of large constructions. The idea behind the development of the Pert tool is to help organize optimization.

The PERT chart is used by managers and companies to:

- set a realistic timetable for project completion

- understand the critical tasks along the process and move the focus on them, because any delays on the execution of these tasks result in a delay to the overall project
- identify tasks that can be performed in less time to reduce the time of entire process
- identify tasks that can be performed simultaneously
- identify slack time where there is no critical activity that could compromise the overall process duration.

3.4.2 The PERT planning

PERT uses a network representation to capture the precedence or parallel relationships among the tasks in the project (Chinneck, 2015, Cap 11. p. 1). There are a series of steps that needed to be followed to design the PERT chart. Bellow there is the description of each steps (Archibald & Villoria, 1967, p. 46).

1. Identify the specific activities and milestones. In this step it is required to identify the acvtivities needed to complete a project. The milestones are the events that highlight the beginning and the end of one or more activities. A table that contains all the information about activities, as sequence and information, can be helpful.

2. Determine the proper sequence of the activities. This phase, in addition to identifying the activities that make up the process, is responsible for determining the sequence in which the activities are carried out and follow one another in the process.

3. Estimate the time required for each activity: At this stage the execution time of the process is estimated, usually as a time unit the week is used but any time unit can be used. Three time estimates for each activity are included in each model:

   Optimal time - is the shortest time the activity can be completed.
   Most likely time - the time of completion that has the highest probability. This time is different from the expected time.

   Pessimistic time - the longest time required to complete the task.

The PERT analysis also considers a probability distribution for time estimates. Using a weighted average to calculate the approximate estimated time for each activity, the formula used is as follows:

Expected time = (Optimistic + 4 x Most likely + Pessimistic) / 6

All these data are entered in the table so that you can have all the important information summarizing the execution of the process. The figure below shows an example of a table containing all the information described above and essential to perform the process analysis according to the PERT chart.

Task Identifier	Task Description	Predecessor Task(s)	Optimistic Time (O)	Most Likely Time (M)	Pessimistic Time (P)	Expected Time (T_E)
A	Establish project		4	5	12	6
B	Establish customer requirements	A	2	3	4	3
C	Produce software specification documents	B	6	8	22	10
D	Write test plans	C	4	6	8	6
E	Write code	C	3	4	5	4
F	Developer testing	E	2	4	6	4
G	System testing	D, F	2	3	4	3
H	Write manuals	C	5	7	15	8

Figure 22. Example of table that summarize information to PERT analysis (Langfield & Duddell, 2015, p. 425)

4. Construct a network diagram: Using the information from the previous step, it is possible to draw a diagram showing the sequence of activities, showing those in sequence and those in parallel. The diagram consists of nodes representing the activities and arrows, which connect the various nodes and represent the relationships between them. The Figure below illustrates the transposition of the table into a chart.

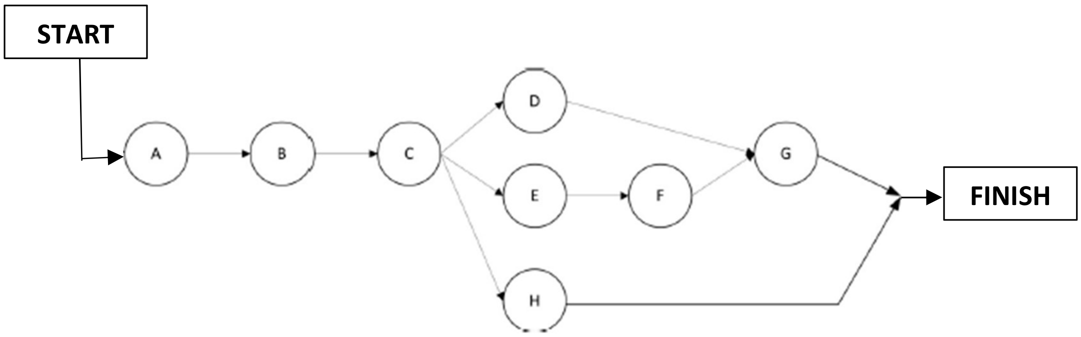


Figure 23 Example of network diagram of a PERT chart (Langfield & Duddell, 2015, p. 426)

5. Determine the critical path: The critical path determines the total calendar time required for the project. The critical path is determined by using the estimated times to work out the earliest start (ES) and finish (EF) times (forward pass), and latest start (LS) and finish (LF) times (backward pass) and identifying the tasks where ES and LS are equal. The Figure shows how to represent the activities in the PERT chart and how the different execution times of the activity are entered.

Early Start	Duration	Early Finish
Task Name		
Late Start	Slack	Late Finish

Figure 24 Representation of task with ES, EF, LS and LF (Langfield & Duddell, 2015, p. 427)

To identify the critical path there are three steps to follow:

Step 1: Forward pass.

It is executed starting from the left of the graph and going to the right. Considering the example shown above, the ES of activity A is week 0, while the EF of this activity is 6, which is calculated by adding to the ES the estimated duration of the activity represented by the number on the last column of the table containing all the data with times. Continuing to the right is activity B, which has week 6 as its first time to start, i.e. when activity A will be complicated. So the ES of activity B is 6 and has as EF the sum of 6 and 3, then 9. When an activity is preceded by two different activities that derive from two different paths, the corresponding EF plus another one of the predecessors is taken as the ES of this activity.

Step 2: Backward pass

It is executed in reverse to the one described above, starting from the right and ending on the left. It then starts from the end and the overall execution time of the process. Considering the example taken into consideration the final time is 33 weeks, so the activities that precede the end of the process, G and H have an LF of 33 weeks. Considering the activity H, which has an execution time of 8 weeks, its LS is 33 - 8 = 25 weeks. For those activities that have more than one activity as successors, for example C, the LF is calculated by taking the lowest number among the different LFs of the activities that succeed it. So for example activity C has as LF 19, which is the minimum number among the different LFs of the activities succeeding it, i.e. D, E and H.

Step 3: Critical path and slack

The last step is to identify the critical path. This is identified taking into account those activities where ES = LS, this means that these activities have no 'time frame' for a task in the project, so if there are problems during the process of delays caused by lack of resources or delays caused by previous activities this would delay the whole process and increase the total execution time. As can be seen in the Figure in the representation, the different execution times of the activities are inserted in order to obtain the critical path. Usually this is also highlighted, changing the color of the arrows that connect the different activities in order to understand which path of the process is critical in its execution.

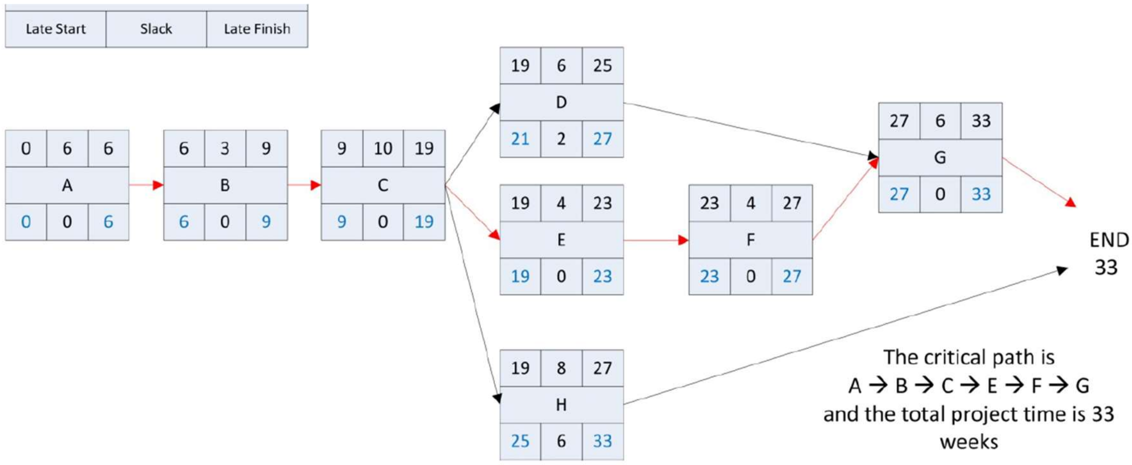


Figure 25. PERT chart with critical path (Langfield & Duddell, 2015, p. 427)

SECOND PART: The study of a German start-up, Amavido

4 The case study of a German startup: Amavido

The theoretical part just described will be applied by studying the case of Amavido GmbH, a Berlin-based startup dealing with slow tourism. This company has been taken into consideration to prove how the use of the tools as EPC, Petri nets and PERT (that are typical of companies with managerial figures) can influence even small companies that are in their first years of activity. In fact, these tools are usually used by companies that already have a well-organised structure because they require an investment at the economic level but also at the personnel level. In this chapter it is explained how these tools can help the daily management processes. The limits that these tools have once applied and the improvements are been pointed out. Thanks to my internship at this startup, I was able to know and understand the process on which the activity is based. This allowed me to understand the strengths and the weaknesses of the process.

4.1 The startup Amavido

“Our vision is to make tourism more intimate. Our goal is to make visible in visible beauty. We believe in ‘small but nice’. We believe that there is a lifestyle hidden in the small hidden villages that is waiting for us and that we can search for in the city, but never find. There are still many great and beautiful places to discover and many stories are just waiting to be told. Traditions are worth living and experiencing and typical dishes are waiting to be tasted. Forgotten feelings need to be rediscovered and extraordinary moments need to be lived. Amavido is a lifestyle that aims to see the world through different eyes, think differently and promote a new way of travelling. Our twelve employees partly travel to your hosts in Italy themselves to ensure that you will have a fulfilling holiday there. Amavido exists since the end of 2015. At the beginning of 2017 we finally moved into our office in Zeuthen, from where we can now fulfill your wishes together” (Amavido, 2015). This is the description that this startup uses in its website to describe what it does.

Amavido for now operates in the German territory, having as reference customers the German tourists who want to discover Italy and its beauties by staying in facilities located in some places that are far away from mass tourism, ad this choice enhances the territory and Italian traditions. The startup acts as an intermediary between German customers and

Italian hosts: the company is able to organize a very personalized offer according to the customer's preferences. Thanks to this customization the tourists can stay in facilities that are difficult to find in large search engines and aggregators of offers. At the same time, Amavido is able to guarantee a targeted service for small and medium Italian structures that want to enter and offer their services to the German market.

The company has not a complex organization (typical of structured companies) but it has a very flexible organization that can be adapted to the various needs that arise during the activity. Despite this, it is possible to identify the various roles assigned within the organization. Workers can be divided into four departments but they can be moved from one to another according to the workload and the needs of the activity. The four departments that can be identified are:

1.Accommodations department

2.Customer department

3.Booking department

4.Accounting department

4.2 Amavido's process

After this introduction on Amavido is and its mission, it is possible to proceed with the mapping of his main process using the tools explored in the third chapter: Petri Nets, EPC and PERT. The process of processing a client's request is represented using the three different analytical tools.

The process starts with the customer's request that is made through the filling in a form on the Amavido website. The form allows the costumer to skim his choices, according to his preferences. He can decide where he prefers to go to: to the sea, to the mountains or to the hills; then he can choose which part of Italy he would visit: the north, the center, the south or the islands. Then he can describe how he imagine his stay in Italy: the entire period in one place, a round trip or every two or three days in a different place and accommodation in order to see and explore more places in Italy. Then he can express what kind of activity he wants to do in Italy: sportive activities, or a culinary and gourmet experience or a cultural experience. Finally he can decide which type of accommodation he prefers for his stay in Italy: a home, an apartment or a room in a hotel. These parameters allow the Amavido team to organize in a better way the offer for the customer. In fact, thanks to this form the Amavido team can collect the basic information to proceed with the process.

The process continues with the evaluation of the customer's requests and eventually the team contacts him for further information. It could happen that the client makes requests that do not match with Amavido offers, in this case the request is not accepted and after the evaluation the process ends: the form is rejected and archived. If the request is accepted, the process continues and here there is the first node where the process can take two different directions. One direction is characterized by a research in the database where there are all the accommodations that collaborate with Amavido. The other one consists in finding new hosts.

When one or more possible hosts are found, the worker proceeds with fixing the option: this means that Amavido asks to the host accommodation to reserve a room, a house or an apartment for three or four days in order to give to the client time to confirm or not the reservation.

After this phase, a new worker intervenes in the process: he has the role of adding and booking one or more activities that the customer will perform during his holiday.

Afterwards the summary documents which collect the different offers are sent to the client.

At this point of the process the customer can decide to confirm or rejected the offer that he has received:

if the customer confirm the offer Amavido proceeds with the booking of the host accommodation;

if he does not like it, Amavido deletes the reservation of the host accommodation.

According to this the process ends with the confirmation and payment of the entire trip or the rejection of the offer.

4.2.1 Rules to follow to design a Workflow

The process of composing and designing a workflow consists of four steps:

1. What: Select the workflow which has to be designed.

2. Why: First establish the objective of the workflow to be designed.

3. How: Then establish the steps which must be carried oud, and in what order.

4. Whom: Finally, establish the allocation of work to resources.

The figure below (Figure 26) shows graphically the process of developing of a workflow. Furthermore, it illustrates how these four phases are distinct but at the same time they are connected.

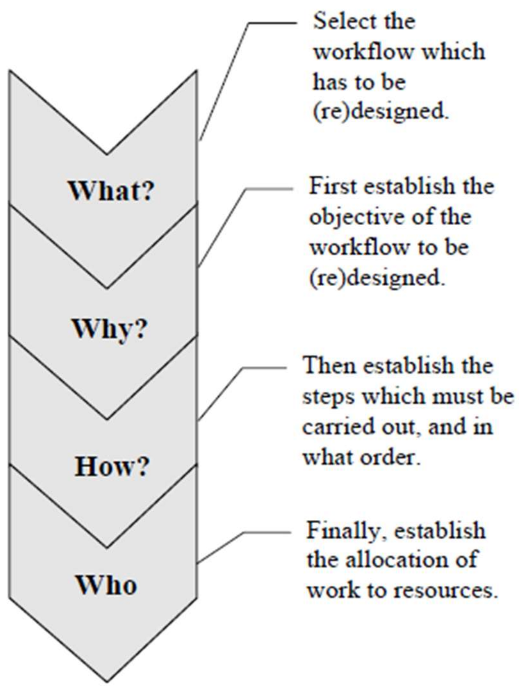


Figure 26 The four phases through which the design of a workflow passes (van der Aalst & van Hee, 2001, p. 93)

The best practice to follow for design a workflow are (van der Aalst & van Hee, Workflow Management, 2001, p. 92):

1. Establish the objective of the process.

At this stage it is important to consider the role of the process within the company's business. It is important and necessary a restructuring of this in order to clearly define the new workflow and to avoid misleading problems.

The example explained below consider the process of a German startup, Amavido. The main process focuses on organizing a travel in Italy for German customers. The process is analyzed because it has to avoid delays and bottle necks to guarantee an efficient and a quick service.

2. Ignore the existence of resource when defining a process

At this stage it is important to define the process by identifying the tasks that make it up without the resources. In fact, the definition of the process is independent of the potential offers by people and machines. It starts by making a list of the tasks required. Then it is possible to proceed forming the links between the various tasks.

This second phase can be considered fundamental for the success of the organization of the process. Below there is a list with the main activities of the process of Amavido:

a) Evaluate customer request
b) Check availability
c) Research host
d) Research a new host
e) Fix option
f) Select the activity
g) Booking the activity
h) Booking host
i) Made documents
j) Delete travel
k) Send confirmation
l) Send documents

3. Check the need for each task

In this phase the need for individual tasks are analyzed. In fact, some tasks are often used as a control or troubleshooting point during the process. These types of tasks increase the duration of the process and also do not add any value to the result. For this reason, it is recommended, after having listed the tasks, to analyze them and eliminate those that are considered unnecessary and do not add value. The process becomes easier and more flexible than before and reduces the execution time.

Analyzing the tasks that compose Amavido's process it is important to understand which of them added value to the process and which could be eliminated. Considering that the company was born only a few years ago, the process is very flexible and simple without a hierarchical structure. For this reason, all the tasks are considered useful and they add value to the process.

4. Consider the scope of tasks

Considering a task as logical unit of work, it is recommended to merge the separate tasks into one composite task. In this way the execution time of the tasks and the whole process will be shorter. At the same time, however, the tasks should not be too long, as they should always be able to be executed at a single time without interruption. Complex tasks could also influence the flexibility of the process that could become very difficult to execute.

The application of this practice into the process of Amavido suggests to merge some tasks. Considering the representation of the process, the process is divided into two sections immediately after the acceptance of the request: the tasks enclosed within these two different directions could be simplified by using only one task that combines the search and reservation tasks of a new host or a registered host. This reduces execution time and simplifies the graphical representation of the process in order to make it more flexible.

5. Carefully weigh specialization versus generalization.

Another important step is not to define a separate process for each type of case. It is important to create a generic process that allows differentiation between case types using the path. For example, if the process starts with an OR-split, this means that the resulting cases are all sub-processes of the main process. These are just versions of the same process. Sometimes generalizing the stages of a process can lead to negative effects. For this reason, it is possible to specialize some phases in order to make them more suitable to the specific qualities of each resource. However, this can lead to a reduction in flexibility and increase the monotony of work. Therefore, it is necessary to be able to correctly identify the cases in which it is possible to carry out a specialization of the tasks.

6. As far as possible try to achieve the parallel processing of tasks.

In this phase of designing a business process the focus is on the tasks that can be performed simultaneously, also called in parallel. In fact, if two tasks can be performed independently of each other, first of all it is essential that the process allows it and if it happens the two or more tasks have to take place at the same time. The positive aspects of this phase are to reduce the length of the process, to improve the flexibility and to perform efficiently too.

7. Study of resources

At this point of the improvement process, resources are introduced, the same resources that were not initially considered. Now they are added to the process, in order to make it complete and to be able to communicate as much information as possible through the graphical representation. The resources are nothing more than the people who work along the process and who facilitate the execution of the activities. Evidently, they can also be technological means such as robots or computers. Obviously adding resources to the process brings advantages and disadvantages: from a graphically point of view the resources generate information in order to understand in a better way the process, but at the same time they produce an higher level of criticality and a reduction of flexibility of the process. In this phase the resources that are involved in the process should be analyzed, so it is possible to understand if the available resources are adequate or not.

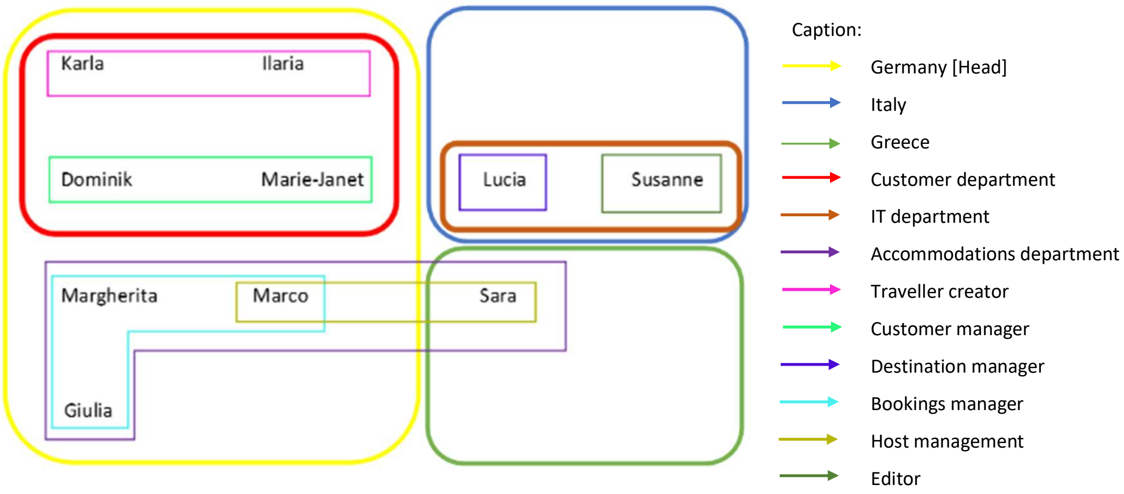


Figure 27. The resources' structure of Amavido

The Figure 27 illustrates the structure of human resources. The representation shows the people who works and are involved in the Amavido's process. There are several rectangles that group resources according to the activities they perform or according to the department to which they refer. From this scheme it is possible to understand how the structure of the resources within the company is organized. The first division is made considering the workplace of resource. In fact, although the main office was in Berlin, there are people that work remotely from Italy and Greece. The yellow dial contains all employees that work in the office in Berlin, while the blue dial contains those work from Italy. The third quadrant contains the only resource that works remotely from Greece. Then there is the division of resources according to the department to which they belong to. The departments are: accommodations department, IT department and customer department. Finally, there is the classification of resources according to their function, based on what they do within the company. This subdivision is more detailed and allows to divide the resources into traveler creator, customer manager, destination manager, booking manager, host manager and editor. Through this classification it is possible to understand clearly how the resources of Amavido are distributed along the process and how they intervene managing the tasks.

8. Use of a resource’s specific qualities

Considering this best practice, it must be ensured that resources are able to use their specific qualities. Therefore, it is necessary to evaluate that resources are positioned in the right place of the process, where they can use their qualities in order to avoid a waste of time, delays or problems during the execution of the activities. It is necessary that the resources are deep integrated into the process, because a working process needs efficient workers and vice versa.

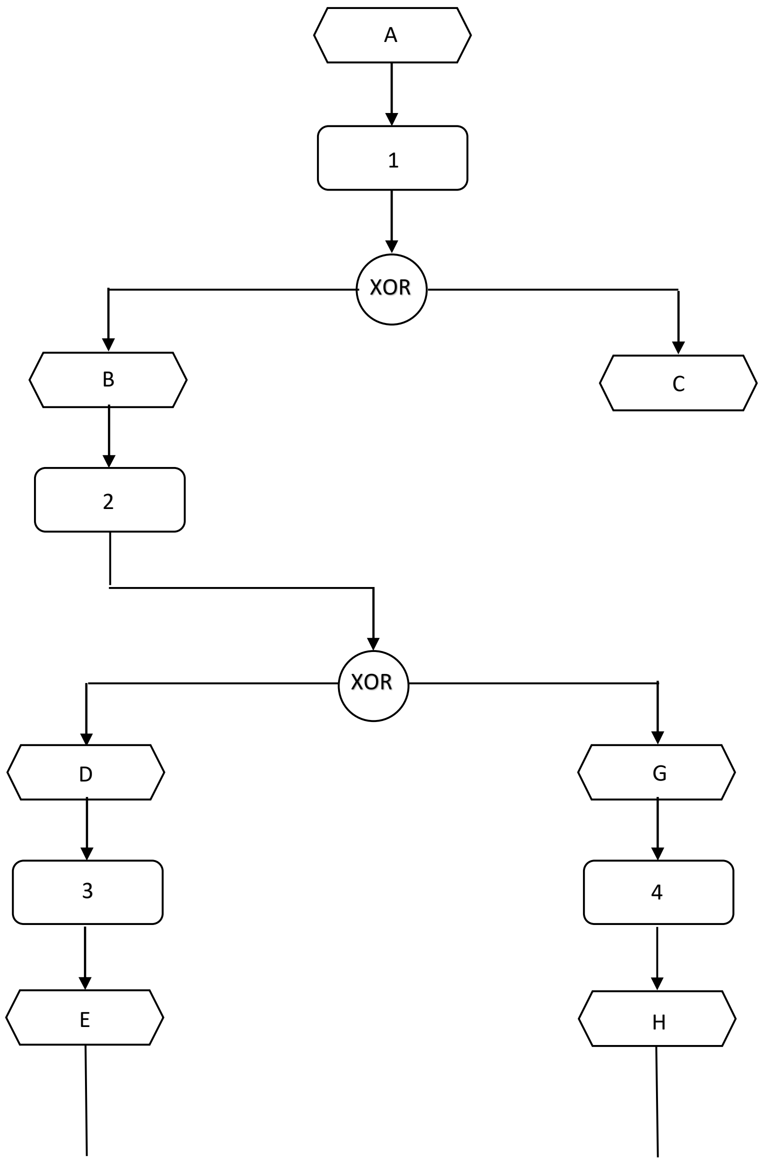
9. As far as possible, allow a resource to perform similar tasks in succession.

This phase, closely linked to the previous one, coordinates workers among themselves. Resources have to perform tasks that are similar in order to reduce the execution time and to improve the routines of the process. The distribution of the tasks allows the process to become more flexible and easier to manage.

The rules described before are useful to study and design the process through the analytical tools introduced in the 3 chapter. The first representation of the Amavido’s process is made through the EPC tool. Its focus is to study the process in order to understand the main activities and functions of the process. Then the EPC scheme is transformed into a Petri nets in order to study the resources and their behavior among events and transitions. Petri nets can be expanded with two extensions: the color and the time extension. This development of the Petri nets tools allows to increase information on the representation. Information are useful to improve the process execution and their behavior. The last tool used for representing the Amavido’s process is the PERT. It is more specific to organize and manage project. For this reason it can be an important start point to understand the critical tasks of the project. The results obtained with the PERT analysis can be implement on the process management improving the EPC and the Petri nets.

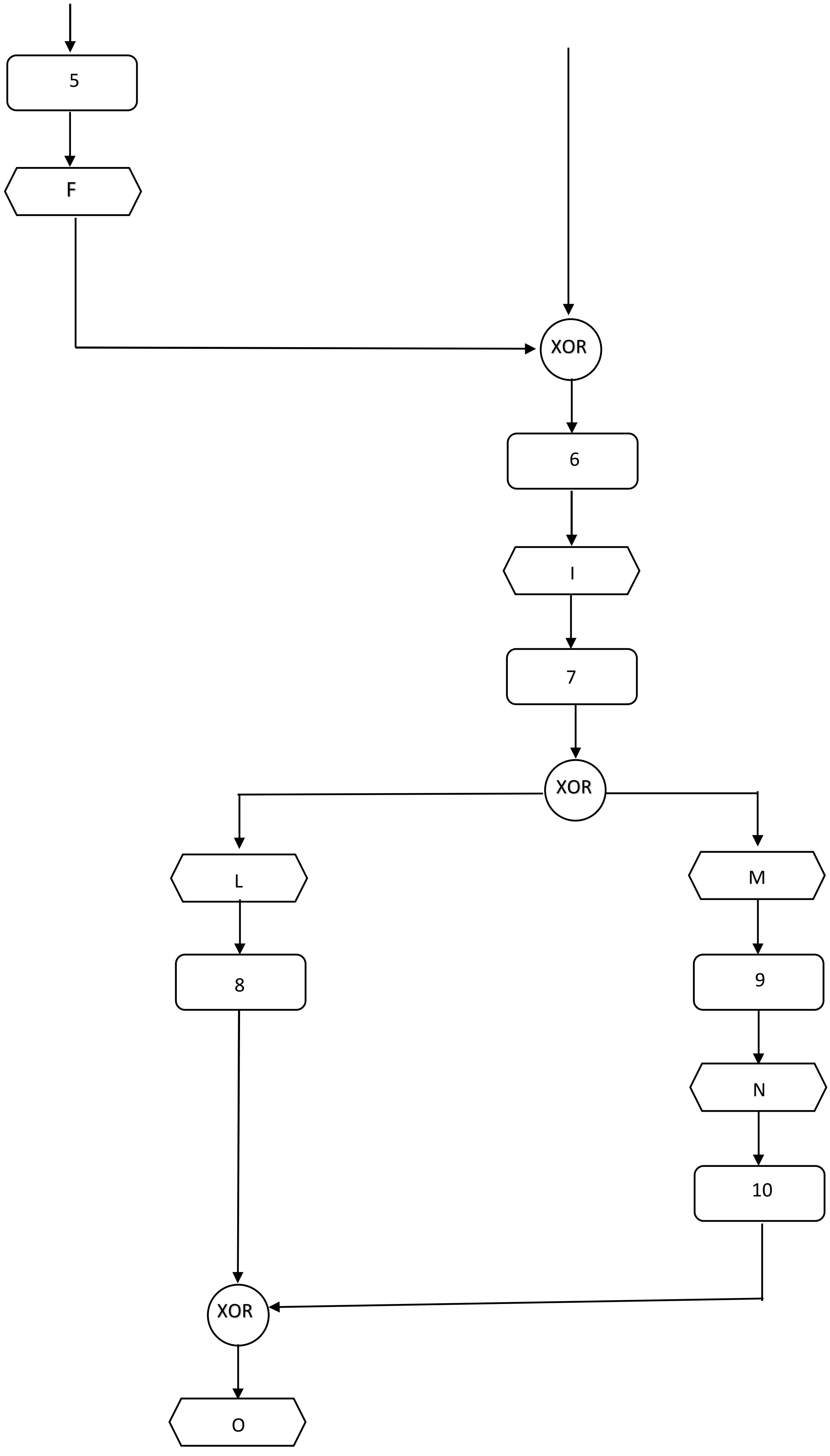
4.2.2 The EPC of Amavido's process

The first tool used to represent Amavido's analyzed process is the event-driven process chain. According to the theoretical framework, this representation is used to describe the process according to the business logic. The goal of this tool is to make clear and readable the process to those who will study the process. The representation of the process that is created using the basic EPC elements is represented in the figure below:



Events (States)	
A	Customer request received
B	Customer order accepted
C	Customer order rejected
D	Host need to find
E	New accommodations found
F	Reservation made
G	Host is in the database
H	Reservation made
I	Travel produced
L	Offer rejected
M	Offer accepted
N	Booking confirmed
O	Travel completed

Functions (Actions)	
1	Compare customer order data
2	Check accommodation
3	Search new accommodations
4	Check availability
5	Check availability and conditions
6	Find and add activity
7	Send documents to customer
8	Delete reservation
9	Confirm the booking
10	Receive payment


5
F
XOR
6
I
7
XOR
L
M
8
9
N
10
XOR
O

This scheme is used in order to get a general idea of the process and in order to understand how to develop it. The main purpose of this representation is to focus the attention on the events and functions of the process. However, this tool does not represent and does not take into consideration the resources.

Analyzing the EPC of Amavido it is possible to understand which are the main events that characterize the process of this start up. In fact, this tool allows to have a simplified graphic representation of the events that characterize the management, the creation and the booking of a trip for a customer. Moreover, in this diagram the main functions that must be performed along the process are clearly revealed. For this reason, this plan can be a help during the organization of the resources because the quantity and qualities of the resources can be chosen according to the different functions to carry out along the process. Other information can be also obtained from this graphical representation of the process: the nodes that appear in the design of the process represent points where the process can take different directions according to the characteristics of the request. Finally, these nodes are critical points for the process, where delays or buffering may occur due to the lack of information.

Below a SWOT analysis of this tool is created in order to point out positive and negative aspects of this and in order to understand when and how to use this type of representation:

Strength: it is an easy instrument because it is composed of few elements and its construction is simple too.

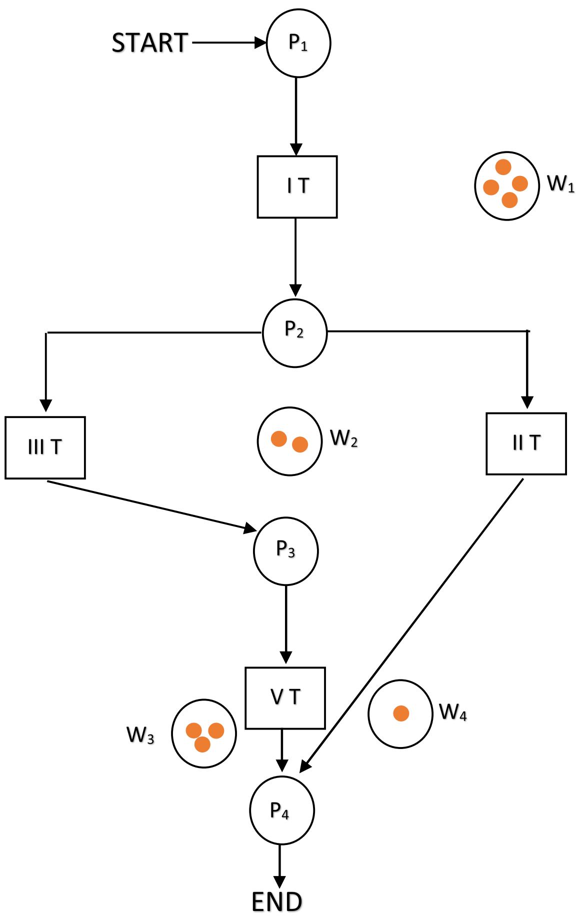
Weakness: from this type of representation the information about resources and workers does not appear directly. In fact, this tool represents the process in a general way through the events functions. Moreover, the nodes (in some cases) are not so easy to interpret and this means that the process could be interpreted incorrectly.

Opportunity: the scheme allows to understand any developments in the process and the improvements necessary by eliminating or adding functions and events. It also helps to understand possible critical points in the process.

Threats: from this tool it is not possible to understand in detail the internal and external factors that may influence the process.

4.2.3 The Petri nets of Amavido’s process

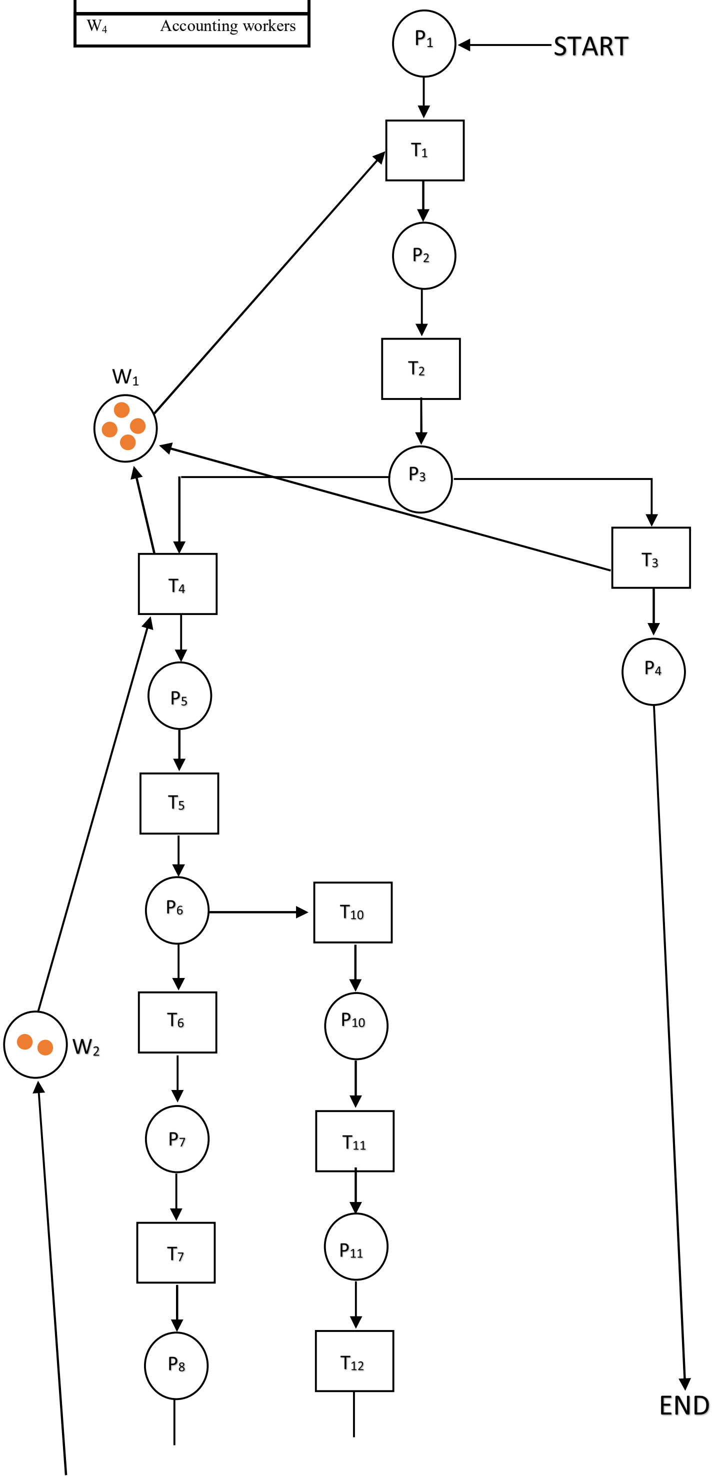
The second tool used for analyzing Amavido's process is the Petri nets. This representation is obtained by applying the theory explained in the chapter 3. Evolving the previous EPC graph into a Petri nets is a crucial step in order to obtain more information about the process. Petri nets diagram is easier to understand than the EPC scheme because Petri nets simplifies the critical nodes and it allows to represent the resources on the diagram. Below there is the figure that shows the Petri net of the Amavido’s process:



P_1	Request
P_2	Request evaluated
P_3	Offer created
P_4	Process complete
I T	Evaluation
II T	Reject request
III T	Create offer
V T	Confirm/delete offer
$W_{1,2,3,4}$	Workers

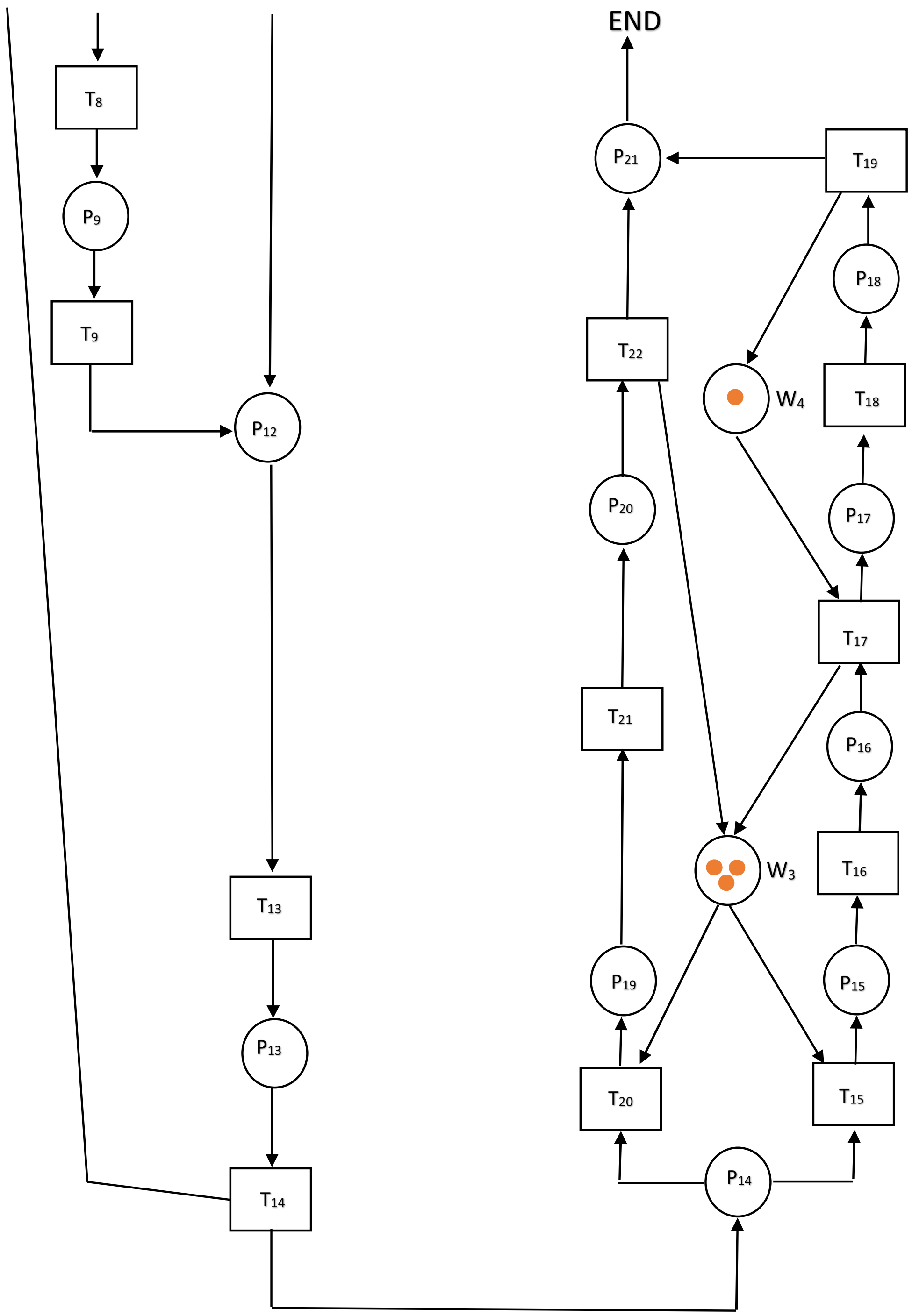
This chart illustrates the general representation of the Amavido’s business process. It is possible to see the five main transitions that characterize the process. The first phase is characterized by IT, the activity to evaluate the request received by customers. The second phase is characterized by IIT and IIIT. IIT is the activity to reject the request while IIIT is the activity to create an offer to the customer. This activity can be broke up into two sub-activity, IIITA and IIITB. The first one will create an offer searching on Amavido database, while the second one will create an offer searching new accommodations. The third phase is characterized by VT. This activity can be breaking up into two sub-activity, as VTA and VTB. VTA will deal to confirm and pay the offer while VTB will deal to reject and cancel the offer. Below there is the chart that represent the whole Amavido's process.

Workers roles	
W_1	Evaluation workers
W_2	Reservation workers
W_3	Booking/deleting workers
W_4	Accounting workers



Places	
P_1	Request
P_2	Took charge of request
P_3	Request evaluated
P_4	Request rejected
P_5	Taking charge of accepted request
P_6	Ready to find accommodation
P_7	New accommodations found
P_8	New host called
P_9	Availability checked
P_{10}	Found accommodation in the database
P_{11}	Availability checked
P_{12}	Option fixed
P_{13}	Activity booked
P_{14}	Customer received offer
P_{15}	Offer ready to be confirmed
P_{16}	Offer confirmed
P_{17}	Offer ready to be paid
P_{18}	Booking paid
P_{19}	Reservation ready to be canceled
P_{20}	Offer canceled
P_{21}	Offer

Transitions	
T_1	Worker takes charges of request
T_2	Evaluate the request
T_3	Reject the request
T_4	Accept the request
T_5	Search accommodation
T_6	Search new accommodations on internet
T_7	Call new accommodation
T_8	Check availability
T_9	Block option
T_{10}	Search new accommodations on database
T_{11}	Check availability
T_{12}	Block option
T_{13}	Search activity
T_{14}	Send offer to customer
T_{15}	Customer accepts offer
T_{16}	Confirm the offer
T_{17}	Customer send the payment
T_{18}	Pay the booking
T_{19}	Send documents to customer
T_{20}	Customer reject the offer
T_{21}	Cancel the reservation



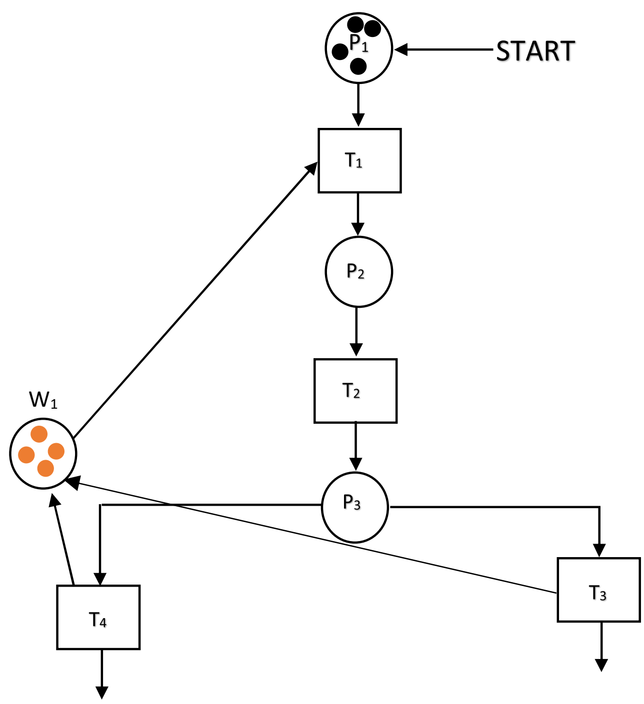
Transforming the previous scheme into a Petri nets makes it easier to compare the two tools. From the representation created using the Petri net tool it is easier to understand the process working behavior, especially by highlighting how resources are managed within the places and transitions. This tool, through the extensions, can implement useful information in order to understand details of the process particularly about resources management and time. The places W are the representation of groups of workers that are involved into the process.

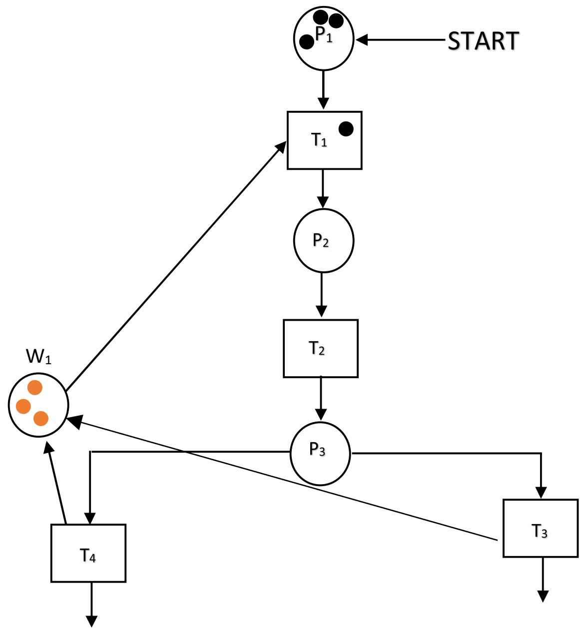
Following there are the representations of Amavido's process through two extension of this tool: the color and the time extension of Petri net.

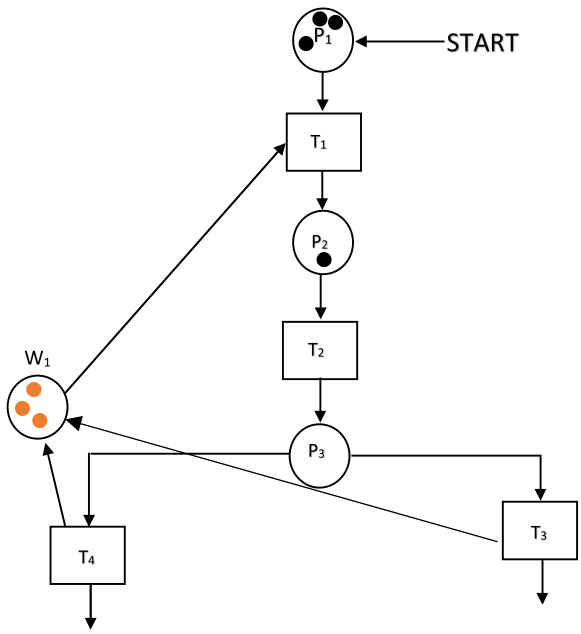
4.2.3.1 The color extension of Petri net

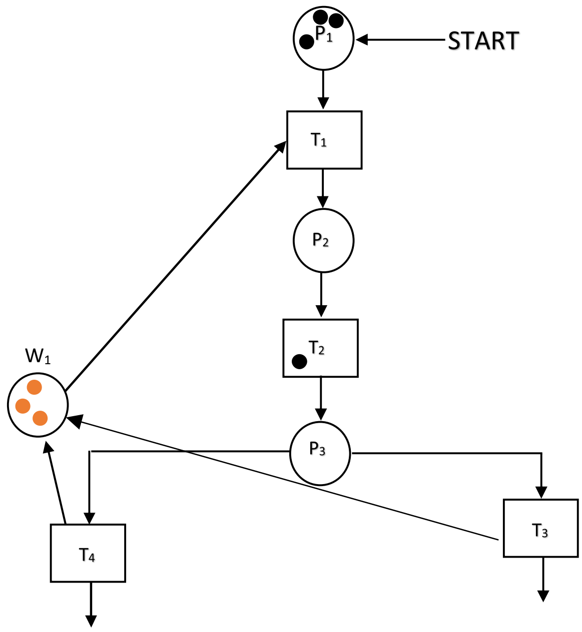
The first extension that can be applied to the Petri network is to assign a color to the tokens. This tool is particularly useful for differentiating the various resources participating in the process and also for clarifying the direction that the resource has to take if there are several directions available.

In the example taken into consideration this extension is useful to understand how resources acquire different properties according to the direction they take along the path. How do tokens (resources) change color? The color of the tokens depends on the evaluation made by the workers that are involved into transaction. In fact, if a token has a specific property it changes its color in order to differentiate itself from the others. Moreover, the color depends on the direction that a token should take. This means that if there are two or more directions after a transaction, the color of the token could change depending on the direction it has to follow. The addition of this extension in the Petri net allow to represent specific case of the process:

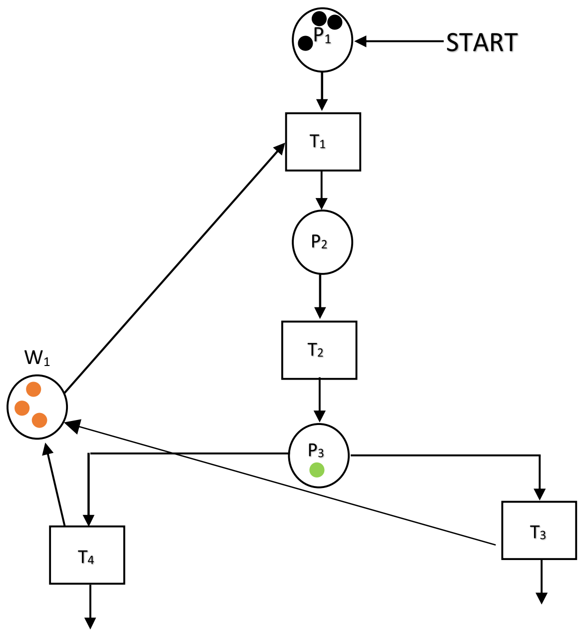



START
P1
T1
P2
T2
W1
P3
T3
T4

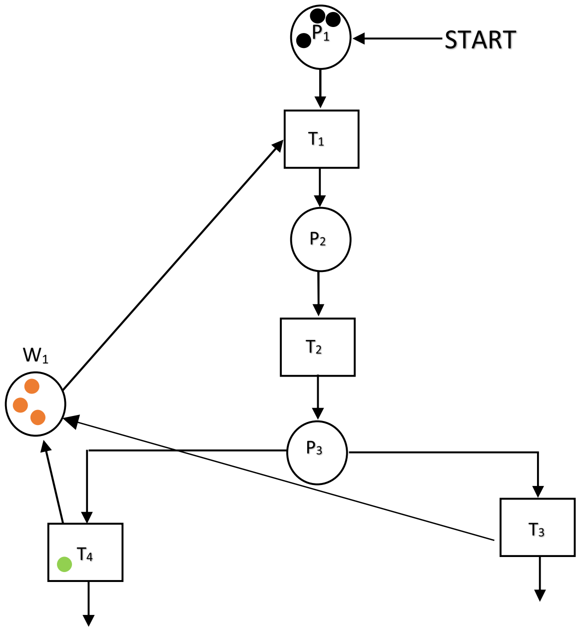

START
P1
T1
P2
T2
W1
P3
T3
T4

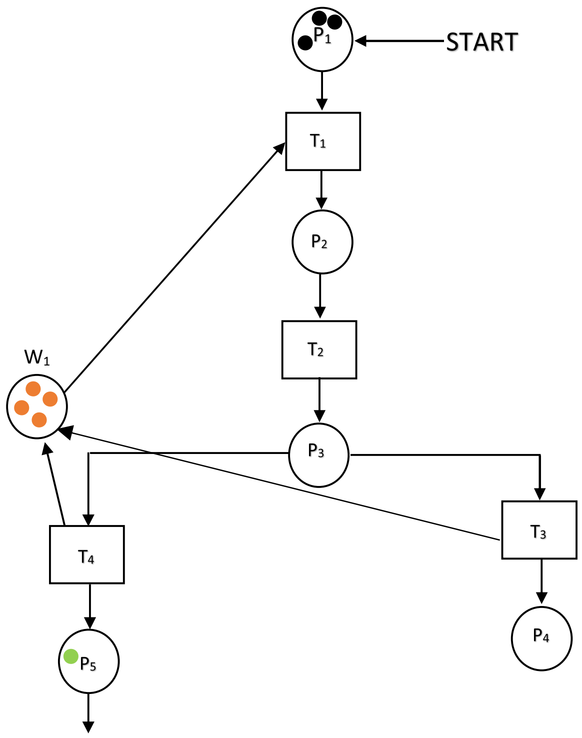


P1
START
T1
P2
T2
W1
P3
T4
T3

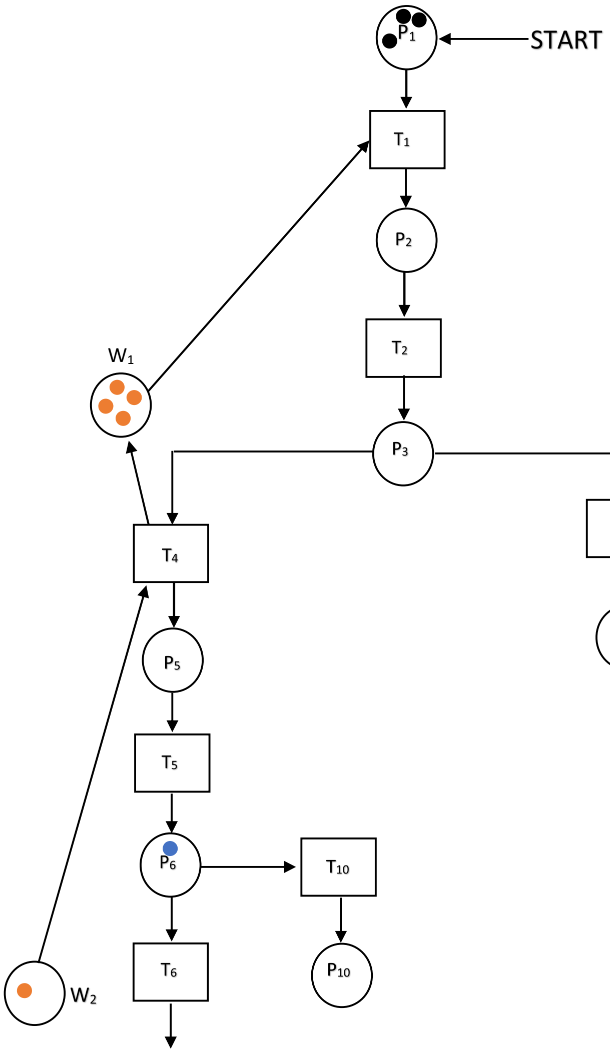


P1
START
T1
P2
T2
W1
P3
T4
T3


START
P_1
T_1
P_2
T_2
W_1
P_3
T_3
T_4


START
P_1
T_1
P_2
T_2
W_1
P_3
T_3
T_4
P_4
P_5

After the execution of T_5, the token changed color again.



As in the example shown above in the Figures, it is possible to see how the tokens change their colors according to their position and characteristics. In this way it is possible to understand which direction they have to take and to realize that the resources are different.

Following there is the description in order to explain the Petri nets with color extension work.

According to the schemes, in the first place P_1 it is possible to find a lot of tokens immediately after receiving requests from customers (START). Let's assume that in the first place there are 4 tokens representing four requests from four different customers and in the place W_1 there are 4 workers (they are represented with 4 orange tokens). When the first transition fires T_1, one token is moved from the first place to the second and one of the orange tokens disappears, this means that one worker is occupied to evaluate one request. After T_2, the black token changes its color, and this is the first expression of the Petri net color extension. In fact, after the event T_2, the token has two possible directions to take, which one excludes the other one, so the choice is mandatory. If the token remains black, it is difficult to interpret the scheme and it is not possible to understand which of the two following transitions need to be fired. For this reason, the token must necessarily change color and it must become green or red after the first transition. In the case of the Amavido startup, the token will become green when the customer's requests can be accepted because the demand respects the criteria of Amavido values, i.e. a stay in Italy, away from the big tourist cities, with the aim of discovering and living the traditions and rurality of Italy, discovering the customs and traditions of the small villages scattered throughout the territory. The token will become red when the customer's requests do not respect these values and it cannot be accepted by Amavido. When the token is green, it has to move through the T_4, while if it turns red it has to move through the T_3. If the token is green, it moves to the part of the diagram where Amavido's team looks for an available structure that respects the customer's requests. At this point the token is in front of a double direction: it has to undergo a differentiation in order to understand which is the correct direction because it must take a single direction which excludes the other one. As in the previous case, when the token is managed by the transaction T_2 to check the available accommodations, it acquires a different color. If the token becomes yellow, this means that the customer's requests can be satisfied thanks to the structures in Amavido's database, a pleace where are registered all the hosts that collaborate with the startup. In fact, the worker calls one or more hosts that have already collaborated with Amavido and that are registered on accommodations database. If the token acquires the color blue, it means that the customer's request cannot be satisfied through a registered structure and therefore it is necessary to do a new search and find one or more new structures. This is another example of how color extension can help in managing the process in a Petri net. Thanks to this property it is easier to understand how the process develops and which places and transitions are involved along the resource management. Tokens change color also at the final stage of the process. In fact, in the Amavido's process after sending the documents with the summary of the travel the client has two possibilities: he can accept or reject the proposal. In this moment an external factor influences the direction that the token can take. If the customer decides to accept the proposal, the token turns green and can then proceed in the direction of confirming the booking to the host. If the customer does not like the proposal, the token turns red and it takes the opposite direction to the green one, going to cancel the reservation.

Below there is the SWOT analysis of the color extension just considered:

Strength: This extension allows to represent graphically the attitude of the processes, with a focus on the movement of the resources in the process and on the management of these movements in the different transitions. In addition, this tool allows to organize the workers along the process.

Weakness: a weak characteristic of this system is the substantial precision to have for paying attention about all the possible cases that can appear. In fact any possible change about the color of tokens have to be explained in order to avoid uncertainties during the representation.

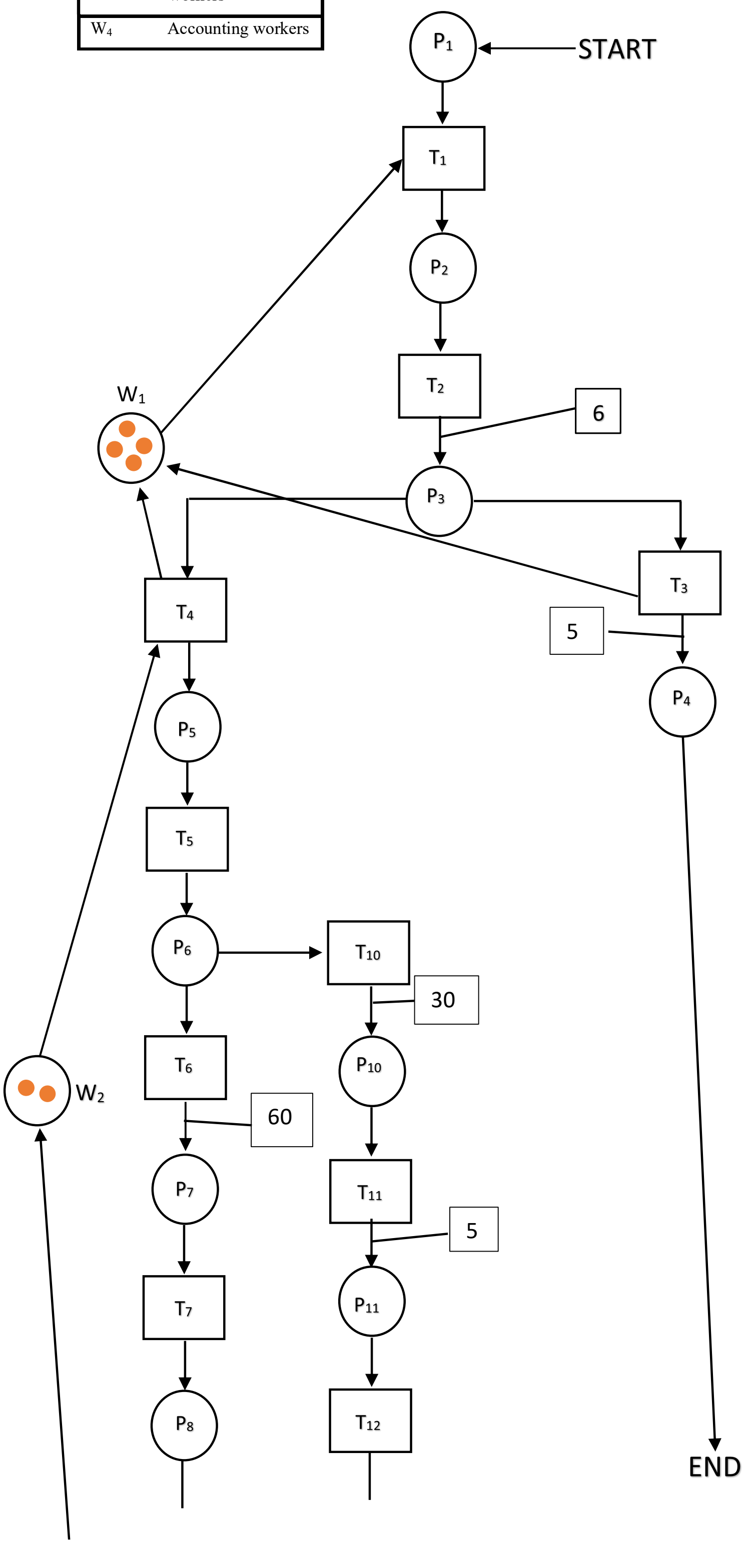
Opportunities: the features of this extension help to process workers in a better way than the simple Petri net. The information helps to better understand the number of indispensable workers and how they are involved in the execution of the processes.

Threats: Focusing too much on resources and their characteristics and not considering other factors that may influence the process as time, delays and bottle necks.

4.2.3.2 The time extension of Petri net

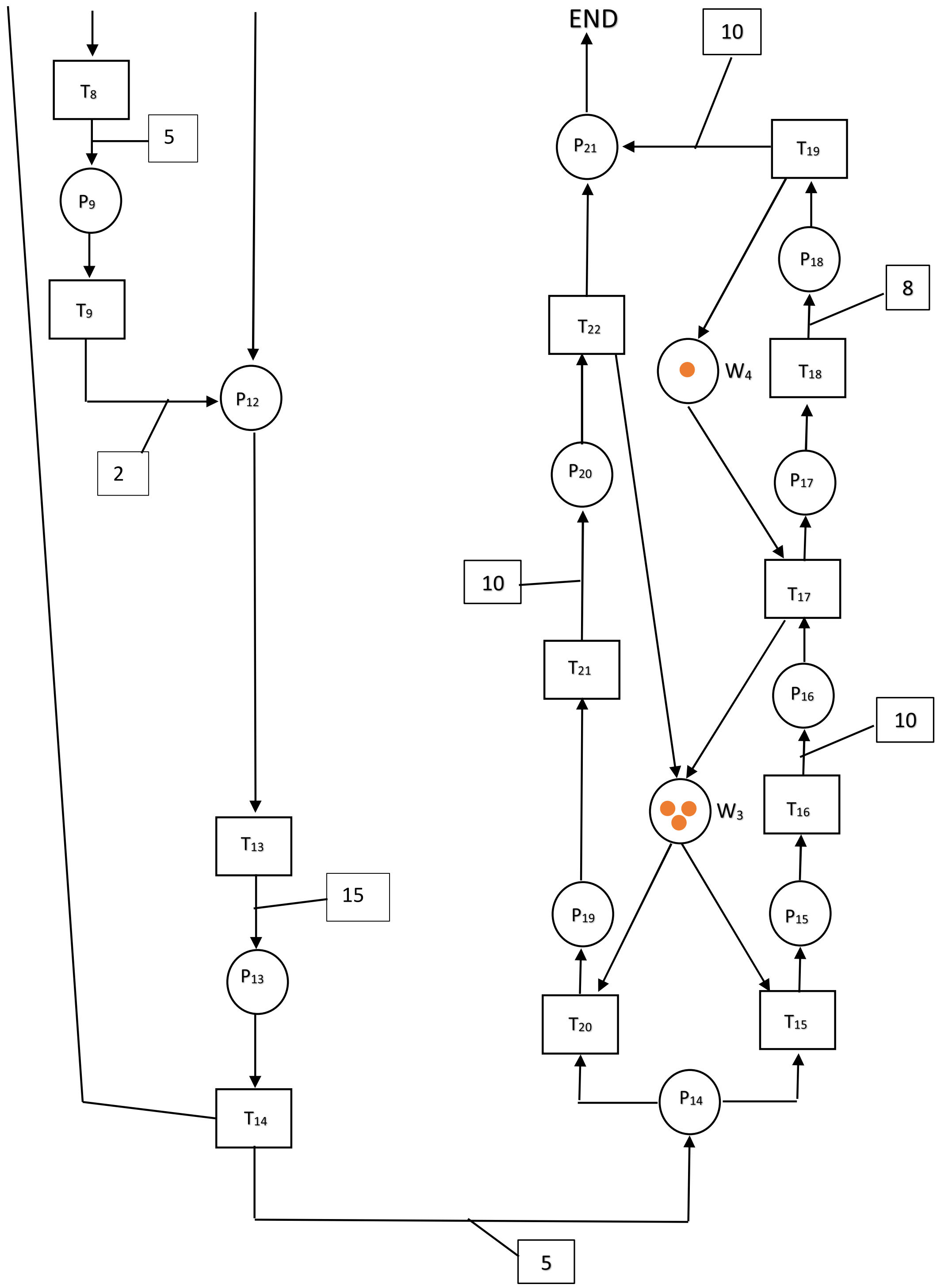
The second extension considered is the time extension of Petri net. This extension allows to add the times with which the different transitions are carried out, so it is possible to know the necessary time to complete the process. In addition, with the time extension it is possible to understand the time needed to execute a transition and the influence that each transition has on the overall time of the whole process. Below in the Figure it is possible to see how the classic Petri net is changed by adding the times of the transitions. This extension helps to improve the execution time of the process if it is too long and it allows to give a certain sequence to the various tasks too.

Workers roles	
W_1	Evaluation workers
W_2	Reservation workers
W_3	Booking/deleting workers
W_4	Accounting workers



Places	
P_1	Request
P_2	Took charge of request
P_3	Request evaluated
P_4	Request rejected
P_5	Taking charge of accepted request
P_6	Ready to find accommodation
P_7	New accommodations found
P_8	New host called
P_9	Availability checked
P_{10}	Found accommodation in the database
P_{11}	Availability checked
P_{12}	Option fixed
P_{13}	Activity booked
P_{14}	Customer received offer
P_{15}	Offer ready to be confirmed
P_{16}	Offer confirmed
P_{17}	Offer ready to be paid
P_{18}	Booking paid
P_{19}	Reservation ready to be canceled
P_{20}	Offer canceled
P_{21}	Offer

Transitions	
T_1	Worker takes charges of request
T_2	Evaluate the request
T_3	Reject the request
T_4	Accept the request
T_5	Search accommodation
T_6	Search new accommodations on internet
T_7	Call new accommodation
T_8	Check availability
T_9	Block option
T_{10}	Search new accommodations on database
T_{11}	Check availability
T_{12}	Block option
T_{13}	Search activity
T_{14}	Send offer to customer
T_{15}	Customer accepts offer
T_{16}	Confirm the offer
T_{17}	Customer send the payment
T_{18}	Pay the booking
T_{19}	Send documents to customer
T_{20}	Customer reject the offer
T_{21}	Cancel the reservation



The Figure above highlights the overall time needed to complete the process of Amavido. Thanks to the times that entered in the representation with this extension, it is possible to give a well-defined and programmed sequence to the different transitions. In fact, at the moment when a token from the first place is moved to the second, it takes a certain time to be processed, in this case it takes 10 minutes. For this reason, a new token has to wait this period of time in order to proceed along the process and in order to move from the first to the second place. This extension also allows to understand which transitions of the process takes a longer period of time to be processed and which one lengthens the overall time. The time of these transitions can be improved by adding a staff who can manage and speed up the execution time. The examination and the study of the process represented whit an extended version of a tool suggests how to improve the execution time of individual transitions that positively influence the overall process time.

The following SWOT analysis of the time extension of Petri Nets takes into consideration the strengths, the weaknesses, the opportunities and the threats of this tool:

Strength: it allows to improve the overall time of execution of the process, analyzing the times of the specific transitions. The improvement of the process execution time can be done by changing transitions' behavior into two ways: dividing the complex transitions into easier ones and increasing the numbers of workers that manage the transition.

Weakness: the time may be influenced by external and unpredictable factors, or by internal factors such as lack of staff or delays that are not explained into the representation.

Opportunities: possibilities to identify the transitions that are difficult to manage and to process.

Threats: the focus is only on the time that it is considered the unique solution to improve the process. Adding workers and transitions in order to reduce the time could have negative consequences as reducing the efficiency and increasing the complexity of the process.

This extension may be useful if it is compared to the PERT analytical instrument described in the third chapter. In fact, both tools study the execution's time of the process. Below the Amavido process is analyzed through another analytical tool, the PERT.

4.2.4 The PERT analysis of Amavido's process

This tool, as described in the third chapter, focuses on the process time and on its critical path. Just like the Petri net extension, the main goal of this tool is to examine the process execution time. Conversely to what Petri Nets extension makes, the PERT tries to understand which part of the process is more difficult to manage in terms of time. In fact, this tool highlights the part of the process that is considered a critical point if there is any problem with the execution due to a delay or lack of resources, this affects the entire duration of the process.

The last tool used for analyzing the Amavido's process is the PERT. This tool is used mainly for the project management. In fact, it makes hypothesis about the execution time of each task that compose the process. It allows to know the critical path of the process, the group of tasks that can influence the execution of the whole time. This tool is different from previous tools because it is used to project the process and its focus is to calculate the probability of realization of the hypothesis on the possible execution time of the whole process.

Below there is the table (Table 1) that summarizes and describes the different tasks and there are the links with the execution times too: the optimistic, the most likely and the pessimistic time. Then, through the formula, the expected time has been calculated. The table displays the tasks and the time of execution of Amavido's process:

				Minutes			
Tasks	Tasks Description	Predecessors		Optimistic time (Op)	Most likely time (Mlt)	Pessimistic time (Pt)	Expected time
Start							(Ot+4*Mlt+Pt)/6
A	Evaluate customer request	-		5	9	12	8,8
B	Research structure on Amavido database	A		30	38	60	40,3
C	Research new strucutre	A		60	78	95	77,8
D	Define terms and conditions	C		9	12	21	13,0
E	Lock option	B	D	2	4	9	4,5
F	Find activity	E		7	12	20	12,5
G	Send document	F		5	7	15	8,0
H	Cancel reservation	G		2	6	17	7,2
I	Send confirmation	G		18	25	41	26,5
L	Payment	I		2	4	10	4,7
	End						

Table 1 The tasks description and their time execution

In the first column of the Table (Table 1) there are the letters assigned to the various tasks in order to diversify them and to be able to recognize them in the graphical representation. In the second column it possible to find the name and a brief description of the tasks. In the next three columns there are the execution time of the different tasks divided between the optimistic one, that is the shorter, then the one that comes closest to reality, that is the most likely, and finally the pessimistic one, that is the longer one. These times give an idea of how tasks can be executed at different times, which could be influenced by the lack of the staff, or by delays or by external factors. These times are useful to calculate the expected time with which the task is expected to be performed. The formula, described in Chapter 3, considers each task execution times in order to give a number as close to reality as possible. The expected time calculated in this table is fundamental for calculating the overall process execution time.

In the table below (Table 2) it is possible to see the expected execution time and how to calculate ES (Earliest Start), EF (Earliest Finish), LS (Latest Start) and LF (Latest Finish).

					Earliest		Latest		
Tasks	Tasks Description	Duration (minutes)	Predecessors		ES	EF	LS	LF	Slack
Start		0			0	0	0	0	0
A	Evaluate customer request	8,8	-		0	8,8	0	8,8	0
B	Research structure on Amavido database	40,3	A		8,8	49,1	59,3	99,6	50,5
C	Research new strucutre	77,8	A		8,8	86,6	8,8	86,6	0
D	Define terms and conditions	13	C		86,6	99,6	86,6	99,6	0
E	Lock option	4,5	B	D	99,6	104,1	99,6	104,1	0
F	Find activity	12,5	E		104,1	116,6	104,1	116,6	0
G	Send document	8	F		116,6	124,6	116,6	124,6	0
H	Cancel reservation	7,2	G		124,6	131,8	148,6	155,8	24
I	Send confirmation	26,5	G		124,6	151,1	124,6	151,1	0
L	Payment	4,7	I		151,1	155,8	151,1	155,8	0
	End	0				155,8		155,8	

Table 2 The ES, EF, LS and LF of the tasks

In the Table 2 the overall time to complete the process is calculated, and in this specific case the time obtained is 155,8 minutes. In addition, the table allows to understand how much time is necessary for processing each task and the consequential execution of all the tasks. This means that after task A, which lasts 8.8 minutes, tasks B or C can be executed. If task A is not completed, these two tasks (B or C) cannot be executed. With this tool it is possible to understand the execution times of the different tasks too. The last column of the table contains the Slack, i.e. the difference between ES (Earliest Start) and LS (Latest Start). The slack allows to understand which tasks with a time lag compose the critical path. The slack equal to 0 identifies the tasks that compose the critical path. The critical path of process can influence the time of the whole process because the tasks do not allow a delay during its execution. The critical path can be understood by looking the plan of the process illustrates below, that can be obtained from the tables 1 and 2.


START
0,0
0,0
0,0
0,0
A
0,0
8,8
8,8
0,0
0,0
8,8
B
8,8
40,3
49,1
59,3
50,5
99,6
C
8,8
77,8
86,6
8,8
0,0
86,6
D
86,6
13,0
99,6
86,6
0,0
99,6
E
99,6
4,5
104,1
99,6
0,0
104,1
F
104,1
12,5
116,6
104,1
0,0
116,6
G
116,6
8,0
124,6
116,6
0,0
124,6
H
124,6
7,2
131,8
148,6
24,0
155,8
I
124,6
26,5
151,1
124,6
0,0
151,1
L
151,1
4,7
155,8
151,1
0,0
155,8
END
155,8
155,8

The Figure above shows the plan of the process obtained from the recapitulatory tables (Table 1 and Table 2). The scheme reports all the information about ES (Earliest Start), EF (Earliest Finish), LS (Latest Start), LF (Latest Finish), estimated duration of tasks and Slack. The tasks that have the slack equal to zero are those that constitute the critical path: that is the part of the process that can influence positively or negatively the total execution time. The diagram shows the direction of the process: from this appears that the task B (search for availability in the accommodation registered in the database) is faster than the tasks C and D of the opposite direction that are more difficult and they have a longer execution time. The focus of this scheme is on the direction of the process and on the critical path that are difficult to manage at the same time.

In addition, this type of analysis is used for calculating the probability that the process may end with more or less time than the calculated time. Through the construction of a table it is possible to calculate thanks to mathematical formulas the probability that the process can end with a shorter or longer time. The figure below shows the table (Table 3) used for calculating this probability for the Amavido example.

Tasks	Tasks Description	Predecessors		Optimistic time (Op)	Most likely time (Mlt)	Pessimistic time (Pt)		sd	VAR
Start									
A	Evaluate customer request	-		5	9	12	8,8	1,2	1,4
B	Research structure on Amavido database	A		30	38	60	40,3	5,0	25,0
C	Research new strucutre	A		60	78	95	77,8	5,8	34,0
D	Define terms and conditions	C		9	12	21	13,0	2,0	4,0
E	Lock option	B	D	2	4	9	4,5	1,2	1,4
F	Find activity	E		7	12	20	12,5	2,2	4,7
G	Send document	F		5	7	15	8,0	1,7	2,8
H	Cancel reservation	G		2	6	17	7,2	2,5	6,3
I	Send confirmation	G		18	25	41	26,5	3,8	14,7
L	Payment	I		2	4	10	4,7	1,3	1,8
	End								

Table 3 Summery of the standard deviation

Critical path			Tcrit (minutes)	hours	Sdcrit	Variance
A C D E F G I L			155,8	2,6	8,0	64,7
Probability estimates						
			Minutes	**Z**	**Probability**	
Probabilty exceed 3 hours			180	-3,0	0,13%	
probability of finishing before 2,5 hours?			150	0,7	76,58%	23,4%

Table 4 Probability estimates of process execution

The table 3 derives from the first table built with the three different task execution times, i.e. the optimistic time, the most likely time and the pessimistic time. With this data it is possible to obtain the standard deviation, through the mathematical formula SD = (Pt - Ot)/6. From these numbers it is possible to calculate the total variance of the various tasks. The variance provides a measure of the variability of the values assumed by the variable itself; specifically, the measure of how far they squarely deviate from the arithmetic mean or expected value respectively. Once completed the table has been reported the critical path of the process taken in analysis, its total execution time has been calculated by adding the averages of the times of the tasks that compose it. Then it is calculated the sum of the variances of the tasks that compose the critical path. From this number is calculated the standard deviation of the critical path by making the square of the variance calculated earlier. Once all these data have been calculated, there are all the necessary information to be able to make predictions, through the calculation of the probability, on the possible execution times of the whole process. The table 4 shows two examples of the calculation. The first hypothesis is the probability that the process ends until 3 hours. This data is transformed into minutes because the unit of measure used for calculating the execution times .is minutes. Once transformed in minutes, 180', it is possible to calculate the Z which is the variable need to calculate the probability through a Gaussian estimate. This variable is calculated using the mathematical formula Z = (Tcrit - Test)/SDcrit. The Gaussian Z variable has its value zero and variance 1. Once this is calculated it is possible to calculate the probability using an Excel formula, the standard normal distribution of Z. Otherwise the formula used to calculate the distribution is

$$\text{Prob}\ (T_{crit} > x) = \text{Prob}\ (\frac{Tcrit-tcrit}{SDcrit} > \frac{x-tcr}{SDcrit}) \approx \text{Prob}\ (\ Z > \frac{x-tcr}{SDcrit}) = \text{Prob}\ (\ Z > \frac{tcrit}{SDcrit})$$

$$= \Phi(\frac{tcrit-x}{SDcrit})$$

From this data it is possible to determine that the probability of execution of the process exceeding 3 hours is 0.13%. At the same time with the data previous obtained, it is possible to calculate the probability that the process ends before the total calculated time. In order to be able to calculate this probability, the process is the same applied in the calculation of the previous probability, except for the final phase. In fact, it is possible to calculate the probability that the process ends before the required time, in this example the probability that the time is more than 2.5 hours. Once the probability has been found, it has to subtract this data and it is possible to obtain the probability that the process ends before 2.5 hours. In the example taken into consideration the probability that the process ends after 2.5 hours is quite high, 76.59%, but the requirement is to find the probability that it ends before this overall time. So, the right probability is 1-0.7659 = 0.234 or 23.4%. This is the probability that the process is executed within 2.5 hours.

As with the previous tools, a SWOT analysis was carried out here as well:

Strengths: this analysis allows to understand which is the critical path of the process, in order to understand which are the tasks that need more attention. It also allows to know the overall execution time of the whole process and how the task management affects positively or negatively the execution time. Another positive point is the fact that this analysis allows to have a clear and simple division of the process into tasks and to estimate the duration of each one. It also allows to decide a logical sequence that tasks must follow when executing the whole process.

Weaknesses: It is limited to project and analyze the execution time of tasks, there is no possibility to have more information about the problems that these can have, such as delays or external agents. There is not a way to understand the reason for the execution time.

Opportunities: allows to improve process management in relation to time. This means that by identifying the maximum execution time and the critical path it allows to focus on improving the execution of these tasks in order to improve the overall execution time of the process.

Threats: improving the process by dividing the most difficult tasks into simpler tasks it could affect the efficiency of the process and its adaptability and flexibility to different situations.

4.3 Possible developments by comparing the tools used

Once the three analyses have been carried out with the use of the respective tools, it is possible to compare the information obtained.

EPC	
Strengths -easy tool because it is composed of few elements and its construction is simple too.	**Weaknesses** -information about resources and workers does not appear directly. -represents the process in a general way through the events and functions. -the nodes (in some cases) are not so easy to interpret.
Opportunities -understand any developments in the process and the improvements necessary by eliminating or adding functions and events. -understand possible critical points in the process.	**Threats** -it is not possible to understand in detail the internal and external factors that may influence the process. -the process could be interpreted incorrectly.

PETRI NETS COLOR EXTENSION	
Strengths -represent graphically the attitude of the processes, with a focus on the movement of the resources in the process and on the management of these movements in the different transitions. -organize the workers along the process.	**Weaknesses** -substantial precision to have for paying attention about all the possible cases that can appear. In fact any possible change about the color of tokens have to be explained in order to avoid uncertainties during the representation.
Opportunities - help to process workers in a better way than the simple Petri net. The information helps to better understand the number of indispensable workers and how they are involved in the execution of the processes.	**Threats** -Focusing too much on resources and their characteristics and not considering other factors that may influence the process as time, delays and bottle necks.

PETRI NETS EXTENSION TIME	
Strengths -improve the overall time of execution of the process, analyzing the times of the specific transitions. -change transitions' behavior into two ways: dividing the complex transitions into easier ones and increasing the numbers of workers that manage the transition	**Weaknesses** -influenced by external and unpredictable factors, or by internal factors such as lack of staff or delays that are not explained into the representation.
Opportunities -identify the transitions that are difficult to manage and to process.	**Threats** -adding workers and transitions in order to reduce the time could have negative consequences as reducing the efficiency and increasing the complexity of the process.

PERT	
Strengths -understand which is the critical path of the process, in order to understand which are the tasks that need more attention. -know the overall execution time of the whole process and how the task management affects positively or negatively the execution time. -have a clear and simple division of the process into tasks and estimate the duration of each one. -decide a logical sequence that tasks must follow when executing the whole process.	**Weaknesses** -there is no possibility to have more information about the problems such as delays or external agents. -there is not a way to understand the reason for the execution time.
Opportunities -improve process management in relation to the time. -by identifying the maximum execution time and the critical path you can focus on improving the execution of these tasks in order to improve the overall execution time of the process.	**Threats** -improving the process by dividing the most difficult tasks into simpler tasks it could affect the efficiency of the process and its adaptability and flexibility to different situations.

Thanks to the SWOT analysis conducted in order to examine the performance of each tool it has been possible to hypothesize that it is advisable to interweave the information and data obtained through the three different analyses for a profound and complete understanding of the process.

The Amavido startup, even though it is small, faces a market that is in continuous evolution and it is very dynamic. The market to which it refers is disputed between large companies and tour operators who share most of the offer and demand. Focusing on a limited and precise offer, Amavido could be able to conquer a slice of the market. Obviously, in order to do this, it needs to improve its "production" process, which consists in creating trips for tourists who are looking for experiences in the Italian rural territory. The improvement of the process also passes through these types of analysis, which allow to simulate and collect important data on the process, so that it can be improved.

Operating in one sector per customer order, the response to the customer must be as rapid as possible in order to meet efficiently the customer's needs. Through the analysis seen above, in particular the PERT analysis, it has been seen that the critical part of the process is the one that refers to the search for new structures in order to satisfy the customer who has requests that cannot be satisfied with the structures already present in the database. This may suggest that Amavido can improve the research for new structures: the team has to continuously looking for new structures for collaborating with them in order to increase the database. An early research could lead to a reduction in the overall execution time of the entire process. This could also be improved by increasing the registrations of the structures present on the Italian territory in order to cover as many places as possible and in a uniform way throughout the Italian territory. In addition, integrating business management with these analyses, building the process but also subsequently with the aim of improving it, can improve the flexibility of the process and at the same time can create standard actions to be repeated with the aim of reducing process time.

Obviously, these analyses and this process management is very time-consuming and costly. In fact, for a startup like Amavido that has few economic resources it is not easy to assign to a person the role for managing and designing the process. However, this does not justify a little attention to the process management. In fact, even if there is no management class with specific purposes to redesign the process, the fact that it is a startup and with a small and flexible team could help in a possible management with the aim of improving the execution. This is an advantage compared to the large companies, based on a very rigid structure, which have a lot of difficulty in modifying a part or the entire production process.

In particular, comparing the data collected through the analysis described above, it is possible to formulate some hypotheses on some changes to be made to the Amavido startup process.

1. Resources and Workers orientation

Through the analysis with the EPC tool and the Petri net with color extension it is possible to focus the study on the resources and on workers involved in the process. Thanks to these two tools, it is possible to divide the process into tasks that are smaller and easier than the previous, and it is possible to understand if it is possible to customize processes in order to develop the production. Analyzing the Petri net with the color extension it is possible to make a prediction of the workers needed to process a specific number of requests and it is also possible to define the phases of actions. In fact, thanks to the movement of tokens along the places it is possible to calculate how many tokens can be managed at the same time, in this way it is possible to improve the business process increasing the automation in order to delete unnecessary steps. Another improvement can be the increase of standardization within the company, in order to increase the efficiency and to reduce costs. For example, the evaluation of the requests could be made by a software rather than by the workers. This improvement can be reduced errors, it could increase the numbers of requests evaluated and it could also reduce the costs. The automation could be also implemented on the task of accommodations searching on the Amavido database. If the searching could be automated, it reduces the time and the costs of the business process. The previous examples can be considered improvements for a business process: automation and softwares can increase standardization of process and verification tools.

2. Timing improvement

Taking into consideration the information obtained from the analysis done with the Petri net and the time extension and the PERT graph it is possible to focus on the time of the execution of the tasks and how much they influence the total execution time of the process. In these two analyses the staff and the external agents are not taken into consideration and the time spent to process the tasks is just observed. Starting from the PERT analysis the critical path that positively or negatively influences the total execution time of the process are derived. This allows to understand which tasks have a more important role along the process. In the case taken as an example, it can be observed that the direction of the process that considers the tasks that deal with finding new structures is more critical than the time. By observing this result, the process management are focused on these tasks, improving their execution with the aim of reducing execution time. By comparing this data with the Petri net with extension time data, which describes the tasks in a more detailed way, it could be possible to see which of them can be managed differently, with the aim of reducing time. In fact, also in the analysis of Petri net through the extension of time a representation of the process is obtained, where the times are scanned between the various tasks. Having all this information allows to think about a solution with the purpose of reducing the execution time.

By taking into consideration all four analyses it is possible to compare the execution time with resource management, travel creation requests and personnel. In this way it is possible to cross the information and to manage the execution time and the staff at the same time. In fact, the execution time of some tasks can be improved by adding new staff, which would also benefit the management of new requests, so in this way more requests for travel creation are managed at the same time.

Conclusions

In the first part of the thesis the existing theory with reference to Workflow and Business Process Management has been explained. It is focused on the definitions of the two frameworks and their history, their first implementations and how they developed. Subsequently, the relationship between these two frames was reanalyzed. Finally, some analytical tools used to study and analyze business processes were presented. Three analytical tools have been described starting from their definition and then exploring their main characteristics. For each instrument an in-depth research has been carried out regarding the different uses and also the different graphic representations. These analytical tools were used to analyze and represent the process of a company with the aim of demonstrating the importance of workflow management and business process management.

The path to be faced in order to reach the complete management of the business process and its redesign is obviously very long and complex, which involves investments in economic and time terms.

In the final part of the thesis, it has been proposed a possible implementation of these systems within a German startup, Amavido, with the aim of demonstrating how important it is also for a small reality founded a few years ago to analyze the process management in order to implement it. This analysis has not been carried out directly with the company, but it wants to be a clear example of how even small realities have to undertake this kind of path.

What it was asked at the beginning of the study was what kind of possible help could give certain types of analysis to the workflow management of a company. In addition, these analyses carried out thanks to certain analytical tools could be compared with each other in order to cross the information obtained for having all the information that was missing in the single representation. Thanks to the analysis of the company's process, in Chapter 4, it emerges that the tools used for analyzing have also some elements in common. In the case of the EPC tool and the Petri net with color extension, they analyze the tasks of the process focusing on the resources. In particular, it is possible to deduce how, by cross-referencing the results obtained from the two analyses, the two tools can be used to better manage the (personal) resources within the process. Analyzing the process with the other two analytical tools, the Petri net with time extension and the PERT, it is possible to analyze the process according to another point of view: the time. This allows to recognize which part of the process is considered critical for the time and for the execution of the process. By putting together the results of the two analyses it is therefore possible to hypothesize how the enterprise should focus on the execution of the different tasks in order to improve this aspect. The number of resources (capacity) could positively influence this type of analysis.

Resources (workers) are the common denominator within the different analyses. Even if they are not represented in the different graphs taken into consideration, they have an extreme importance in order to allow an adequate execution of the process. After mapping the Amavido process through the use of analytical tools as EPC, Petri net with color and time extension and PERT, it emerged that these types of representation of the process management are also crucial for small business companies that do not have enough economic and physical resources for improving the business process. The ways to improve the process are those set out and demonstrated with the examples given in Chapter 4 as the possibility to identify the critical path through the PERT analysis for improving the execution time of the business process, and as the augmentation of standardization and automation in order to reduce costs and errors through the use of analytical tools like the EPC and the Petri nets with color extension. This type of solution requires a re-engineering of the process under analysis, focusing on the distribution of human resources. Obviously, this type of solution is related to the current structure of the company and its willingness to invest in this type of restructuring.

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