LEAN PROJECT MANAGEMENT

Assessment of project risk management processes

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ABSTRACT

Traditional methods of project management are not appropriate for complex projects anymore. Since projects are becoming increasingly complex and uncertain, interaction between activities and resources is growing in ways not considered by these methods. Nowadays, managers need more agile project management methods that are able to recognize and deal with uncertainty and to produce the expected results. Lean project management, the most recent approach of lean methodology, appears as an alternative approach capable of dealing with complexity and uncertainty. The latest investigations in the field show that traditional methods are still adequate for simple projects, while lean methods are more appropriate for complex projects.

This thesis aims to investigate the nature of lean project management and to examine project risk management processes so that managers can assess the complexity of projects before their beginning and decide which method to apply in order to manage them. To achieve these aims, a theoretical framework has been established throughout an exhaustive literature review. Then, to describe lean project management it has been explained the need to redefine project management, followed by the theoretical basis of this new approach, its history and main applications. These applications include the lean project delivery system and the last planner system, together with a Spanish example of its application. To conclude this part, the limits of lean project management have been enumerated. Subsequently, project risk management has been explained, as well as the distinction between risk and uncertainty and the main uncertainties in projects. Finally, the principal project risk management processes have been established.

Key words: lean production, critical chain project management, lean project management, risk project management
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1 Introduction

1.1 Background

Projects of today and without doubt those of the future are increasingly dynamic, unpredictable and forced to finish early (Levitt, 2011). Decreasing the duration of a project implies interaction between activities and resources in ways not considered by traditional methods of project management. At the same time, reduction in duration augments complexity in projects since interaction rises. In addition, technical and design complexity is growing as well. (Howell and Koskela, 2000) Therefore, in simple and small projects the resulting problems can be resolved without great difficulty. However, complex projects can no longer be managed with traditional methods since with their imperfect assumptions and idealized theory they reduce project performance. Nowadays, managers need more agile project management methods that are able to recognize and deal with uncertainty and that present a new definition of control capable of producing the expected results. (Levitt, 2011; Ballard and Tommelein, 2012)

During years, it has been argued that project management, as it is defined in the Body of Knowledge of the Project Management Institute (PMI), needs to be redefined. Of all the reasons explained before, the main cause of project failure is its faulty theory, which tries to decrease uncertainty instead of dealing with situations of uncertainty and complexity. Because of that, researchers have focused on enhancing the basis of theory in current methods. (Howell and Koskela, 2000; Koskela and Howell, 2001; 2002a; 2002b; Cicmil, Hodgson, Lindgren and Packendorff, 2009) Koskela (1992) as cited in Ballard and Tommelein (2012) was who first stated that the reform in project management could be made from production management theories. These theories would complement the transformation theory of projects, in which projects are only seen as the transformation of inputs into outputs, with the management of workflow as well as with the creation and distribution of value. Other authors, as Winter and Szczepanek (2007), have pointed out the need to consider projects as value creation processes. Among all theories of production management, there is common agreement between researchers that the approach that best suits is lean production, since it deals with delivering quickly, products that meet customer’s unique specifications, maximizing value and minimizing waste, and without having inventory. Therefore, the basis of lean methodology fits with the need to deliver quickly and efficiently, complex, uncertain and unique projects.

During the last years, researchers have focused on adapting lean principles to project management, specifically in the field of construction. The elaboration of the lean project delivery system (Ballard, 2008; Alarcón and Pellicer, 2009), as well as the Last Planner (Ballard and Howell, 2003; Rodríguez, Alarcón and Pellicer, 2011), a crucial method of lean project management, shows the adaptation of lean principles to the project area.
In their latest research, Ballard and Tommelein (2012) conclude that lean project management approaches are better to complex projects than traditional methods; however, for simple and certain projects, traditional methods can be successful. They have recognized the need to examine methods for more exactly evaluating the complexity of projects before their beginning. Investigation of risk management practices has been stated to be a good starting point, since risk evaluation is the current process for determining project challenge. With this, once the challenge and complexity posed by each project are established, it will be possible to choose the method, traditional or lean, that is better suited for managing the project. The greater the complexity the more lean methods are required. Furthermore, these authors have pointed out that the assessment of the complexity of projects prior to its start would allow managers to design project delivery processes specified to the difficulty presented by each project. Nevertheless, in this context, there is an obvious absence of research in the examination of risk management processes.

1.2 PROBLEM DESCRIPTION

Up until now, researcher’s attention has been paid in explaining lean as a philosophy of management, with its principles and objectives. Furthermore, it has been described the need to reform project management and how lean can be adapted from manufacturing to project management in order to enhance current project management practices. It is well known the increasing interest of companies in new project management methods that allow them to reduce duration, increase performance and avoid confrontational relations during project execution.

So far, lean project management practices are relatively new and few authors have explained its theoretical foundations as well as its convenience for different types of projects according to their complexity. On the contrary, researchers have focused on decreasing uncertainty instead of trying to deal with situations of uncertainty and complexity. In addition, since projects will continue to become more uncertain and complex over time, a change in investigation needs to be done. Thus, a study about lean project management together with project risk management and its practices results necessary in order to enable managers to assess project complexity. Then, when the challenge presented by each project is established, it will be possible to choose the best approach to manage the project, traditional or lean.

1.3 AIM AND OBJECTIVES

The problem description in the previous section reveals that this thesis has an extensive area of interest. The aim of this thesis is twofold:
On the one hand, it will be described the new method of project management, called lean project management, which constitutes an application of lean principles from manufacturing to project management.

On the other hand, they will be investigated risk project management processes in order to provide means for assessing project complexity, so that managers can choose the best method to manage the project.

In order to achieve the aim of the thesis, the following objectives have been identified:

- Define lean production system, as well as describe its history, evolution and principles
- Explain what critical chain project management is, including its theoretical basis and methodology
- Describe deeply lean project management, starting with the need to redefine traditional project management, followed by the theoretical foundations of this new method and its history. Then, describe what lean project delivery system is, as well as the last planner, a key method of lean project management, together with a Spanish example of its application. Finally, explain the limitations of lean project management
- Explicate what project risk management is, the difference between risk and uncertainty, the main causes of uncertainty in projects and the current project risk management practices

1.4 LIMITS

The study of current processes in risk management is made in order to provide means to managers for determining project complexity and then selecting the best management method. However, according to Ballard and Tommelein (2012), once the complexity of a project is established, in order to make a decision and decide which method should be applied, more information will be required. Therefore, further research is needed in this regard.
2 Theoretical Background

2.1 Lean Production

Lean production is a production system that can be described by comparing it with craft and mass production, since it combines their benefits and avoids their main disadvantages in order to produce goods. This implies producing at low-cost what the customer specifically orders, avoiding the high cost of craft production and the rigidity of mass production. To achieve these goals, lean uses teams of multi-skilled workers at all levels of the business and employs flexible and automated machines that allow producing goods in a high variety. (Womack et al, 1990)

The major aim of this system is to produce high quality products in an economical and efficient way. This means reducing waste in all areas of production, for instance using less inventory, less human effort, less time to develop new products and less time to respond to customers demand. (Smith and Hawkins, 2004) The main difference between mass and lean production lies in their objectives since mass producers seek for producing in a ‘good enough’ way, what implies an acceptable number of defects, a maximum acceptable level of inventories, and a limited selection of standardized products. However, lean producers search for perfection and this means zero defects, zero inventories and a high product variety. Although any producer has not achieved these objectives, their importance lies in the culture of continuous improvement. (Womack et al, 1990)

2.1.1 The History and Evolution of Lean Production

Automobile industry has been for a long time, and still it is, one of the most important economic activities worldwide. Its importance lies not only in its revenues, but also on the changes that this industry has entailed in society. It has changed several times essential ideas of how things are produced. Consequently, lifestyle and way of thinking have evolved according to these industrial transformations. (Womack et al, 1990)

First change happened after World War I when manufacturing evolved from craft production to mass production thanks to Henry Ford and Alfred Sloan. Before that moment, European companies had led craft production, and after that change, the United States began to lead world economy. (Womack et al, 1990)

Second change took place after World War II when Eiji Toyoda and Taiichi Ohno, which were working at the Toyota Motor Company at that moment, pioneered the concept of lean production. The current importance of Japan’s economy is due to the implementation of this production system by many Japanese companies. (Womack et al, 1990)
Nowadays, different companies all over the world are trying to understand and introduce lean methodology. For instance, Endesa Red, a Spanish company responsible for the regulated activities of transmission and distribution of electricity in Spain, has recently applied lean principles to its business model with successful results. (Grau and Torrubiano, 2008)

Nevertheless, the transition from mass to lean production can be difficult. The key is to identify waste and value, to develop a knowledge management base and to be aware that sustainable improvement needs a culture of continuous improvement. (Melton, 2005)

**The evolution of manufacturing**

Manufacturing is “the process of converting raw materials, components or parts into finished goods that meet customer’s expectations or specifications” (Business Dictionary, 2012).

Craft production was the first manufacturing system. It is based on highly skilled workforce, which spends many years learning their craft, and simple and flexible machines that allow producing exactly what the customer asks for. In addition, it uses general machine tools often made by workers and a low production volume characterizes it. In order to obtain a finished product, craftsmen prepare the row materials and pass the product through different manufacturing steps. Therefore, with this system it cannot be obtained two equal products, since craft techniques involve variations in production. Usually, these products are expensive, due to the long time required to produce them. (Womack et al, 1990; Smith and Hawkins, 2004)

The main disadvantages of craft production are its costs, which does not decrease with volume, and the lack of product quality, reliability and durability because of the absence of a system of testing. Furthermore, it is difficult for small producers to develop new techniques and innovations. (Womack et al, 1990)

Approximately in 1730, the invention of the “flying shuttle”, made by John Kay, for the textile industry gave rise to the Industrial Revolution. It entailed an enormous remodelling of society due to the emergence of the working class. (Smith and Hawkins, 2004) In addition, it resulted in the division of labour, “a narrow specialization of tasks within a production process so that each worker can become a specialist in doing one thing” (Business Dictionary, 2012).

In 1785 the steam engine, produced by James Watt and applied to the cotton industry brought about the replacement of human, animal and waterpower by machine assisted motive power. The use of machines to manufacture enabled the production of goods with interchangeable parts which was the key of the assembly line, and therefore, of the emergence of mass production. Soon, the concepts of division of labour, machine-assisted manufacture and assembly of standardized parts were established in Europe and
the United States. Because of the great quantity of factories that were flourishing, it was required a large amount of people, which constituted the beginnings of society’s first “middle class”. (Smith and Hawkins, 2004)

In 1881 as a consequence of the studies of Frederick W. Taylor in the organization of manufacturing operations, Industrial Engineering appeared. The improvement of methods and tools allowed workers to produce more with less effort. Some years later, several studies about time-motion gave rise to quantitative methods to the design of contemporary manufacturing systems and processes. (Smith and Hawkins, 2004)

After Henry Ford completed the build of his first horseless carriage, in 1896, he announced the Model T, a motorcar for the great multitude. The assembly of this car was conducted using the most advanced technology known so far, the assembly line. With this technology, a full chassis was assembled in about 93 minutes, with the precise timing of a constantly moving of the conveyance parts, subassemblies and assemblies. At least five years of work had been necessary in order to reduce the initial assembly time of 728 minutes in just the mentioned 93 thanks to eliminate waste of time in each operation. This was the first approximation of the manufacturing technology to lean thinking. (Womack et al, 1990; Smith and Hawkins, 2004)

**Waste, the aim of Henry Ford**

During World War I, due to the shortages and price increases, Ford was aware of the need to control raw materials and make his own parts of the car. However, the production was increasing quickly and it was impossible to coordinate actions so that each product would reach the right place at the right time. First, Ford tried to accumulate large amounts of inventory to avoid breakage of products on the assembly line, but he realized that this implied a huge waste of money. So, he decided to extend the movement to inventories and production. (Smith and Hawkins, 2004) The main aim of Ford was to build automobiles as cheaply as possible, and because of that, he was obsessed with the elimination of waste in all areas of production, since wasted money, material, and time increased the cost per unit of each automobile.

Around 1920, while other companies were learning from Ford’s practices, he was still making the Model T really cheaply (Womack et al 1990). The mass production system allowed customers to have a low cost because of the use of standard designs, but at the same time, they had a low variety. Furthermore, the workforce found the mass production system really tedious. (Melton, 2005) In spite of his success, Ford did not realize that the consumer’s tastes had become more varied. Owing to that, Ford introduced the Model A but it did not have a spectacular success, so the Ford Motor Company was third in sales in 1936 in the U.S auto industry. However, it is undeniable the strong influence of Henry Ford in manufacturing, and years later, this influence had a deep consequence on Japanese industries. (Smith and Hawkins, 2004)
Ford's influence on Japanese manufacturing

In 1936, Ford was the main producer of automobiles in Japan with the production of the model A. The same year, Sakichi Toyoda started in Japan an automobile company and his son, Kiichiro Toyota, travelled to America in order to learn the operation of the Ford Motor Company. When he went back to Japan, he not only applied all the knowledge that he had learnt, but he expanded it. (Smith and Hawkins, 2004) Since the Japanese market was very different from American, due to restrictions in their marketplace, it was necessary to adapt the American operating system to a smaller market with many varieties. (Womack and Jones, 2003) In addition, he achieved managing the logistics of materials to coincide with production consumption thanks to a network of suppliers that supplied component material as needed. This system was called Just in Time (JIT). (Womack et al, 1990)

When Eiji Toyoda was designated managing director at Toyoda Group in 1950, he also decided to go to the United States and to learn from the American automobile system. Back in Japan, he introduced new concepts that he had learnt as the continuous improvement process, called Kaizen. In 1957 the company was changed the name to Toyota and opened the first company at the United States. (Smith and Hawkins, 2004)

Taiichi Ohno, who was already working at Toyoda, extended the Just in Time concept to achieve a reduction in waste. After World War II, Taiichi Ohno dealt with harsh conditions, as material shortages, developing methods to support the assembly operations. This was possible due to two concepts that he brought from the American industry, the assembly production system and the supermarket operation system. In this system, items were replenished when consumers purchased them or pulled, so he called this method ‘pull system’ since the demand pulls the production. (Smith and Hawkins, 2004) Nowadays, Taiichi Ohno is considered the father of the Toyota Production System and consequently of Lean Manufacturing since Toyota includes the current main features of lean, increasing productivity by eliminating waste. Figure 1 shows the evolution of manufacturing.
Figure 1: The evolution of manufacturing

**Lean Manufacturing**

The term *lean* was coined in 1990 by a research group led by James P. Womack, after studying the Toyota Production System. The term *lean* that means ‘slim, thin’ was immediately accepted since this system uses fewer resources compared with mass production. However, as it has been explained before, Toyota did not invent these practices but applied and improved what they had learnt from the American companies. The main characteristics that Toyota took from the American industries were (Smith and Hawkins, 2004):

- Waste reduction
- Integrated supply chain
- Enhanced customer value
- Value creating organisation

Lean manufacturing focuses on improving productivity by removing waste from the manufacturing process. At the same time, it builds quality from the first time, and establishes continuous improvements in order to respond to customer needs. To achieve this, it is necessary to know as much as possible about the business operation. Therefore, lean focuses on workers since they know which problems are in their workplace and are able to solve them more efficiently. Since the main objective of lean is the continuous improvement of processes focusing on waste elimination and creating value to the customer, the Japanese added the following concepts to what they had learnt (Smith and Hawkins, 2004):

1 Adapted from Smith and Hawkins 2004
- Integrated supply chain
- Enhanced customer value
- Value creating organisation
- Committed management
- Winning employee commitment
- Optimized equipment reliability
- Measurement systems
- Plant-wide lines of communication
- Making and sustaining cultural change

2.1.2 Waste and Flexibility

According to Taiichi Ohno (1988), any activity in the manufacturing process that consumes resources and does not add value from the customer perspective is considered waste. Generally, waste should be removed. However, in some steps of the process, waste is a necessary part that adds value to the company and cannot be removed, for instance financial controls. (Melton, 2005) With the waste removal, the operating efficiency can be improved on a large margin. In addition, efficiency should be improved at each step of the production process and jointly with the entire plant. Seven types of waste were established (Ohno, 1988; Melton, 2005):

1. **Overproduction**: It implies to produce components, paper, copies, telephone calls and reports that are made for no specific customer and therefore generate a low use and value. This is one of the most serious forms of waste, because it leads to another form of waste, the inventory. Producing according to the capacity of the line and not according to customer demand can be an example of this type of waste. The objective is to produce exactly what is required, just in time and with quality.

2. **Waiting**: It indicates the lost time between operations or during operations due to forgotten material, unbalanced lines and planning errors. People, equipment and product waiting to be processed, do not add value to the customer.

3. **Transportation**: It refers to unnecessary movement of materials, either from a supplier or a warehouse to the process or between processes and even within the same process. While the product is in movement, it is not being processed and consequently it is not adding value to the customer.

4. **Processing**: It is generated when a product or service is subjected to more work than necessary. Therefore, the customer is not willing to pay for it since it does not add value to the product. This form of waste is easy to identify and remove.

5. **Inventory**: It entails the accumulation of products and materials in any part of the process. The inventory is especially harmful because is often used to hide problems in the process operation, which cause people are not motivated to make improvements in their job. All types of inventory cost money.
6. **Movement:** It is defined as any movement that is not necessary to complete adequately an operation or activity. For instance, human movements that are not necessary and generate overexertion. While people are moving they cannot support the product processing. Excessive movement of data, decisions and information are considered as waste movement.

7. **Defective products:** It implies producing defective parts during the process that require re-work or additional work.

In a lean system, flexibility is necessary to achieve a high level of competitiveness. Since lean methodology is based on the principle that supply must adjust to demand, it is required that all the elements that compose the system are provided with a high flexibility, so that tasks can be changed quickly and without unnecessary loss of time. Therefore, in comparison with traditional methods of economies of scale that opt for specialization in order to achieve a high production level, versatility is required in lean, since the market pulls of production, what means that the production should always adjust to what the market requests. (Rubio, 2009)

### 2.1.3 Key principles

Womack and Jones (2003) established five key aspects in lean methodology that are necessary to avoid waste. Lean thinking provides a method to specify value, align the actions that create value according to the optimal sequence, carry out these activities without interruption when someone requests them, and perform them with increasingly effectiveness. Figure 2 shows the key principles of lean management.

![Figure 2: Lean principles](image)

**Specify value**

The basic starting point of lean methodology is the value. Value is what a customer is willing to pay for a product or service. It is defined according to the end consumer and is expressed in terms of a specific product that meets customer’s needs with a concrete
price and at a given time. In order to achieve this, it is necessary to redefine the concept of value in companies, since sometimes the main objectives of stakeholders and managers exceed the concept of creating and specify value to the consumer or client. Once the product is defined, it has to be determined an objective cost, based on the necessary amount of resources and efforts needed to produce the product. (Womack and Jones, 2003; Rubio, 2009)

**Identify the value stream**

The value stream is composed by all the necessary tasks that should be completed in order to deliver the product or service to the ultimate customer. Creating a value stream map for each product or family of products allows the manager to identify the tasks that add value to the product and those that do not add value. (Womack and Jones, 2003)

Those activities that do not add value are considered waste and can be removed from the value stream. However, it can be distinguished between activities that are partially without value but needed in order to complete the tasks and all the activities that do not have any value and therefore should be eliminated. (Melton, 2005)

**Process flow**

The traditional process of manufacturing goods has been constituted in an environment of queues and waiting. The lack of flow creates huge warehouses to store the inventory that consumes the working capital of the company (Melton, 2005). In a lean environment, a different approach should be taken. This system focuses on the customer and creates a value stream, designed specifically to meet customer’s needs. In addition, it eliminates waste and reduces the waiting period for the delivery of products and services. That means that the time delay in the value stream should be reduced in order to remove unnecessary obstacles in the process. Furthermore, it should be achieved a continuous movement of the product through the value stream. Doing this at the beginning of the project, will allow to (Rubio, 2009):

- Release spaces
- Discover the inventory excess
- Change an inefficient process
- Understand that employees cannot be multifunctional

Some of the typical obstacles that should be removed from the value stream are (Rubio, 2009):

- Rigidity of the functional departments
- Recurrent approval cycles
- Constant changing in project requirements
- Unnecessary interference from managers
**Pull**

Applying the pull system in a company implies to acquire the ability to design, program and do exactly what the customer requests. This should be done at the time that the customer orders and with a reasonable cost. Due to that, it is only produced what the customers want in each moment. This system is totally contrary to others that seek to increase the sales of a specific product in a particular time, such as special promotions.

Project teams should allow their customers to be involved in the design process in order to extract value from them. Only what customers need should be produced and by this way, companies allow their clients to establish their agendas and tell them what should be done every day. (Rubio, 2009)

**Perfection**

A lean project requires constant vigilance to maintain and improve its operation. It requires team discipline and zero tolerance towards the waste of resources. In order to avoid fortuitous and chaotic events, it is necessary to seek perfection continuously. Therefore, improvement cycle is never ending.

Many obstacles appear when trying to achieve a lean environment. However, it is necessary to get over them to permanently remove all the waste of the value stream. This is impossible to achieve it in a single project but with lean philosophy more efficiency can be attained every time. In addition, technology and concepts needed to remove waste are in many cases simple and ready for implementation. (Womack and Jones, 2003; Melton, 2005; Rubio, 2009)

**2.2 Critical Chain Project Management**

Critical chain project management (CCPM) is a project management technique based on the Theory of Constraints (TOC) that offers a practical method for planning, scheduling and control both, single and multiple projects. The original idea of CCPM was initially published in the book ‘Critical chain’ (Goldratt, 1997) in which the author applied the TOC to project management. (Rand, 2000; Cohen, Mandelbaum and Shtub, 2004)

Critical chain was developed as a response to the existing problems that traditional methods, Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT), had not been able to eliminate. These problems were, among others, late completion, over spending and the need to reduce specifications. In order to solve these problems, CCPM with the TOC approach tried to find the core problem and then achieve an innovative solution. (Rand, 2000)

CCPM focuses on the project schedule through reducing project changes and improving schedule performance, which is considered the major responsible of project cost
overruns. CCPM changes project plan, project measurement, control system and some behaviours of the project team in order to accomplish its objectives. This methodology offers positive aspects that should be taken into account in order to reduce the overall project duration: (Leach, 1999; Raz, Barnes and Dvir, 2003)

- Identifies the critical chain as the project constraint instead of the critical path and it does not change during project performance as a result of the CCPM procedure
- Establishes 50% estimate activity times
- Deals with duration uncertainty making buffers explicit, and shows buffer size and placement with workers, management and sponsors
- Considers the buffers as a tool for controlling project schedule
- Considers resource availability
- Focuses on key tasks and resources
- Constant information about the amount of buffer in the schedule
- Provides knowledge of expected work to critical resources
- Tries to change project team behaviour; does not divide manager attention among numerous tasks and encourages the workers to report early completion of activities

CCPM is a controversial topic since there are different opinions about it. On the one hand, this approach is seen for most authors as a new technique to managing projects, a different approach that could reduce delivery time while allow managers to meet schedule and budget commitments. On the other hand, some authors state that the principles of this method are known for years and its new contribution are the terms used to coin the concepts that have been already explained in previous methods. Despite all these opinions, this method offers positive aspects, listed above, that should be taken into account. (Steyn, 2001; Raz, Barnes and Dvir, 2003)

### 2.2.1 The Theory of Constraints

The Theory of Constraints was developed at the beginning of the eighties by Goldratt in his book ‘The Goal’ (1984). TOC is a management tool that was first applied to production systems and has had a wide application in operations management. In this theory it is established that “any system must have a constraint. Otherwise, its output would increase indefinitely or go to zero” (Goldratt, 1984 cited in Leach, 1999, p.40). Therefore, the basic principle of TOC is that every system has at least one constraint and the results of the system can only be improved by enhancing the results of that constraint. In physical systems the constraint is identified as a bottleneck since it limits the flow through the system. (Leach, 1999; Steyn, 2001; Raz, Barnes and Dvir, 2003; Leach, 2005) The continual improvement process of the TOC consists of these five steps (Leach, 1999; Rand, 2000) that can be seen on figure 3:
1. Identify the system’s constraint: The system constraint is the part of the system that limits its objective. The constraint, also called bottleneck in a production environment, should be identified in this step.

2. Exploit the constraint: The use of this constraint needs to be maximized. If for instance the constraint is a machine, it should be operating all the time.

3. Subordinate everything else to the constraint: When the constraint has been identified and exploited, the planning decisions have to be subordinated to the constraint so that it can work without difficulty.

4. Elevate the system’s constraint: In this step, the system constraint should be improved in order to enhance the objective of the system. The main difference between this step and the second one is that step four requires a bigger amount of investment, in terms of time, money or effort.

5. In case of rupture of the constraint in the previous step, go back to the first step. Do not permit inertia to become the constraint: Because of the increased capacity in the step four, the system’s constraint might have changed. Thus, the new constraint needs to be identified and the process should be repeated.

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**Figure 3: Continual improvement process**

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2 Adapted from Leach, 2005
2.2.2 CRITICAL CHAIN METHODOLOGY

Planning

The first step of CCPM consists of enumerating all the project tasks together with their estimated duration and dependences. Then, it is created an initial schedule for the project tasks considering their dependences and the availability of resources. The critical chain method calculates the project duration after the resource levelling. Therefore, this schedule is probably longer than the obtained with the critical path, since some of the resources have limited availability and some of the critical activities can be postponed until the needed resources are available. (Raz, Barnes and Dvir, 2003)

Then, the critical chain is identified. Traditional methods determine the critical path “the set of activities which determines the earliest completion of the project” taking into account that the dependences between tasks and resource limitations are only considered after establishing the critical path. However, the critical chain is based on the idea that a resource with limited availability that is needed to execute different tasks sequentially can determine the longest time required to complete the project. Thus, this approach identifies the constraint of a project as the critical chain and this is defined as “the sequence of tasks that determine the project duration, taking into account the dependencies between tasks and the resource limitations”. The resources that are used by critical activities are named critical resources. (Leach, 1999; Raz, Barnes and Dvir, 2003; Cohen, Mandelbaum and Shtub, 2004)

Once the critical chain has been established, a new project schedule is created consisting in the same tasks but with reduced durations. The reduction in task duration is produced by removing safety margins included in time estimation. According to Goldratt, the use of the safety margin is the main reason for project overrun. (Rand, 2000) Since all tasks have some level of uncertainty, managers usually add a safety margin in order to be sure to complete the tasks in time. Therefore, tasks durations are overestimated to provide a reasonable level of certainty of completion. In spite of these safety margins, a high level of overruns is still produced due to delayed starts. The explanation of this fact lies in the management’s comprehension of the workforce. The delayed starts are produced due to the employees’ feeling that there is still some time left to start the tasks and therefore they are not motivated to start on time. (Rand, 2000; Raz, Barnes and Dvir, 2003)

Furthermore, tasks are usually finished before the established due date and therefore they do not need the safety margin. However, since this margin is internal to the tasks, when it is not used, it becomes waste. In addition, the resources are not available until the scheduled time. Thus, the manager will use the buffer anyway, even if it is not necessary because there is no inducement to finish the project early. Conversely, delays in the tasks that are part of the critical chain will make the project to finish late even if there are safety margins in each task. (Raz, Barnes and Dvir, 2003)
Traditional methods (PERT and CPM) deal with uncertainty in the same way for all activities establishing a duration estimate with a probability of completion of 95% for each task. CCPM states that estimates should be reduced to the probability of 50% and it relocates safety margins in strategic positions. The difference between these two estimates is placed as a different task at the end of the critical chain and is called the project buffer. This buffer is used to protect the project due date from variations in critical chain tasks and as a part of the project it has to be scheduled and assigned resources. (Rand 2000; Raz 2003; Cohen, Mandelbaum and Shtub, 2004) According to Leach (1999) the project buffer capacity is the 50% of the duration of the critical chain. Figure 4 shows the difference between traditional schedule and CCPM schedule. The CCPM representation is useful to show the uncertainty of each project while PERT/CPM try to show false certainty.

![Figure 4: Comparison between PERT/CPM schedule and CCPM schedule](image)

Although it can seem that the total duration of the project would increase by making the safety margins explicit, the combined project buffer is less than the sum of the safety margins of the individual tasks. This is justified by the statistical theory, which explains that the standard deviation of the sum of a number of mutually independent random variables is less than the sum of the individual standard deviations. (Raz, Barnes and Dvir, 2003)

The next step in CCPM is the creation of feeding buffers. This type of buffer is located at the end of the non-critical task chain and the manager can adjust its size. However, some authors state that its capacity is the 50% of the duration of the non-critical task chain. The function of this buffer is to avoid that delays in non-critical tasks can cause delays in the critical chain. Therefore, it provides protection against uncertainty in the non-critical chain. (Rand, 2000; Raz, Barnes and Dvir, 2003; Cohen, Mandelbaum and Shtub, 2004) Figure 5 shows a project network with a feeding buffer.

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3 Adapted from Raz, Barnes and Dvir, 2003 and Rand 2000
Finally, CCPM uses a third type of buffer called resource buffer, which is a fictitious task, located before critical chain tasks that need critical resources. Its aim is to alert the critical resource that it is going to be used in a short time by a critical task. By doing this, the resource will stop making non-critical work and therefore be ready to start working on the critical chain as soon as the predecessors are finished. This buffer does not consume resources and it does not imply cost or time to the project. (Rand, 2000; Raz, Barnes and Dvir, 2003; Cohen, Mandelbaum and Shtub, 2004)

**Execution**

During project execution, resources that work on the critical chain are supposed to work with one task at a time and without suspending their work to attend other tasks since works in parallel are not accepted in the CCPM. In addition, the resources have to do their work as quickly as possible and without taking into account the scheduled dates. (Raz, Barnes and Dvir, 2003)

Therefore, a task can be completed before, after or on the scheduled date. If a task is finished before the scheduled date, the subsequent task has to begin immediately. Then, if the subsequent task uses a critical resource and this resource has a resource buffer, when the buffer begins, advanced warning is given to the resource so that it can be available for the critical task. On the other hand, if the task finishes after its scheduled date, the project buffer will absorb the delay. (Raz, Barnes and Dvir, 2003)

**Control**

In order to control the project, CCPM focuses on the extent that the buffers have been consumed. Because of that, project buffer and feeding buffers should be monitored. The correct management of feeding buffers avoids that the critical chain changes during project execution. When the buffer consumption is out of proportion is a good signal for

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4 Adapted from Raz, Barnes and Dvir, 2003 and Rand 2000.
implementing corrective actions, as for instance the reassignment of resources. By adjusting buffer sizes, the CCPM schedule is recalculated preserving the final due date of the project. (Leach, 1999; Raz, Barnes and Dvir, 2003; Cohen, Mandelbaum and Shtub, 2004) Managers make decisions according to the project and feeding buffers size, which are measured in days (Leach, 1999):

- No action in the first third of the buffer
- Evaluate the problem and plan an action within the middle third of the buffer
- Initiate an action at the beginning of the third third
Projects are considered temporary production systems, and these systems are considered ‘lean’ projects when they are organised in order to maximize value and minimize waste. There are many differences between traditional projects and lean projects. The main differences between these two systems are their objectives, the organization of their phases, the relation between phases and the participants in each phase. (Ballard and Howell, 2003)

Lean project management constitutes an alternative perspective to traditional production, in which producing is more important than designing and projects are considered as a minor way of production. In the new perspective, producing and designing are both considered important parts of production, and in order to design and make something for the first time, it is necessary to have a project. For this reason, a project constitutes the fundamental form of a production system. (Ballard and Howell, 2003)

Although lean project management has not been widely applied, there are some examples that show how this approach can be successfully implemented. In a recent study, carried out in BBC Worldwide, Middleton and Joyce (2012) have explained how lean principles can be applied to software project management in order to improve the performance of the software and consequently, project results. This approach uses tools as visual management, team-based problem solving, smaller batch sizes, and statistical process control to enhance software development. In addition, the delivery of projects focusing on the creation of value to the customer, allows them to reduce technical and market risks.

3.1 THE NEED TO REDEFINE PROJECT MANAGEMENT

The critical chain project management technique that has been explained in the previous section as well as the traditional methods PERT and CPM are forms of project management integrated in the Body of Knowledge of the Project Management Institute (PMI). The PMI, as cited in Howell and Koskela (2000), define project management as “the application of knowledge skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project. Meeting or exceeding stakeholder needs and expectations invariably involves balancing competing demands among:

- Scope, time, cost and quality
- Stakeholders with differing needs and expectations
- Identified needs and expectations”

At the same time, according to Packendorff (1995), a project is defined as “the set of related tasks, with start and end dates defined, which use a number of limited resources
to achieve a specific purpose. In addition, it is considered as a unique, once in a lifetime task, with a predetermined date of delivery, subject to one or several performance goals and consisting of a number of independent activities”.

Project management, as the Project Management Body of Knowledge (PMBOK) describes it, needs to be redefined because nowadays it results unsatisfactory and its performance is decreasing since projects are becoming increasingly complex, uncertain and they need to be completed more quickly. There are several reasons why the current project management is failing. Firstly, it makes imperfect assumptions and has an unsatisfactory theory, which causes problems that badly reduce performance in terms of duration and cost. Some deficient assumptions are: (Howell and Koskela, 2000)

- Uncertainty is considered low and in fact, is normally very high and changing
- The relation between tasks is considered simple and sequential; however, tasks usually are interdependent, as they tend to share most of the resources. In addition, the pressure for speed increases interaction
- Task boundaries are inflexible. This assumption is not correct, since upstream tasks are usually not complete when downstream activities begin
- Control based on standards for tasks in order to assure outcomes. It is thought that outcomes can be improved by enhancing tasks. This system of control has as a consequence that people make their work without caring about the work of others

Regarding the problems in theory, it is difficult to identify the causes of dissatisfaction, since there is not a well-defined model. However, in the next section, it is going to be described the underlying theory of project management highlighting its main deficiencies and proposing new approaches that complement the current model.

Secondly, the existing model is based on a deficient comprehension of the work in projects and an inadequate definition of control, which does not provide the expected results. The techniques included in the PMBOK were appropriate when there was no hurry to finish and the complexity of projects was lower. However, nowadays the pressure to finish early causes increasing interaction between activities, and consequently project complexity increases since to reduce project duration, more activities should be done at the same time. As a result, the simple and sequential relation between activities assumed in the PMBOK techniques is not valid for projects today. In addition, technical and design specifications are also increasing. (Howell and Koskela, 2000; Koskela and Howell, 2001)

Because of all these changes and failures in current projects, project management needs an exhaustive theory that shows the way in which work should be done, identifies and deals with uncertainty, controls project processes and reforms control. During the last years, it has been argued that the reform should be done with production management theories that include activities, workflow between activities and the creation of value. Of all the production management theories, the approach that best suits is lean
production, since it deals with delivering quickly, products that meets customer’s unique specifications and with having no inventory. In project management the product that needs to be delivered is the project, a unique, once in a lifetime task. Therefore, the basis of lean production fit with the need to deliver quickly complex and uncertain projects. (Howell and Koskela, 2000; Koskela and Howell, 2001)

3.2 NEW THEORETICAL BASIS OF PROJECT MANAGEMENT

Project management, as it has been explained before, has imperfect assumptions and unsatisfactory theory that constitute the main reasons of project failure. The main theoretical problems are related to the comprehension of project and the comprehension of management. According to the PMBOK, projects have two different processes; product oriented processes (theory of project) and project management processes (theory of management). In spite of the fact that there are no explicit theories, it is possible to indicate the essential basis of project management by dividing it into the theory of project and the theory of management both mentioned before. These theories are shown in table 1. (Koskela and Howell, 2001; 2002a; b)

<table>
<thead>
<tr>
<th>Subject of theory</th>
<th>Project Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory</td>
<td>Planning</td>
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<td></td>
<td>Management as planning</td>
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<tr>
<td></td>
<td>Execution</td>
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<td></td>
<td>Classical communication theory</td>
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<td></td>
<td>Control</td>
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<td></td>
<td>Thermostat model</td>
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3.2.1 THEORY OF PROJECT

Regarding the theory of project, it is stated that project management consists of managing work by decomposing it into smaller activities or tasks, as they are called in the PMBOK. These activities or tasks are independent, and they constitute the unit of analysis for project management processes, as for instance scope, time and cost management. In addition, the dependency relation between tasks is simple and sequential and to assure that activities meet schedule and budget objectives, the management and control is centralized. In this theory, the uncertainty of the tasks and requirements is considered low. (Koskela and Howell, 2002a; b)

Comparing this theory of project management with the theories of production management, it can be seen that the former theory lies in the transformation theory of the latter. The transformation model of production has been used in manufacturing during the major part of the 20th century. In this model, a project is considered as the transformation of inputs into outputs and it is managed through different principles, which indicate that the total transformation of a project can be decomposed into sub-
transformation or smaller transformations, tasks. At the same time, these principles suggest that optimizing each task separately can optimize project results. Therefore, improving tasks can enhance project performance. (Howell and Koskela, 2000)

However, some authors claim that the theory of project with the transformation view should be enhanced and new theories need to be included since this theory has two main problems. On the one hand, it does not admit that there are other activities in production apart from transformations and, on the other hand, it does not identify that the transformation does not gives value to the product, but that the customer’s needs conform the value of a product. In addition, production theories are older than project management itself and therefore, the transformation theory is not the best available nowadays. (Howell and Koskela, 2000; Koskela and Howell, 2002a; b)

According to Koskela and Howell (2002), it is a good option to incorporate the flow view of production into the theory of project because it includes time as a quality of production. This point of view comes from the lean production view, and it constitutes one of the main principles of this production system, as it has been explained in the previous sections. Since uncertainty and the relations between tasks influence time, the flow view focuses on these two aspects. Furthermore, the flow view accepts the uncertainty and deals with it, unlike the transformation theory, which tries to reduce it. The objectives of the flow view in project management are specifically not to do unnecessary work, remove waste from the flow processes and reduce time and variability.

Another view of production, the value generation view, has to be included in the theory of project. (Koskela and Howell, 2002a; b; Winter and Szczepanek, 2008) Again, this theory derives from the lean production, and its goal is to achieve the best value from the customer point of view. The inclusion of the customer is the major difference between the transformation and the value generation view, since the latter theory states that the customer specifications are not available from the beginning of the project and the assignation of specifications through the parts of the project can be difficult. Winter and Szczepanek (2008) have illustrated the essential notions of the value generation view in relation to a recent practice of a large integrated food group in the UK. In their study, they conclude that the model of value creation can be employed to describe the aim and extent of individual projects.

Koskela (2000) as cited in Koskela and Howell (2002) suggests that the transformation, flow and value theories, are seen not as a competing theories but as a complementary theories. The new theories (see table 2) of flow and value, add the consideration of time, variability and customer to the concept of transformation.
In this context of value creation appears also agile project management, which tries to deliver customer value in an economical, quality and fast way. The methods included in this approach have created a lot of interest in the IT industry, since they enable project teams to fast and consistently deliver customer value while they learn and adapt their methods to the shifting needs of the customers and the environment. Therefore, agile project management focuses on project performance, teamwork and leadership. As in lean production, the delivery of customer value consists of producing a product with the exact specifications that the customer asks for, when the customer orders it and with a reasonable price. (Elliott, 2008)

Agile project management includes practices such as release planning, sprint planning, daily scrum meetings, fixed-length sprints, sprint review and sprint retrospective. This approach focuses on recognising best significant items and delivering them as soon as possible. (Elliott, 2008)

Specifically, Scrum is a process that regularly applies a set of best practices to work collaboratively as a team and get the best possible project outcome. In this method, regular partial deliveries of the final project are performed, prioritized by the benefit that they bring to the receiver of the project. Therefore, Scrum is best suited for projects in complex environments, where there is the need to obtain results soon and where the requirements are changing or poorly defined. It is also useful, when innovation, competitiveness, flexibility and productivity are critical. In addition, Scrum is employed to resolve situations where the customer does not receive what he/she needs, the quality of the delivery is not acceptable, and when a specialized process in product development wants to be used. (Proyectos agiles, 2012)

### 3.2.2 Theory of Management

According to the PMBOK, there are several processes into project management: initiating, planning, execution, controlling and closing. However, the main processes are planning, execution and control since they form a closed circle (figure 6), in which the

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6 Koskela and Howell, 2002b
planning process gives a plan that is realised by the execution process. Then, the variances from the model and requests for modification provide improvements in execution or adjustments in upcoming plans. (Koskela and Howell, 2001; 2002a; b)

Figure 6: Core processes of project management

**Theory of planning**

Traditionally, planning processes have predominated in the PMBOK since there is only one executing process and two controlling processes. The planning processes are divided into ten core processes (Koskela and Howell, 2001; 2002a):

1. Scope planning
2. Scope definition
3. Activity definition
4. Resource planning
5. Activity sequencing
6. Activity duration estimating
7. Cost estimating
8. Schedule development
9. Cost budgeting
10. Project plan development

These planning processes give rise to the project plans, which constitute the input to the executing processes. Comparing this theory of planning with the theories of production management, it can be seen that the former theory lies in the management as planning theory of the latter. In this approach, plans are created, revised and implemented through a centralized vision in which there is a view of strong casual connection between the actions of management and outcomes of the organization. (Koskela and Howell, 2001; 2002a; b)

However, some authors state that this approach has several problems. Firstly, this model assumes that it is not possible to maintain an up-to-date plan. Secondly, it considers a centralized model of management in which the organization has a management and

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7 Adapted from Koskela and Howell, 2001
execution part clearly differentiated that does not correspond to organizational reality. Finally, the tasks are pushed to the execution process without consider the significance of the production system. This model implies that the outputs and the process itself are not examined. (Koskela and Howell, 2001; 2002a)

Because of all these problems, another approach of management has been proposed as a complement to the management as planning. This new approach (table 2) is called management as organizing and it is based on the idea that the human activity is essential what means that the organized environment might contribute to purposeful acting. Furthermore, instead of a centralized model of management, the management as organizing model assumes that there are different representations for several sub-units that are able to sensing, planning and acting. This approach is not exclusive, as it accept plans and representations as a fundament of purposeful action. (Koskela and Howell, 2002a; b)

**Theory of execution**

Theory of execution is briefly described in the PMBOK and the relation between plan and work is only explained regarding the work authorization system. By comparing the theory of execution with the theories that are used in manufacturing, it can be seen that the execution theory is similar to the model of job dispatching. This approach is based on the allocation of tasks or jobs to machines by a central authority. It uses logical decision rules to choose a machine that has just come available and assumes that tasks can be started by a notification of the execution to the executor. (Koskela and Howell, 2002a; b)

The dispatching model is composed by two elements; the decision, in order to select which tasks should go to each machine, and the communication or authorization of the allocation. Nevertheless, in the field of project management, the decision stage is done in the planning process and therefore dispatching is reduced to communication, an oral or written approval to start work. Thus, the theory of execution is the classical theory of communication in which there are groups of symbols that are communicated from sender to receiver in a one-way communication. (Koskela and Howell, 2002a)

However, the theory of dispatching has several critiques. Firstly, this theory assumes that the tasks and the resources needed by each task are ready at the time of authorization. Usually, this is not possible because, as it has been pointed out before, with the planning as management approach is difficult to maintain an updated plan. Therefore, sometimes the tasks that are pushed by the plan do not correspond to reality. Secondly, this approach assumes that there are a fully comprehension of the tasks and the work that should be done once the plan has been authorized. (Koskela and Howell, 2002a)

Because of all these shortcomings, a new theory has emerged, the language-action perspective. This approach states that work is done by creating and maintaining
commitments. These commitments form a cycle that starts with a request, continues by a promise, implementation and a declaration of completion. With this method, action is coordinated by the promises people make instead of by central control acting through commands. (Koskela and Howell, 2002a)

On the other hand, the communication part of the dispatching theory also has two deficiencies. Firstly, the traditional theory of communication is a one-way communication and it should be a two-way communication between the controller and the executors. Secondly, the executor should be committed with the job that is going to be done so that it can be completed. (Koskela and Howell, 2002a)

**Theory of control**

The process of control is divided into two sub-process; performance reporting, in which corrections are prescribed for the executing processes, and overall change control, in which changes are prescribed for the planning processes. Focusing on performance reporting, this process corresponds to the thermostat model of management control. This approach has the following parts: a standard of performance, then the performance is measured at the output and the variations between the standard and the measured value are used for correcting the process so the standard can be achieved. (Koskela and Howell, 2002a)

The thermostat model has an important limitation; it is not compatible with the theories of planning and executing. This model focuses on time and costs instead of tasks. Because of that, the closed circle that has been explained before consists of two different parts: on the one hand planning and execution and on the other hand controlling. Since it is difficult to maintain an updated plan, the differences between the expected results and the real results are very high. However, this approach does not focus on the reasons of failure but it focuses on explanation of variances. (Koskela and Howell, 2001)

There is a different model to the theory of control, the theory of scientific experiment which addresses learning and improvement in order to find the reasons for deviations, eliminate the root causes of problems and improve performance. Therefore, this model adds the element of learning to control. (Koskela and Howell, 2001; 2002a; b)

### 3.3 Historical background of lean project management

According to Ballard and Tommellein (2012), Lauri Koskela, a research scientist, was who first connected lean to project management. The connection, which took place in 1992, was specifically in the area of construction, after Koskela noticed the existing problems of project management in this field. There was an existing need to adapt and redefine this area with the new practices that were developing in the manufacturing industry, specifically in the company Toyota. Yet in 1993, Koskela and Glenn Ballard
carried out the first annual convention of the International Group for Lean Construction. This group is composed of researchers as well as practitioners, who are committed to the elaboration of a theory of production, which considers a project as the basic system for designing and producing things.

So far, lean project management has been developed both theoretically and practically. During approximately a period of ten years, Koskela and some researchers have been studying the theoretical basis of project management and, as it has been explained in the previous section, they have opposed their transformation-flow-value theory of project versus the transformation theory, in which projects are seen only as the transformation of inputs into outputs. With this integrative vision of the production and flow of information and materials, he tried to accomplish the following objectives: reducing costs, saving time, and increasing customer value (Howell and Koskela, 2000). Koskela and Howell (2002) proposed to give more emphasis to the flow view instead of the over attention on the transformation view. These new approaches of project management have had great acceptance among researchers and practitioners and have also shown its effectiveness.

Koskela and Howell (2002), as cited in Bertelsen (2004), compared construction projects with scientific experiments. By comparing them, they accepted the random nature of these types of projects, which constitutes a general feature of complex projects. Thus, the change in the theoretical basis of project management was justified because in a simple project, reducing variability can enhance order. In addition, chaos can be controlled with the appropriate use of buffers with well-established processes and with the elimination of causes of mistakes. However, uncertain projects need to be managed with values of collaboration, discussions and education.

Although the theoretical part has been studied deeper than the practical part, the Lean Construction Institute, founded in 1997 in the United States by Gregory Howell and Glenn Ballard, has led the practical study. These researchers have proved that in order to apply lean principles in the field of project management some changes are required, since each production system has its own particularities. Thus, the question was how to apply lean principles to the field of project management.

Firstly, it was thought that it could be created connected workstations, where tasks could be fixed as in repetitive manufacturing. However, construction is a kind of fixed-position manufacturing, in which the built objects, often too big, cannot move over different static workstations. Because of that, the situation needed to be changed; the workstations were converted into mobile stations where the objects pass through. In addition, instead of a static structure, planning was used to sequence and time the activities in the workstations. This adaptation was possible thanks to a succession of white papers published by the Lean Construction Institute, in which the lean project delivery system was developed. Furthermore, in these papers there were established fundamental characteristics of lean methodology to project management, for instance: (Ballard and Tommelein, 2012)
- Design and production need to take into account all the phases of the life cycle
- Project phases as well as development between phases is realized by means of dialogues, which are consistent with the lean principle of doing work only on request
- Joint decisions about product and process design
- The main management methods to lead project delivery over all its phases are work organizing and production control

Secondly, despite the fact that some Toyota’s manufacturing methods need to be adapted to project management, the Toyota’s product development system is directly applicable to construction. In construction projects, the use of the products starts when the construction is finished, as in the manufacturing field where the product development system finishes when repetitive manufacturing starts. The main difference between them is that the product development of manufacturing produces several copies of a product, while construction projects produce only one copy. (Ballard and Tommelein, 2012)

Recently, investigation has focused on defining and designing the phases of a project, applying the cited concepts and methods of lean methodology, from the Toyota Product Development System. Since 2000, Ballard has provided a description and presentation of the processes and practices of this system. In his work the ‘Lean Project Delivery System’, which is a method for managing projects that will be explained in the next section, he considers a project as a method of arranging ends, means and constraints. (Ballard, 2008) Furthermore, the elaboration of the Last Planner shows the adaptation of lean principles from manufacturing to the project management field. This method was developed in 1992, but since then, it has been in continuous development and improvement. (Ballard, 2000)

### 3.4 LEAN PROJECT DELIVERY SYSTEM

The holistic philosophy of lean construction is embedded in the lean project delivery system (LPD), whose mission is to develop the best possible way to design and build infrastructures (Alarcón and Pellicer, 2009). The LPD system appeared in 2000 after some practical and experimental investigations and is in process of continuous development. According to Ballard (2008) lean project delivery system is “a prescriptive model for managing projects, in which project definition is represented as a process of aligning ends, means and constraints (figure 7). Alignment is achieved through a conversation that starts with the customer stating:

- What they want to accomplish
- The constraints on the means (location, cost, time) for achieving their ends”
The general framework of the model is defined by the intersection between projects and production systems; this domain usually is designed as project-based production systems. The LPD model is applied to temporary production systems, like the construction industry and, as it has been explained before, the main differences between traditional and lean project delivery system are the definition of phases, the relation between phases and the participants in each phase. The main characteristics of the LPD model are: (Ballard and Howell, 2003; Alarcón and Pellicer, 2009)

- Projects are organized and managed as value generator processes
- Attention is on the production system
- All product life cycle stages are considered in design
- Agents that are subsequently implicated are involved also in the initial planning and design by means of multi-functional teams
- Project control is an executive function in contrast to the classic posterior detection
- Optimizing efforts is focused on achieving a reliable workflow, in contrast with increased productivity
- Pull techniques are used to managed the flow of information and materials through networks of specialists
- Buffers are used to absorb variations
- The feedback cycles are incorporated into each level, so quick adjustments can be made

The project delivery team is in charge of providing what the customer wants, but, in addition, they should help first the customers to decide what they want. Therefore, is important to comprehend the purpose and constraints of the customers, as well as to

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8 Ballard, 2008
show them available options to accomplish their purposes. In addition, the team should indicate the customers the effects of their requirements. This method certainly modifies the variables: ends, means and constraints. (Ballard, 2008)

The conversation starts by the customer explaining its desires, then, the project delivery team needs to identify the customer purpose so they can determine which characteristics are valuable in order to accomplish the purpose. Next, it is necessary to translate values into engineering specifications or design criteria so that the values can be included into the product. Then, before the product is designed, the use of the product needs to be identified. With this prior analysis of facility operations, sometimes is possible to improve an existing facility instead of building a new one, avoiding cost and time. Once the ends and means have been exposed, it is easy to identify constraints. (Ballard, 2008)

The LPD model is organized in five phases: definition, design, supply, assembly and usage. The different phases cited above give rise to eleven stages: purposes, design criteria, design concepts, process design, product design, detailed engineering, fabrication, logistics, installation, start, operation, maintenance and end of life. (Ballard and Howell, 2003; Ballard, 2008; Alarcón and Pellicer, 2009) The definition phase consists of establishing customer and stakeholder objectives and values, design criteria and design concepts. Conversations between stakeholders are needed, since each of this stages can affect the others. All the participants in each stage in the life cycle of the facility are implicated in this first phase, including participants of the construction team. The phase of design also includes conversations, which are used to develop and align process and product design in a functional level. The supply phase includes detailed engineering, fabrication and logistics. This stage requires the previous phase to be completed, so they can detail, fabricate and deliver the components. Finally, the assembly phase starts with delivering components and information so they can be installed. On the other hand, this phase ends when the customer starts using the facility. (Ballard and Howell, 2003)

At the same time, production control and work structuring cover all the stages and phases. In addition, the post-assessment module links the occupational end of a cycle to the next, generating a feedback learning. (Alarcón and Pellicer, 2009) The graphic description of the LPD model is shown in figure 8.
The LPD model includes management concepts that have been partially addressed in previous initiatives in the field of project management, for instance the strategic partnering. Partnering can be defined as two or more organizations that work together in order to optimize the construction of an infrastructure, including putting into operation and full exploitation the infrastructure, or a whole set of actions covering various related projects. The concept of partnering arises in the United Kingdom at the beginning of the eighties, with the purpose of deal with the modernization of the construction sector and, at the same time, cope with the difficulties of the government to finance infrastructure. (Alarcón and Pellicer, 2009)

LPD include this approach in a broader and global context that seeks to create the conditions so that the project development is a value creation process. This process includes concepts such as collaboration and development of confidence between the parts, which are present in the partnering, and others aspects like learning and continuous improvement, the optimization of the overall system and not just its parts, and the obtaining of reliable commitments. This includes the participation of all stakeholders from the earliest stages of the project in a collaborative design process with cost and schedule goals established in conjunction with innovative contractual arrangements. These arrangements regulate the relationships between the stakeholders and allow project stakeholders to share both risks and rewards. (Alarcón and Pellicer, 2009)

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9 Ballard, 2008
3.5 LAST PLANNER SYSTEM

The last planner system (LPS) is a crucial method of lean project management, which is inspired by the lean production philosophy. The elaboration of this system shows the adaptation of lean principles and methods to the project area. (Ballard and Tommelein, 2012)

Members of the Lean Construction Institute developed this system in the United States after they discovered in 1992 that only 54% of activities in weekly work plans were finished on time (Ballard and Tommelein, 2012). Until now, it has been developed as well as improved. The LPS is possibly the most widespread technique in the lean construction philosophy, and it is not only a tool to replace or compete with traditional methods as critical chain, but it complements and enriches them by improving variability and workflows. In addition, it focuses on the implementation phase, particularly in the building work. This system tries to increase reliability of planning and therefore, increase the performance in the building work. For this purpose, the system provides tools for effective planning and control. The LPS is specifically designed to enhance control in the uncertainty of the building work; this is accomplished by applying specific actions at different stages of planning. (Alarcón and Pellicer, 2009)

The LPS is a cascading planning system whose main purpose, apart from controlling the project, is to decrease variability of work by the application of these four principles (Rodríguez, Alarcón and Pellicer, 2009):

- Personal commitment of last decision makers (last planners)
- Coordination of the last planners through regular meetings
- Use of a basic indicator called planned tasks completed as planned (PPC)
- Public visibility of the obtained weekly results

Recent experiences of implementation in several American countries, show that the LPS is a real tool of continuous improvement of organizations, since it provides the adequate elements and tools to create a culture of improvement in the building work, achieving it in a natural way. The improvements achieved in individual projects are remarkable; however, the real value is achieved when companies succeed in implementing and consolidating these new practices at the entire organization, creating a culture of continuous improvement. (Rodríguez, Alarcón and Pellicer, 2009)

3.5.1 PHILOSOPHY OF THE LAST PLANNER SYSTEM

The reason why some building works are usually delayed is that work planning does not consider all specific project variables, as it is planned taking into account cases with a high degree of uncertainty. Some variables that are not usually taken into account are, for instance: availability of inventory from suppliers, uncertainty of designs and
requirements, problems of availability of manpower, administrative problems and wrong estimates about performance. This prevents the normal development of the works and causes constant interruptions, affecting the productivity of activities and the achievement of deadlines. If planning consists of determining what should be done to complete a project and to decide what will be done in a certain period of time, it must be recognized that because of some constraints, not everything can be done, producing repeated delays (see figure 9). In most building works, what can be done and what will be done are both subsets of what should be done; if the plan is developed without knowing what can be done, the work actually carried out will be the intersection of both subsets. (Rodríguez, Alarcón and Pellicer, 2011)

In order to reverse this situation, it is crucial that before deciding what will be done, it has adequate knowledge of what can be done. In periodic planning processes, managers and executors of the activities must first identify what can be done and subsequently agreeing what will be done during the week (see figure 10). This can avoid the annoying interruption of activities by any constraints. Thus, this situation helps enormously to the performance of activities, since it avoids annoying stoppages because of materials and workforce shortages. Figure 11 shows the mechanism for converting what should be done into what can be done. The inclusion of these assignments on weekly work plans represents what the planners actually will do. (Ballard, 2000; Rodríguez, Alarcón and Pellicer, 2011)

The planning process should focus mainly on managing what can be done; the most we can do, the most will be the real possibility of progress. This progress can be affected if the amount of activities that can be done is low. In order to avoid that, planners should focus their efforts on releasing the constraints that avoid tasks to be initiated or continued. By this way, it can be incremented what can be done increasing options of progress. It is important that the management is done on the root problem, since it cannot be obtained anything positive from applying more speed to the executors of the

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10 Adapted from Rodríguez, Alarcón and Pellicer, 2011
11 Adapted from Rodríguez, Alarcón and Pellicer, 2011
activities if they do not have the resources on time. (Ballard, 2000; Rodríguez, Alarcón and Pellicer, 2009; Alarcón and Pellicer, 2011)

Figure 11: The last planner system

Construction, therefore, requires planning by different people, in different positions at the organization and during different moments of the life cycle of the work. The LPS defines specific criteria of assignment that are considered advanced commitments of production in order to protect the productive units from uncertainty and variability. The process of applying the system is carried out as follows: (Rodríguez, Alarcón and Pellicer, 2011)

1. Review the general plan of the work (master scheduling)
2. Development of the phase scheduling in case of complex and extensive projects. It is identified the phase that is going to be developed next and the plan is devised
3. Development of the intermediate scheduling for an horizon of one or three months approximately, carrying out constraints analysis in order to eliminate bottle necks, framed within the master scheduling
4. Preparation of weekly scheduling, with the participation of decision makers or planners: managers, foremen, subcontractors, wholesaler, etc. as part of the inventory of ready activities achieved in the intermediate planning
5. Meeting of last planners to verify fulfilment of the weekly scheduling, identifying causes of non-fulfilment and establishing the plan for the next week.

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12 Ballard, 2000
The reliability of the plan is measured in terms of the percentage of planned tasks completed as planned (PPC) at the end of each week. The causes of failures of fulfilment are also investigated each week in order to avoid them in the future. The planning reliability is directly related to productivity. (Rodríguez, Alarcón and Pellicer, 2011; Ballard and Tommelein, 2012)

### 3.5.2 Master Scheduling

Master scheduling defines the tasks that should be done. It includes planning of all the activities of the project, establishing time and space relations between different planned activities. It also sets the milestones required to accomplish the established deadlines and it defines the scope and timing of partial deliveries. (Ballard and Tommelein, 2012)

For the proper development of the master scheduling is essential to identify those responsible for the fulfilment of each part of the program and include suppliers and subcontractors involved in each planned activity. Relationships between those responsible for the tasks and the suppliers and subcontractors should be included. At the same time, it must be stated the period of the program in which they should act. (Ballard, 2000; Ballard and Tommelein, 2012)

It is also important to identify the external participants that influence the implementation of planned activities. These actors are important, since they effect the development of the planned activities, which affects the overall achievement of the project. (Rodríguez, Alarcón and Pellicer, 2011)

The rigorous definition of each one of the activities that comprise the project, the responsible for these activities, suppliers, subcontractors and external actors involved in each activity as well as their interactions in time and space, allow the assembly of a initial master scheduling that more closely reflects the project reality. The initial master scheduling is revised from the learning achieved in the analysis of fulfilment in the intermediate scheduling and the weekly scheduling. (Rodriguez, Alarcón and Pellicer, 2011)

### 3.5.3 Phase Scheduling

The phase scheduling is the second level of planning and it is required when projects are long and complex. The master scheduling can be separated into phases, with activities that are composed of sets of tasks that cover the full duration of the activity. In addition, each working group needs to be created in a spatial and temporal proximity. (Rodríguez, Alarcón and Pellicer, 2011)

This phase is not always necessary in simple or small projects, but in larger projects it has a function that should not be ignored. Phase scheduling represents a more detailed
subdivision of the master scheduling, prepared by people that manage the work in the phase, to support fulfilment of the master scheduling milestones. From this perspective, it presents a clear opportunity to achieve credible commitments of planning with the participation of major actors in each phase of the project. (Rodríguez, Alarcón and Pellicer, 2011)

3.5.4 **INTERMEDIATE SCHEDULING**

Intermediate scheduling, usually called lookahead in the literature, goes deeply into the planning of activities in an intermediate term. This term should be defined according to the needs of each particular case; therefore, it can vary from 4-5 weeks to 15-16 weeks. Thus, the intermediate scheduling defines what can be done in this period of time. Table 3 shows a simple way to carry out an intermediate scheduling. (Rodríguez, Alarcón and Pellicer, 2011; Ballard and Tommelein, 2012)

The necessary supplies for the development of the activities and their responsible need to be identified in the intermediate scheduling and incorporated in the scheduled period. In addition, flow tasks such as inspections, tests, trials and interventions by external actors, which are needed to advance in the development of the master scheduling, are planned. By this way, when these tasks are incorporated into the planning, they do not constitute a focus of mismatches and delays. (Rodríguez, Alarcón and Pellicer, 2011)

<table>
<thead>
<tr>
<th>WEEK 1</th>
<th>WEEK 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

The intermediate scheduling accurately identifies the resources needed for the development of planned activities as well as the availability of these resources. It should also incorporate the security features that are needed to develop properly tasks and activities related to environmental conservation and waste management. (Rodríguez, Alarcón and Pellicer, 2011)

Once incorporated all these elements into the intermediate scheduling, it should be identified the constraints that need to be eliminated in order to develop the established scheduling. At the same time, it must be recognized the responsible of the elimination and the dates in which it is necessary that the constraints are removed. The main objective of the intermediate scheduling is to establish clearly what can be done on

13 Adapted from Rodriguez, Alarcón and Pellicer, 2011
schedule and to manage the existing constraints so they do not introduce delays in the schedule. Those activities that can be executed come to constitute the inventory of the ready work. (Rodríguez, Alarcón and Pellicer, 2011)

Integrating all these elements in the intermediate scheduling can help to discover problems not identified in the master scheduling. These problems, such as delays or advances that are produced in the analysis of the problems found, should be integrated into the master scheduling. (Ballard, 2000; Rodriguez, Alarcón and Pellicer, 2011)

### 3.5.5 Weekly Scheduling

Weekly scheduling is responsible for defining what is going to be done during the next week depending on the objectives achieved in the weekly planning finished, those planned in the intermediate scheduling, and the existing constraints. Activities that are going to be done should be included in the inventory of the ready work defined in the previous phase. Table 4 shows an example of weekly scheduling. (Rodríguez, Alarcón and Pellicer, 2011)

#### Table 4: Example of weekly scheduling

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>Start date</th>
<th>End date</th>
<th>OBJECTIVE</th>
<th>Fulfilled (Y/N)</th>
<th>WEEK 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODE</td>
<td>ACTIVITY</td>
<td>RESP</td>
<td>Execution</td>
<td>Executed % Achieved</td>
<td>M T W T F</td>
</tr>
<tr>
<td>Supplier</td>
<td>Subcontractor</td>
<td>Team</td>
<td>Security</td>
<td>Environment</td>
<td>External</td>
</tr>
</tbody>
</table>

In order to carry out this planning, it is convenient to establish a meeting at the beginning or at the end of the week, in which it is analysed the fulfilment of expired planning and the planning of the next week. It is essential to carry out this meeting with all the people that are involved in the execution (last planners or planners), including management representatives, suppliers, subcontractors and crew chiefs responsible for the different tasks in the building work. Furthermore, it is desirable that the meeting does not exceed two hours. (Ballard, 2000; Rodriguez, Alarcón and Pellicer, 2011)

The first task that should be done in the weekly planning meeting is the analysis of fulfilment of the expired planning, detecting which are the causes of non-fulfilment so that the necessary measures can be taken in order to correct the mismatches. These measures are included in the intermediate scheduling. As it has been explained before, the learning process is essential during the process. The systematic attack on the causes of non-fulfilment may increase the reliability of future planning. Figure 12 shows

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14 Adapted from Rodríguez, Alarcón and Pellicer, 2011
possible causes of non-fulfilment that may affect the building work. (Rodriguez, Alarcón and Pellicer, 2011; Ballard and Tommelein, 2012)

This iterative weekly process leads to feedback with the achieved conclusions in the weekly fulfilment analysis, which can introduce adjustments in the master scheduling and the intermediate scheduling. At the weekly meeting are also established the tasks that will be done during the next week according to the fulfilment of the results of the finished weekly scheduling, to what has been planned in the intermediate scheduling and the existing constraints that had been eliminated, always taking into account the inventory of ready work. (Ballard, 2000)

A basic aspect of lean construction philosophy and therefore of LPS is the commitment of all participants (represented by the last planners) in the execution of the construction. This commitment is reinforced by the public visibility of the weekly-achieved results, what is basic to strengthen the commitment of last planners. (Ballard and Tommelein, 2012)

### 3.5.6 IMPACT OF THE SYSTEM ON PROJECT PERFORMANCE

The LPS has been successfully applied in numerous projects worldwide. Specifically in Chile, the “Centro por Excelencia en Gestión de Producción” (Centre for excellence in production management) at the Catholic University of Chile supported and observed the impact of the implementation of the LPS in about eighty construction projects over a period of three years. During that period, the PPC fulfilment increased by about 20% and the companies reported productivity gains between 6% and 48%. It should be mentioned that the measurements were obtained from cases where there was a

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15 Adapted from Rodriguez, Alarcón and Pellicer, 2011
preliminary application of LPS so that the CPP increase should be attributed to the learning process and a progressive increase in the degree of system implementation. (Alarcón et al, 2008, cited in Rodríguez, Alarcón and Pellicer, 2011)

Before implementing the LPS, the planning fulfilment was erratic and a low average fulfilment in weekly scheduling, even below to 50% in some cases. By introducing some very basic aspects of the LPS, such as conducting weekly meetings, PPC control, and productivity monitoring activities, there were positive developments in the PPC. In addition, it should be noted that even in the latest measurements, the observed degree of implementation is still limited, which allows managers to assert that the potential of improvement is even greater. Fulfilment results in individual projects are close to 100%. Figure 13 shows an example of evolution of PPC. (Rodriguez, Alarcón and Pellicer, 2011)

![Figure 13: Example of evolution of PPC](image_url)

In many projects, it was difficult to accurately measure the application impact through specific indicators. Due to that, the evaluation of the implementation impact took into account qualitative aspects. Projects managers pointed out the following positive aspects of the impacts (Alarcón and Pellicer, 2009; Rodríguez, Alarcón and Pellicer, 2011):

- Improved management and project control
- Greater involvement of middle managers through a more active role in project management and greater commitment to planning
- Reduction of urgent orders and contingencies
- Increased processes productivity, although it can not be measured directly
- Reduced periods on implementing the constructions

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16 Adapted from Rodriguez, Alarcón and Pellicer, 2011
In a broader evaluation, the LPS is seen by executives as a method to increase the global certainty of the achievements of organisation commitments. Project management concepts related to the LPS offer a great potential for increasing performance in projects. Recent experiences of implementation show that this system is a real tool of continuous improvement of organisations since it gives the adequate elements and tools to create improvement thinking in projects and it allows to achieve it in a natural way. Progress achieved in individual projects is notable, however, the real value is obtained when companies achieve to implement and consolidate these practices at the entire organization, creating a culture of continuous improvement. (Ballard, 2000; Rodríguez, Alarcón and Pellicer, 2011; Ballard and Tommelein, 2012)

3.5.7 Spanish Example of LPS Application

The philosophy of lean construction is almost unknown in Spain, as it can be seen by looking at the communications of the international congress organized by the Lean Construction Institute and the International Group for Lean Construction. It is only remarkable the contribution of Carlos Bosch (2003), as cited in Alarcón and Pellicer (2009), who analyses the application of the lean philosophy and techniques to the Dragados company. His work examines different areas where the company adopts lean construction as a systematic way of production. The author shows its practical application by describing a successful real case: production, transportation and placement of the new dam at the port of Monaco.

Despite this apparent lack of interest in new approaches, before the crisis that affects nowadays the country, the Spanish construction sector occupies one of the first places in the sector form the international perspective. The turnover of the Spanish construction companies in the European Union was around 15%, and four Spanish companies were among the five world leaders in infrastructure concessions. Perhaps this high rate of success in international markets leads Spanish companies to think that it is not necessary to adopt new management approaches. It is also possible that several companies are applying some recommendations and techniques from the lean construction, but they do not make them public either by the lack of time or to not give clues to their competitors. (Alarcón and Pellicer, 2009)

According to Alarcón and Pellicer (2009), for the big construction companies the adaptation for the planning systems to the lean approach does not imply an excessive effort, since most of them already have internal planning systems. The implementation of the LPS would be a more systematic planning of operations at all levels of the organization, as well as the participation of the entire chain of command in the ongoing planning of productive activities of the company.

The future also presents the opportunity to delve into the use and application of public-private contracts, also called partnering. However, it is important to remember that lean
construction focuses on systems and their reliability, while partnering focuses on communication and trust; both are linked by the relationship reliability-confidence.

In the next stages it will be described a Spanish example of LPS application. This example constitutes one of the few applications of this system in Spain, since it has been explained before, the LPS is not a widespread technique in this country. The presentation of this application was presented at the first annual meeting of the Spanish Group for Lean Construction (www.leanconstrucion.es).

**Background**

The building ‘Porta del Mar’ is located in Valencia, in Plaza Porta de la Mar, at the end of the Colon road together with the Military Government and close to the Justice Palace. This is a very central location, with good communications and high housing demand. (Sánchez and Rodriguez, 2011)

The building was built at the beginning of the seventies as the venue of the Valencia courts. It was intended for a tertiary use and specifically, it had:

- Twelve floors and two basements
- Main structure metallic
- Unidirectional framework, concrete beams and ceramic vault
- Antiquated facilities

With the construction of the City of Justice, the building fell into disuse and was auctioned by the Department of Justice. First, it was considered the rehabilitation of the building instead of the demolition so not to loose built capability with the change of use.

With the new destination, the building has a mixed use, commercial and residential. There are two different sectors created in the building, one for housing and the other for offices.

**Problems: Adjusted executing term**

The delivery date of the building ‘Porta del Mar’ was fixed and established on July 2011. The initial planning gave an execution time of twenty-five months. However, some problems in project approval delayed the beginning until October 2009. With this, the executing period was twenty-two months, three less than the initially considered. In order to execute the building work in twenty-two months a strict planning, supervised by the project manager, was required. (Sánchez and Rodriguez, 2011)

**Planning**

Initially, planning is done with the traditional method of project management, in which the building work is monitored and the updates are introduced in the work plan with the
software Microsoft Project. However, because of the appearance of some problems and the concerns of the group leader, the planning approach was changed to the Last Planner. (Sánchez and Rodriguez, 2011)

In order to improve planning, and as an initiative of the team leader, fortnightly meetings were established at the beginning of the work. In these meetings, the planning is revised together with the subcontractors and suppliers in order to achieve a high level of planning fulfilment so that the works could be finished on time. (Sánchez and Rodriguez, 2011)

To get the involvement and commitment of subcontractors and suppliers, certificates of completion were introduced from November 29, 2010 in the fortnightly planning meetings. These certificates were attached to the set of activities that each supplier or subcontractor had to develop. With them, they were committed to finish the works and if not, these certificates allowed project managers to sanction suppliers and managers with sanctions of 400€/month. (Sánchez and Rodriguez, 2011)

**Results**

With the use of the LPS, it was achieved a commitment of the suppliers and subcontractors. The improvement in the fulfilment was from 38% to 80%, and in the fortnightly meetings, the companies that did not fulfill the planning were exposed to all people involved. The 25th of May, managers communicated to the subcontractors that the sanctions were removed, except from four punctual cases that were published. (Sánchez and Rodriguez, 2011)

Although the method used in the construction of this building is based on the LPS and fulfill the four main principles of this system, there are several differences between them: (Sánchez and Rodriguez, 2011)

- It did not introduce the intermediate scheduling
- The weekly scheduling was changed to a fortnightly scheduling
- It achieved the commitment between suppliers and subcontractors by using different methods
- Owners and managers of the building work were not involved

### 3.6 LIMITS OF LEAN PROJECT MANAGEMENT

The limits of lean project management have not been widely studied, in contrast, few authors have written about this topic. Of the few references that can be found in the literature, in a recent article, Ballard and Tommelein (2012) state that lean project management is specifically appropriate for complex and uncertain projects, in which successful results are achieved. However, for simple and certain projects, which present stable scope, traditional project management can be successful. They assume a high
degree of certainty and low levels of complexity that allow them to add time to schedules and money to budgets and still maintain projects economically viable. Traditional methods include:

- Sequential processing
- Fixed-price contracting
- Work breakdown structuring
- Traditional project control
Nowadays, risk management constitutes a fundamental part of successful project management, since suitable risk management can help the project manager to reduce both, identified and unexpected risks in all types of projects. An ineffective risk management can give rise to undesired effects in terms of scope, time and cost as risk has a great potential to negatively affect project performance. These negative effects can trigger off longer duration in tasks that can cause problems to the manager in order to fulfill the project objectives. Because of that, the Project Management Institute (PMI) recognizes risk management as one of its nine main knowledge areas in the PMBOK. Although there are some elements that can determine a project to be successful, an adequate risk management increases the likelihood of success. In addition, it is vital to have a method or process to manage and plan risks that is easily understood by the project team. (Carbone and Tippett, 2004; Kutsch and Hall, 2010)

According to the PMI (2008) project risk management includes the processes related to management planning, identification, analysis, planning of risks response and monitoring and control in a project. The objectives of risk project management are increasing probability and consequences of positive events, and minimizing probabilities and consequences of adverse results to the project. The processes cited above, interact with each other and with the other areas of knowledge, although they have been presented as differentiate elements. Each process can imply the effort of one or more people, depending on the project needs. In addition, each process is executed at least one time in each project and in one or more phases of the project. Moreover, in practice these processes interact.

According to Ward and Champman (2004), as cited in Bannerman (2008), risk management implies several benefits to the project and the organization. Firstly, it entails the recognition of favourable complementary ways of action; secondly it increases reliance in accomplishing project targets, and it also improves opportunities of accomplishment and reduces unexpected events. In addition, it reduces uncertainty providing more accurate estimates, and finally, with the understanding of risk control programmes it decreases the effort needed to manage the project.

In order to be successful, the organization should be committed with dealing with risk management in a proactive and consistent way throughout the entire project. A conscious choice should be made at all levels of the organization to actively identify efficient management over the project life. Risks exist from the moment in which the project is conceived. Therefore, continue on a project without taking a proactive approach in risk management, increases the impact of a risk on a project and that can lead it to failure. (Project Management Institute, 2008)
4.1 Distinction between risk and uncertainty

Most research has focused on trying to explain the distinction between uncertainty and risk, since it results necessary in order to explain their influence on project performance. Despite being extensively studied, risk and uncertainty have not a clear and shared definition. Traditionally, risk has been defined as an uncertain event, often related to an undesirable and adverse consequence. (Perminova, Gustafsson and Wikström, 2008) However, this definition implies two mistaken assumptions.

On the one hand, there is common agreement between researchers that risk should be linked with both, positive and negative consequences. Specifically, Chapman and Ward (2003) state that risk management should be related not only with removing the possibility of underperformance, but also with the consideration of positive aspects of uncertainty, which can present opportunities instead of threats. Taking this into consideration, the PMI (2008) defines project risk as “an uncertain event or uncertain condition that, if occurs, has a positive or a negative effect on at least one project objective, such as cost, time, scope or quality.” According to the same source, a risk can have one or more causes and if occurs, one or more impacts. The causes are composed of requirements, suppositions, constraints or conditions that generate positive as well as negative consequences. Risk conditions can comprehend some environmental aspects of a project, for instance deficient practices in project management, lack of integrated management systems or the dependence of external actors that cannot be controlled.

Other authors, as Perminova, Gustafsson and Wikström (2008) have also pointed out that risk and uncertainty are not synonyms, and that they should be defined properly. They state that the definition given by the PMI gives rise to conclude that risk is uncertainty, since it does not define the latter term adequately. They agree with researchers that describe uncertainty as changes that may bring new opportunities into the project in addition to the negative description, in which uncertainty can have undesirable impact in project performance and project’s objectives. From their point of view, risks should be comprehended as one of the implications of uncertainty, instead of considering that risk is uncertainty.

On the other hand, risk should also be associated to future project circumstances, instead of only be related to punctual events. These future circumstances are difficult to forecast at the initial phases of the project life cycle, they can be positive or negative and in addition they can change and become more difficult than expected during project life cycle. Furthermore, when considering risks only as punctual events, the level of impact, which varies with the conditions, is not taken into account. (Klemetti, 2006) The traditional approach of risk project management states that planning, together with identification, analysis, monitoring and control has a great importance in risk project management. However, despite the fact that planning at an initial phase is an important activity in project management is not sufficient to guarantee project success. Projects are generally complex and have constraints of time, cost and resources; in addition, sometimes they are affected by some restrictions that cannot be identified at an initial
stage. Therefore, it is crucial to make correct decisions about the different actions that can be taken, which implies information about results of the previous activities. (Perminova, Gustafsson and Wikström, 2008) According to Artto and Känkönen, as cited in Klemetti (2006) risk has other scope, called the scope of perception. This implies that each manager perceives risk in a different way, as adverse or significant or as an opportunity or less significant aspect. Until now, risk perception is one of the main enhancement areas in risk project management.

Due to all the reasons exposed above, some researchers have pointed out the need to replace risk with a more impartial term that presents a broader scope. According to Ward and Chapman (2003) the term uncertainty can be used as a replacement, since it also denotes the variability and ambiguity aspect of risk. Uncertainty is considered as an essential characteristic of successful project management. Project definition, which has been given in the previous part, highlights the changing character of projects, the need to allocate different resources dealing with constraints, and the importance of objectives in project definition. In addition, the new organization and unique scope of each project entail intrinsic uncertainty, which must be taken into account in order to perform successful project management.

However, these authors finally conclude that although ‘risk and uncertainty management’ can replace the term ‘risk management’ the latter is extremely well established in the literature to be changed. Thus, they keep this term but with a broader definition, highlighting the importance of opportunity management in an uncertainty management context.

4.1.1 FUNDAMENTAL UNCERTAINTIES IN PROJECTS

In this section, different types of existing uncertainties in projects are going to be described. Uncertainty is present in a diversity of sources that require managers’ attention. In addition, it is often high and difficult to quantify. However, some practices deal well with managing uncertainty; they describe what can and needs to be made in a proactive way.

Atkinson, Crawford and Ward (2006) have established three key areas of uncertainty: uncertainty related to estimates, uncertainty connected with project parties and uncertainty linked with steps of the project life cycle.

Uncertainty related to estimates

When managers make estimates about the time and resources that an activity is going to require, they have to deal with the uncertainty of these decisions, since they do not know exactly the resources needed to carry out the activity. This constitutes an example of the existing uncertainty in the size of project parameters, for instance, cost, duration
and quality. Some of the main causes of uncertainty in this regard are: (Crawford and Ward, 2003; Atkinson, Crawford and Ward, 2006)

- Absence of explicit description of what is needed
- Novelty of lack of knowledge in that specific activity
- Difficulty related to the quantity of influencing factors and interdependences
- Imperfect examination of the practices implicated in the activity
- Events or conditions that may affect the activity
- Unknown factors at the beginning of the project

Some of these causes could have not been taken into account without the consideration of uncertainty as anything that can influence the project from the point of view of risk management. The other causes are related to the absence of knowledge regarding what is implicated, in terms of default data, detail and imperfect assumptions. (Crawford and Ward, 2003)

**Uncertainty linked with project parties**

The participation of multiple parties in a project originates uncertainty since the relations between them can be complicated. (Atkinson, Crawford and Ward, 2006) Although some projects are often technologically complex, the presence of multiple parties implies greater uncertainty. This uncertainty can be caused from ambiguity regarding: (Atkinson, Crawford and Ward, 2006)

- Ambiguity concerning the achieved results
- Purposes and motivation of each team member
- Value and consistency of the work carried out
- The adjustment of the party and owner’s objectives
- The aptitudes of the party
- Accessibility of the party

These factors can give rise to important uncertainties that can be increased if the parties come from different companies. In that case, is probably that the parties do not share information, duties and purposes. This can originate different perceptions of the risks that entail their purposes and moreover, they can have different understanding about the type of causes of uncertainty and the different ways to manage it. (Atkinson, Crawford and Ward, 2006)

**Uncertainty linked with steps of the project life cycle**

Management processes that constitute the project life cycle are responsible for numerous important causes of uncertainty. These causes appear all over the project life cycle and are best undertaken at the beginning of the project. Chapman and Ward (2003), as cited in Atkinson, Crawford and Ward (2006), offer an exhaustive
explanation of project life cycle phases and the uncertainties related to them. Table 5 shows these phases together with their uncertainties.

Table 5: Phases of the project life cycle and the uncertainties related to them

<table>
<thead>
<tr>
<th>Stages of the PLC</th>
<th>Uncertainty management issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceive the product</td>
<td>Level of definition&lt;br&gt;Definition of appropriate performance objectives&lt;br&gt;Managing stakeholder expectations</td>
</tr>
<tr>
<td>Design the product strategically</td>
<td>Novelty of design and technology&lt;br&gt;Determining ‘fixed’ points in the design&lt;br&gt;Control of changes</td>
</tr>
<tr>
<td>Plan the execution strategically</td>
<td>Identifying and allowing for regulatory constraints&lt;br&gt;Concurrency of activities required&lt;br&gt;Capturing dependency relationships&lt;br&gt;Errors and omissions</td>
</tr>
<tr>
<td>Allocate resources tactically</td>
<td>Adequate accuracy of resource estimates&lt;br&gt;Estimating resources required&lt;br&gt;Defining responsibilities (number and scope of contracts)&lt;br&gt;Defining contractual terms and conditions&lt;br&gt;Selection of capable participants (tendering procedures and bid selection)</td>
</tr>
<tr>
<td>Execute production</td>
<td>Exercising adequate coordination and control&lt;br&gt;Determining the level and scope of control systems&lt;br&gt;Ensuring effective communication between participants&lt;br&gt;Provision of appropriate organizational arrangements&lt;br&gt;Ensuring effective leadership&lt;br&gt;Ensuring continuity in personnel and responsibilities&lt;br&gt;Responding effectively to sources which are realized</td>
</tr>
<tr>
<td>Deliver the product</td>
<td>Adequate testing&lt;br&gt;Adequate training&lt;br&gt;Managing stakeholder expectations&lt;br&gt;Obtaining licences to operate</td>
</tr>
<tr>
<td>Review the process</td>
<td>Capturing corporate knowledge&lt;br&gt;Learning key lessons&lt;br&gt;Understanding what success means</td>
</tr>
<tr>
<td>Support the product</td>
<td>Provision of appropriate organization arrangements&lt;br&gt;Identifying extent of liabilities&lt;br&gt;Managing stakeholder expectations</td>
</tr>
</tbody>
</table>

17 Atkinson, Crawford and Ward, 2006
Furthermore, in order to identify effectively the project risks, these authors propose six questions that allow managers to identify the root causes of uncertainty.

- “Who are the parties ultimately involved?
- What do the parties want to achieve?
- What is it the parties are interested in?
- How is it to be done?
- What resources are required?
- When does it have to be done?”

If the uncertainty embodied in these questions is completely understood, it will be possible to identify and manage project risks. In addition, a good comprehension of the project life cycle, specifically the two first phases, would produce better specifications for production. Thus, the execution phase will not need additional specifications, although a common cause of uncertainty in this phase is the changes in design, which can produce alterations in schedules that can affect time and budget.

4.2 Project Risk Management Processes

As it has been explained before, although sometimes risks can have positive effects in projects objectives, they often entail problems to the manager in order to achieve project objectives related to scope, time and budget. This eventually implies that activities have longer duration than expected with the resulting increase in cost.

In order to manage these risks, many processes have emerged during the years, which with their structure and discipline provide the formality required to manage risks effectively and efficiently. Formality is understood in the sense that it provides the necessary framework to develop good practices, ensuring that answers and questions about risks are developed and completely understood. (Chapman and Ward, 2003)

The Project Management Institute (PMI), an organization that has been cited before, has established risk management as one of its nine knowledge areas in the PMBOK. But apart from this organization, there are many others who have identified the process needed to deal with risk. The principal associations are: the Office of Government Commerce (OGC) and the UK Association for Project Management (APM). (Kutsch and Hall, 2010)

Although these processes have different elements, which are described in a different level of detail (see table 6), they are all iterative processes in which the phases are being developed all over the project life cycle. They provide methods with similar structures and with one common aspect, “an activity that deals with planning actions that will be implemented in order to reduce the exposure to risk” (Ben-David and Raz, 2001 cited in Kutsch and Hall 2010, p. 246) This activity is composed of four phases; the first phase, risk management planning, identifies the necessary activities to deal with project risks. The second phase, risk identification, enables managers to identify the potential project
risks. Third, risk analysis provides a quantitative and qualitative analysis to evaluate the probability of happening and the results of risks. Finally, risk response establishes practices and methods to diminish the identified risks as well as monitoring them and recognize new risks. These phases will be described subsequently in greater detail.

Table 6: Main project risk management processes

<table>
<thead>
<tr>
<th>Major phases in project risk management</th>
<th>PMBOK-PMI risk management processes</th>
<th>OGC- management of risk</th>
<th>PRAM- APM risk management process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Risk management planning</td>
<td>Context</td>
<td>Focus</td>
</tr>
<tr>
<td>Identification</td>
<td>Risk identification</td>
<td>Risk Identification</td>
<td>Define</td>
</tr>
<tr>
<td>Analysis</td>
<td>Risk analysis</td>
<td>Asses, estimate</td>
<td>Identify</td>
</tr>
<tr>
<td>Response</td>
<td>Risk response planning</td>
<td>Asses, evaluate</td>
<td>Structure</td>
</tr>
<tr>
<td></td>
<td>Risk monitoring and control</td>
<td>Plan</td>
<td>Estimate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Implement</td>
<td>Evaluate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communicate</td>
<td>Plan</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Ownership</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Manage</td>
</tr>
</tbody>
</table>

According to Kutsch and Hall (2010), these processes are all based in the expected utility theorem, which basically establishes that, the likelihood and results of the choices in the decision-making determine their usefulness. However, although this theory has been commonly accepted, these authors state that this theorem does not pay enough attention to the absence of relevance. They stress the need to investigate the effectiveness of these processes considering behavioural aspects of irrelevance in managers, since in some cases the unawareness of project managers entails several problems to the project.

Risk management processes must be applied at the initial phases of the project, so there is the chance to make important modifications. Each project needs to be analysed in detail in order to choose the best method at each phase. In addition, processes should be adapted to each specific project, since the main reason of project risk management is to guarantee good basis for decision-making. (Klemetti, 2006)

4.2.1 Risk management planning

Risk management planning is the process of deciding how to plan and deal with risk management activities of a project. A thorough and explicit planning improves the probability of success of the other five risk management phases. It is important to plan the process of risk management to assure that the level, type, and visibility of risk management are in proportion with the risks and with the importance of the project for the organization. In addition, risk management planning is important to provide the necessary resources and time for the risk management activities. The process of risk management planning should be started as soon as the project is conceived and must be completed in the early planning stages. (PMI, 2008)

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18 Kutsch and Hall, 2010
4.2.2  **RISK IDENTIFICATION**

Risk identification has been pointed out as one of the most important phases by many researchers. Its importance lies in the evident fact that without recognizing the risk managers cannot deal with them. In addition, the non-recognising of risks is a limited view in which risk management is seen as the identification of uncertain events. (Kutsch and Hall, 2010) As it has been explained before, risks have several perspectives and many authors have stressed the need to consider them with a wide definition. This definition includes the step of risks as uncertain events to risks as anything positive or negative that can happen to a project, not just events and its associate responses.

Chapman and Ward (2003) state that the achievement in the subsequent phases is conditioned by the accomplishment in the identification phase because this phase constitutes the bases of the risk management process. If this phase has a great quality, the remaining phases will be successful. Risk identification takes place during the entire project life cycle, because of that, some risks can change during this time and new risks can appear.

However, Skitmore and Lyons (2004), as cited in Klemetti (2006), have different opinions. They conclude that the success in the risk management process depends mostly on the analysis phase instead of the identification phase. Nevertheless, their study shows that the tools and techniques of the identification phase are the most used. With this, it is proved that risk identification must be a continuous procedure with several iterative sequences even in the latest phases of the project.

Each one of the main processes described above, PMBOK, OGM and PRAM have methods in order to identify risks. These methods include: questionnaires, checklists, surveys, brainstorming, interviewing, lessons learned database and experts analysis. All these methods provide a risk register.

4.2.3  **RISK ANALYSIS**

Risks should be analysed regarding their likelihood of happening and effect, once they have been identified. Because of the limited budget, some projects have a reduced quantity of resources to the risk management area. Therefore, knowing the possible impact of risk is important in order to concentrate these resources in the most harmful risks. So as to give priority to the risks, their probability of occurrence and effects are fundamental. In order to examine risks, managers can use both, quantitative or qualitative analysis. (Klemetti, 2006; PMI, 2008)

Qualitative analysis evaluates the effect and probability of the recognized risks, and at the same time, develops ranked lists with these risks for additional examination or palliation. The project team evaluates the likelihood of impact and occurrence on project objectives. In addition, this team, which is composed of experts, provides
assistance in order to evaluate the risks in their particular subjects. Commonly, qualitative analysis is used to provide a preliminary evaluation of project risks. Generally this evaluation is quick and constitutes the favourite method in simple and small projects, since quantitative analysis is not required in these cases. Qualitative analysis often follows the following structure together with a matrix where the results are written (see figure 14): (Klemetti, 2006)

- Project risks are considered by the project team
- Evaluate the risk knowledge from the risk identification phase
- Examine the risk with the team
- Discuss the probability of happening to that risk and write the result that the team approves. The probability of happening is indicated in simple scales, for example from low to high.
- Discuss the impact that the risk can have on the project and write the result that the team approves, again with a simple scale that goes from low to high.
- Rank the risks founded on the outcomes of this analysis. The result is a list with all the risks ranked according to their probability of occurrence and effect on the project.

![Probability/Impact matrix](image)

Figure 14: Probability/Impact matrix

Regarding quantitative analysis, it is used when the risks are identified and ranked with the qualitative analysis. This analysis is in charge of document the likelihood of happening as well as the effect of risks. It implies calculate mathematically the likelihood of a project to achieve time and budget objectives. In addition, it is based on a concurrent evaluation of the effects of all recognized and ranked risks. (PMI, 2008)

One of the most common quantitative tools is the Monte Carlo simulation, which evaluates project risks and uncertainty. This tool provides project estimates with a general result variance for expected project budget and plan. (PMI, 2008)
4.2.4 Risk Response

Risk response consists of taking action to improve positive effects and decrease negative impacts to the project objectives. Once the project risks have been identified and analysed, the project team and managers should decide the response to these risks. Since the project team have the ranked risks at their disposal, they should prioritize action according to the risks importance. In order to implement response actions, managers have several tools available. The possible actions in response are chosen based on the risk analysis, and they include: avoid, transfer, mitigate and accept. (Klemetti, 2006; PMI, 2008)

- Avoid entails modifying project schedules so that the risks do not affect them
- Transfer implies the change of risks to different parties using contracts or insurances
- Mitigate consists of discovering means to decrease the likelihood or effect of risks
- Accept entails recognizing and dealing with risks although they can have negative consequences

Risk response usually implies monitoring and controlling in order to determine if the responses have been successful and effective. Monitoring implies check the project to find trends that suggest positive or negative deviations in project execution. (Kutsch and Hall, 2010)
During the last years, project management has been a controversial discipline because of the discussion about its capability to achieve project objectives. Traditional project management, which includes methods such as Critical Chain Project Management, Critical Path and Program Evaluation and Review Technique, has entailed several problems, above all for complex projects, since it is not able to deal with uncertainty. Basically, these problems arise because of its faulty theory and imperfect assumptions that do not address correctly work and control in projects. In addition, in order to manage resources and coordinate work, these methods have too much dependence on central authority and project schedules what give rise to deviations in workflow, which causes an increase in duration, cost and confrontational relations between the parties. Some of the main imperfect assumptions are:

- Uncertainty is considered low and usually it is very high and changing
- Relation between tasks is considered simple and sequential; however, generally tasks are interdependent since most of the resources are usually shared
- Tasks boundaries are considered inflexible but this is not correct since upstream tasks are generally not complete when downstream activities begin
- Control is based on standards for tasks in order to assure outcomes since it is thought that outcomes can be improved by enhancing tasks. This system of control causes that people make its work without caring about the work of others

Since managing uncertainty and workflow in projects are crucial aspects, production management theories have shown to be the best appropriate to reform project management. They include the management of activities, workflow between activities and the creation of value. Of all the theories of production, lean production is which best fits, as it adds the value and flow view to the transformation view in projects, in which projects are only seen as the transformation of inputs into outputs. With these new points of view, managers try to deal with uncertainty instead of avoid it, and to achieve the best value from the customer perspective.

These new approaches give rise to the new project management method, named lean project management, which is organized in order to maximize value and minimize waste. This new perspective considers projects as the fundamental form of production systems, since in order to design and produce something for the first time it is necessary to have a project. In the context of this new approach appears the lean project delivery system, a method for managing projects used in temporary production systems, like the construction industry. Its main characteristics are:

- Projects are organized and managed as value generator processes
- Attention is on the production system
- All product life cycle stages are considered in design
• Agents that are subsequently implicated are involved also in the initial planning and design by means of multi-functional teams
• Project control is an executive function in contrast to the classic posterior detection
• Optimizing efforts is focused on achieving a reliable workflow, in contrast with increased productivity
• Pull techniques are used to managed the flow of information and materials through networks of specialists
• Buffers are used to absorb variations
• The feedback cycles are incorporated into each level, so quick adjustments can be made

Another key method of lean project management is the last planner system (LPS), which shows the adaptation of lean principles and methods from manufacturing to the project area. This method is used to complement and enrich traditional methods such as critical chain and it implies a culture of continuous improvement. In addition, it tries to improve control in the uncertainty of the building work by the application of these principles:
- Personal commitment of last decision makers (last planners)
- Coordination of the last planners through regular meetings
- Use of a basic indicator called planned tasks completed as planned (PPC)
- Public visibility of the obtained weekly results

The improvement achieved in the Spanish example is remarkable. With its utilization, the fulfilment increased from 38% to 80%. Other experiences in several American countries also show that the LPS is a real tool of continuous improvement.

Despite all these achievements, traditional project management has proved to be successful for simple and certain projects, where the problems that arise from the interactions between activities can be resolved without difficulty. Therefore, lean project management is appropriate for complex and uncertain projects, where the management of the workflow, and the value perspective focused on customer’s specifications can allow managers to deal with uncertainty. Thus, to decide which method should be applied, it results necessary to evaluate the uncertainty and risks of each project before their beginning. In order to do that, risk project management appears as the perfect way to evaluate risks and complexity in projects.

Because of the great importance of risk project management, some institutions, as the Project Management Institute have incorporated this discipline into its main areas of knowledge. It provides tools for helping managers to achieve project objectives since it aims to increase probability and consequences of positive events, and to minimize also probabilities and consequences of adverse results to the project. To that end, it is important to have a broader definition of risk, since generally it is seen as a negative event. Thus, it should be seen as anything that can affect the project in a positive or
negative way. Some authors state that risks are part of uncertainties in projects, since uncertainties include positive and negative consequences. Regarding uncertainties, there are three common uncertainties identified in projects:

- Uncertainty related to estimates
- Uncertainty linked with project parties
- Uncertainty linked with steps of the project life cycle

Some organizations, as the PMI, OGC and APM, have established the processes needed to deal with uncertainty. These processes are iterative and their phases are developed over the project life cycle. Although these processes are described in different level of detail by each of these organizations, they have all the same core phases. These phases are:

- Risk management planning, identifies the necessary activities to deal with project risks
- Risk identification, enables managers to identify the potential project risks
- Risk analysis provides a quantitative and qualitative analysis to evaluate the probability of happening and the results of risks
- Risk response establishes practices and methods to diminish the identified risks as well as monitoring them and recognize new risks

Therefore, these processes enable managers to identify project risks and uncertainties and to establish the complexity of each project, so that they can choose the best method to manage it, traditional or lean.
REFERENCES


