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Phased-Based Project Management at Aker Yards Langsten
A Lean Shipbuilding Perspective

Iuliana Cristina Ciobanu
Ganesh Prasad Neupane

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Author (-s): 1. Iuliana cristina ciobanu
2.Ganesh Prasad Neupane

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MOLDE UNIVERSITY

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ABSTRACT

Researchers and practitioners are arguing for a Lean Shipbuilding concept with its specific tools and principles which are not just another chapter in the Lean Construction concept. The evolution of the two industries can be seen as similar to a certain point since they have some common features. For decades, shipbuilding industry has been using project management tools inspired from construction and that gave the idea that they are very much alike. But, there are proofs that shipbuilding uses also tools from manufacturing, an area considered quite incompatible with the construction. However, the evolution of a new concept in manufacturing inspired a new attitude in the construction industry. And then, the need for better and more competitive building processes in the ship industry created the path toward a new concept i.e. Lean Shipbuilding. In our paper we try to present the evolution toward this new concept from the traditional management used nowadays to the new concept called Lean Shipbuilding. Through our case study we hope to contribute to the development of this concept.

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1.1 Introduction

Shipbuilding industry has been and will continue to be an important key of the maritime commerce. It is, with all its adjacent branches and activities, a major value and employment generator. But, especially in Europe, the character and the nature of this industry are rapidly changing. Until few years ago the majority of the European shipyards were self sufficient in all disciplines of building a ship. Today, the most advanced shipyards have more and more shifted toward the use of subcontractors. Standardization and modularization of ships systems and subassemblies are now seen as key to reduce production cost and ever more often the shipyards have the sole role of assembling the hull and perform selected parts of the outfitting. However, such trend requires developing special skills for process integration and for an efficient production planning (Andritsos et. al., 2000).

The challenges given by the global market force the Norwegian shipbuilding industry to adapt quite fast to the given circumstances. A “boom” of shipbuilding contracts in Asia has, together with high prices on the international market, contributed to a good offshore supply vessels market. Norwegian shipyards used to have a strong position in the offshore market but the Chinese and other Asian yards are threatening such position due to their lower labor costs. In the same time, the European Union enlargement brings on the shipbuilding industry new and tough competitors. Norwegian shipyards have the comparative advantages given by a short-time total project accomplishments and right-on-time delivery of highly technological complex vessels. In the short-medium term, important gains in the building process can be achieved through rationalization of work phases, thorough planning and integration. Norwegian market with its high national cost level is dependent on gaining productivity advantage in order to remain competitive on this market (Hervik et. al. 2005). A solution to obtain these gains in an appropriate period of time could be lean thinking concept.

1.1.1. Toward the Lean Concept

No new ideas bounce ready and fully developed from a void. Most of the new ideas materialize from an environment and a set of conditions in which aged solutions no longer seem to work. An economical context with its crisis in the industrial environment came to a point where the emergence of lean thinking was the only solution: First to survive and then to overcome the market. And, as we see in the specific literature, there is almost always a crisis which generates the thoughts about implementing lean thinking.

The emergence of *lean thinking* happened during late1980s when Massachusetts Institute of Technology started a research aimed at analyzing the production system behind Toyota's success. The study took five years and ended with the book "The Machine that Changed the World", one of the most cited references in operation management over the last eighteen years (Holweg, 2001). This book came with a new name for a system known as Toyota Production System (TPS). Despite the fact that Just in Time (JIT) production or Autonomation were known for more than a decade before the publishing of the book, this had a tremendous role in spreading the concept outside of Japan (Holweg-2001). The western world needed a more friendly explanation, another name for such a specific system and some concrete examples to show that it is applicable in other types of cultures. And, during the last twenty years the lean concept was proved to be fitted not only to different cultures, but also to most of the industries.

The researches continue today through few organizations or institutes like The Lean Enterprise Institute, Lean Global organizations, Lean Construction Institute, etc. who are promoting lean thinking in a large range of industries like manufacturing, service, construction, transportation, public sector, etc.

1.2 Research Definition

This research is focused on shipbuilding industry in Norway and tries to argue the lean concept applicability in this special business environment. By special business we imply the fact that building a ship is considered a one-of-a-kind and engineered to order project which is managed as a specific entity inside the shipyards. In our research we argue the possibility of enhancing the today's business model used by shipyards in managing their shipbuilding processes.

According to the available data, lean shipbuilding practitioners seem satisfied with the positive evolution of their business results after introducing principles and tools inspired from lean concepts. In Norway, the interest on this concept raised quite fast from a theoretical approach to the beginning of the implementation phase in a few of the biggest shipyards. Much of the lean concept promoting efforts are made by institutions like FAFO, Molde Research Institute and Lean Construction Institute Denmark who are conducting a broad research project in some of the most relevant Norwegian shipyards. Our research is part of this big project which has the scope to vitalize and restore shipbuilding in Norway by contributing to process innovation particularly directed toward project accomplishments and logistics.

One of the shipyards interested in understanding how lean principles are working in the practical circumstances is Aker Yards Langsten, our main focus for the empirical study part of the research. As a part of the project, Aker Yards Langsten's team management is interested in analyzing the causes and the effects of the project's non-completed activities which delay the project and increase the costs significantly. Thus, the efforts of our research were focused on finding the roots of the problems and to identify applicable lean principles and tools fitted to the process of diminishing or eliminating such troubles. The center of our attention was the project containing ten sister ships to be built between 2007 and 2009 for a Danish customer. Then, another issue to approach in out research was the learning curve evolution registered during the life cycle of the project. However, due to our time limitation, the research stopped after the third ship came to Norway.

1.3 Research Methodology

We divided this part of the research into two categories - data sources and data collection - in order to offer a better overview of the methodology we applied in our research. The project we were allowed to study includes ten specialized offshore vessels build for A.P. Møller-Maersk a Danish supply carrier. Due to organizational and strategically factors, the ten sister-ships are built in three shipyards all belonging to Aker Yards ASA. The three project's shipyards are Langsten, Brattvåg and Tulcea (Romania). Hull construction and pre-outfitting phases will take place at Tulcea, while the final outfitting, testing and delivery phases will take place in Norway. Brattvåg shipyard will complete seven out of the project's ten ships and Langsten three of them (no 2, 3 and 5).

The team assigned for this project contains 32 people from the Project Manager to the departmental leaders. Most of the project management team is located at Brattvåg while at Langsten are located three middle level managers like one Planner and two Production Coordinators plus the departmental leaders for: Piping, steel, electrical, accommodation, painting, machinery and testing, a total of 10 people. A similar team exists also at Brattvåg (one Planner, two Production Coordinators and seven departmental leaders). At the same yard is situated the middle management team containing Safety Supervisor, Quality Assurance, Procurement, Electric & Automation, Steel outfitting, Technical engineer. Lower level managers from Steel/outfitting, Technical assistance and Accommodation, Engineers/winch and Control 3 Drawings are also located at Brattvåg together with the Project Manager and Technical Secretary.

1.3.1. Data Collection

The primary way of collecting data was direct interviews with the available project participants during the period between January and May 2008. All the interviews were conducted individually, behind closed doors with duration between 0.5 to 1.5 hours per respondent from. These interviews provided a real-world experience on shipbuilding main processes. We also conducted three electronic interviews with some of the people who were not available for a direct discussion due to travels or other reasons.

The thirteen conducted interviews are:

- **3 Open interviews**: two with the Project Manager and one with a Planner;

- **10 Structured interviews**: 3 in-depth interviews with middle managers; 4 in-depth interviews with departmental leaders; 3 electronic interviews with middle managers. With two groups of two similar middle manager positions were conducted parallel interviews for a better understanding of the sister-ship effect evolution.

1.3.2. Data Sources

The theoretical part of our research is based on books, articles and dissertations coming from official and academically recognized sources. All information was gathered through Molde Research Institute and Molde University's library with its data base of electronic articles.

For the empirical part of the research we collected data from different sources located at the two Norwegian shipyards (Langsten and Brattvåg) involved in the project we study. We performed interviews with some of the managers and some of the departmental leaders. Most of these interviews were structured in questionnaires of 10 to 18 questions adapted to each managerial level. The questions were inspired from the theoretical part of the research, information from previous interviews and from the documents we collected from authorized people. It is important to notice the sincerity and the honesty of all people we interviewed. A typical feature of our questionnaires was the focus on lean thinking approach. Types of problems we try to identify: Waste in different phases of the production processes; Challenges in the planning process; Flow of information and communication; Bottlenecks in the system, etc.(the interviews are attached in appendix)

Acknowledgment: The collection and data sources were limited to the Norwegian team. We do not have clear or justified data from the Romanian shipyard and that might have hindered our empirical analysis.

1.4 Research Content

Among other new industries applying concepts and principles from lean thinking, the shipbuilding industry is one of newest - at least from a Western point of view. The researches in this field are in the development phase thus there are not so many scientific papers written about a clear Lean Shipbuilding Concept. Some researches argue that the similarities between construction and shipbuilding industries make the latter a complementary part of the former. Others' arguments come to emphasize the specificity of Lean Shipbuilding which successfully combines principles and tools from both manufacturing and construction. In our research we approached a methodology which presents Lean Manufacturing (thinking) and Lean Construction concepts followed by features we consider appropriate for our case study. The findings are presented throughout this research paper which is divided in two main parts: A theoretical review included in the first part, and a case study presented in the second part of the paper.

We start our theoretical review with a description of one of the most used concepts in today's project managerial processes i.e. Project Management (PM) concept. Such approach is characteristic to project based business environments dealing with one-of-a-kind and engineered-to-order products like construction and shipbuilding. After presenting some principles and characteristic features of PM concept, we describe in chapter three several of its most common used managerial tools.

The fourth chapter presents the lean concept from its roots to currently applications. We consider important such review due to the fact that lean shipbuilding is inspired to a certain extent by manufacturing industry. Then we present – in chapter five – the next significant concept for our research i.e. Lean Construction with its principles and specific project approach. Chapter six describes Lean Shipbuilding concept which is limited by the lack of academic researches. Because some of the tools used in lean shipbuilding are common to both manufacturing and construction, we allocated the seventh chapter to a brief description of some of the tools we considered fitted to our case study. Chapter eight is devoted to our case study with its analysis and managerial implications. Chapter nine contains the limitations and the recommendation at the end of our research. And in the appendixes we attached the questionnaires we used in the collecting data process.

Chapter two: Project Management

2.1 Historical Development

The history of project management is often associated with the construction of the Egyptian Pyramids and the Great Wall of China (Burke, 1999). As a discipline, project management developed from different fields of application including construction, engineering, and defense. The first signs of project management as a distinct field of practice were the network analysis and planning techniques that emerged in the 1950s for use on major projects in construction, engineering, defense, and aerospace industries (Morris, 1994).

Henry Gantt is accredited as the father of planning and control techniques. He designed bar chart in the early 1900's as a visual aid for planning and controlling his shipbuilding projects. After a while these bar charts were recognized as Gantt Charts. Such chart was significantly reducing the time to build cargo ships during World War 1. Most of the prevailing project management techniques today were developed during the 1950's and 1960's by the US defense-aerospace industry (i.e. NASA). Such techniques contain Program Evaluation and Review Technique (PERT), Earned Value, Configuration Management, Value engineering and Work Breakdown Structures (WBS). Critical path method (CPM) and Precedence Diagram Method (PDM) were developed from the construction industry. These tools were focused on supporting network diagram and resource smoothing so that acquiring scheduling urgency and engineering management would be possible (Morris, 1994).

At the same time, technologies for the project cost estimating, cost management, and engineering economics was also evolving. In 1956, the American Association of Cost Engineers (AACE) was formed by early practitioners of project management and the associated specialties of planning and scheduling, cost estimating, and project control.
In 1969, the Project Management Institute (PMI) was formed to serve the interest of the project management industry. The PMI consider that the tools and techniques of Project

Management are common among the widespread application of projects from the software industry to the construction and shipbuilding industry. In 1981 PMI (in USA) developed “A Guide to the Project Management Body of Knowledge” (PMBOK) that contains the standards and guidelines of practice that are widely used throughout the profession. The international Project Management Association (IPMA) was founded in 1967 as a European Institute. Similar developments were accomplished with the help of IPMA’s Competence Baseline within Europe. The focus of this Baseline begins also with knowledge as a foundation, and adds considerations about relevant experience, interpersonal skills, and competence (Burke, 1999).

The international project management association issued their IPMA competence baseline in 1998. From the mid 1990s onward, interest in the project management grew progressively stronger, with a move towards the concept of project management as an organizational capability, stimulated by a series of new publications and some devoted authors promoting successful stories. The practice of benchmarking for corporate project management emerged during the same period. Two clear initiatives: the PMI supported fortune 500 project management benchmarking forum, and the human systems knowledge network were formed in the mid 1990 and 1993 respectively. These initiatives were contributing to organizational project management development by offering techniques of publication and conference presentations (Morris, 1994).

2.2 The growing focus on Project Management

There are powerful environmental forces contributing to the rapid extension of project management approaches to project based business problems. Project management way of doing business is developing progressively into a standard practice because an increasing number of typical firms are devoting money and effort in implementing such business model. Gary & Larson (2006) found some of the factors contributing to this trend are:

- **Shortening of the product life cycle**. Some years ago a product life cycle was about 10 to 15 years (19 years for Ford model T) while today we can talk about 1 to 3 years. Time to market is essential for many products and being slow can mean bankruptcy.

- **Global competition**. Today's customers understand their power hence demanding cheaper and better product became a challenge to answer to for every producer. Such pressure brought the need to change the organizations' way of doing business in their attempt for achieving better results.

- **Knowledge explosion**. Permanent development and evolution of human society brings with it challenges to every organization. Adapting to these challenges means continuous efforts for every organization. The expansion of knowledge has increased the complexity of projects because projects encompass usually the latest progresses in their areas.

- **Corporate downsizing**. The last decade has seen a lot of dramatic restructuring of organizational life. For some organizations such downsizing was a necessity in order to survive and that changed also the way of approaching a project. Using outsourcing as a solution, many project managers found out that they have to manage not only their people but also their counterparts from other organizations. A challenge for the project management theory who claims that it offer effective solution for such complex problems.

- **Increased customer focus**. Customization of products and services is today required by customers at an increasing rate. A closer relationship with the customers is a necessity in order to understand their requirements and to bring the right products on the market.

- **Rapid development of Third World and Closed Economies**. Such trends make organizations to fight for a slice on these markets. Entering new environments imply also adaptation and project management work.

In summary, we can find many and important environmental forces interacting in today's business world and increasing the need for good project management across all industries and sectors. As a solution, project management seems quite suitable for business processes which require innovation, speed, flexibility, accountability and continuous improvement (Gray & Larson, 2006).

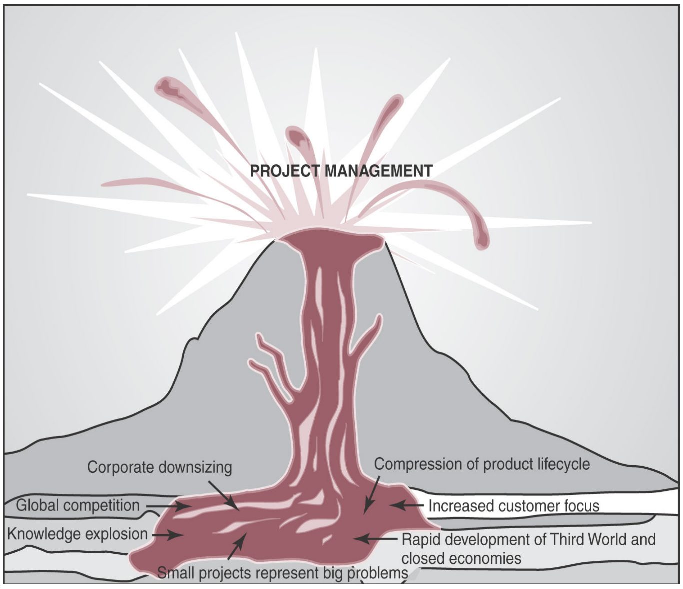

Figure 1: The age of Project Management (Gray &Larson, 2006))

In order to understand how project management approach evolved and became such used managerial concept we need to bring into attention some of its definitions and to describe some of its relevant tools.

2.3 Defining Project Management

In general a successful completion of any task is totally dependent on the organization of all the required resources. How well the resources are organized is an important matter of study in order to ensure the project success. Gray & Larson (2006) state that "all of mankind's greatest accomplishments—from building the great pyramids to discovering a cure for polio to putting down a man on the moon—began as a project." They define project as a complex, non routine, one time effort limited by time, budget, resources, and performance specifications designed to meet customer needs (Gray & Larson, 2006).

Large and expensive investment projects, such as building a ship, building production facilities, are ultimately about integrating a number of smaller deliverables into a productive entity. The smaller deliverables, such as machine tools for a production line, are usually sourced from separate specialized manufacturers. These specialized manufacturers, their project-running customers, and their suppliers form a so called project-based supply chains. One particular characteristic makes these supply chains especially interesting and that is the interface between the project-oriented and the repetitive production logics. For example, a contractor in charge of building a new production plant is running a project, at the same time as the manufacturer delivering the equipment for the production lines has most likely arranged its own processes according to the traditional repetitive logic (Kamara et. al, 1999).

Project management involves planning and control of several conceptually different issues including at least: scope, schedule, cost, risk, quality, and organization (Turner, 1999). And there are several well-established practices for managing these areas. For example, there are tools such as cost breakdown structure and earned value management for planning and controlling costs (APM, 2000; PMI, 2000). Similarly, there are generic tools for managing risk, quality, and organizational resources (e.g. PRAM, QFD,OBS, etc). However, from the perspective of the equipment suppliers, the most important issues lie in the management of scope and schedule because those practices define what is required and when (APM, 2000).

Project can also be defined as a temporary organization and process set up in order to achieve a specified goal under constraints of time, budget, or other resources and where project management denotes the managerial activities needed to lead a project to a successful end (Aaron et. al. 2007). Turner (1993) defines a project as: "….*an endeavor in which human/machine, material and financial resources are organized in a novel way, to undertake a unique scope of work, of given specification, within constraints of cost and* *time, so as to deliver beneficial change defined by quantitative and qualitative objectives.*" Mantel (2001) argues that a project is a temporary effort undertaken to create a unique product or service. It is specific, timely, usually multidisciplinary, and always conflict ridden. Moreover, projects are parts of overall programs and may be broken down into tasks, sub tasks and further if desired. It is clear that every project is characterized by a specific start and completion dates and stands for non repetitive operations which oppose the operations requiring permanent or semi-permanent functional work to repetitively produce the same product or service (Mantel et. al. 2001).

Project management institute (1996) defines project management as: "*…the application of knowledge, skills, tools, and techniques to project activities in order to meet stakeholders' needs and expectations from a project.*" Mantel (2001) argues that project management differs greatly from general management. Every project is planned, budgeted, scheduled and controlled as a unique task. Unlike non-projects activities, projects are often multi disciplinary and usually have considerable need to cross over departmental boundaries for technology, information, and resources. Project managers have responsibility for accomplishing a project but no or very little legitimate authority to command the resources from the functional departments. The project manager needs to have skill to get win-win negotiation while obtaining the required resources. The primary challenge of project management is to achieve all the project goals and objectives while adhering to classic project constraints usually scope, quality, time and budget. The secondary and more ambitious challenge is to optimize the allocation and integration of inputs necessary to meet pre-defined objectives (Mantel et. al., 2001).

To summarize the definition we emphasize its five major characteristics:

1 Has an established objective
2 Has a defined life span with a beginning and an end
3 Usually, involves several departments
4 Does something which has never been done before
5 Has a precise duration, costs and required performance

Project management usually follows major phases (with various titles for these phases) including feasibility study, project planning, implementation, evaluation and maintenance. In other words Project Management is a discipline which provides specific managerial tools for leaders managing project based work (Gray & Larson, 2006).

2.4 The life cycle of a project

The life cycle of a project represent one of the most distinguishing characteristic of project management which is that it has both a beginning and an end. Between them, there are four important phases: Defining, Planning, Executing and Delivering.

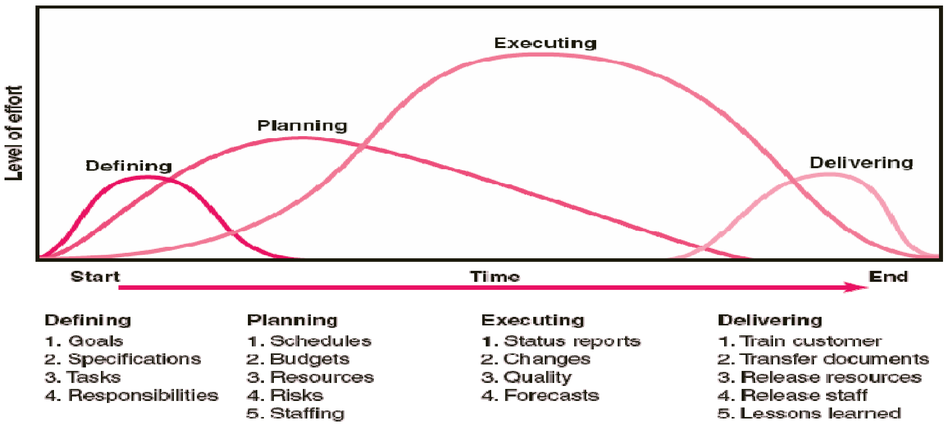

Figure 2: Generic project life cycle (Gray &Larson 2006)

The life cycle emphasizes the fact that projects have limited life span and there might be predictable changes in the level of effort and focus over the life of the project.

For our research we consider relevant Gray and Larson's model presented in figure no.3. This figure is self explanatory: First stage depicts all the project's objectives and specifications are established, the teams are formed to take responsibilities and the major responsibilities are assigned. In the second stage plans are developed to determine what the project will demand in term of team efforts, quantity and quality of materials, budget and schedule. The third stage is dedicated to the execution of the project. Most of the work takes place and a physical product is produced. Time, Cost, and Specification are used as control parameters measuring completed and non-completed activities. The final stage deals with delivery of the project and redeployment of the resources. Customers training and transferring the project documents are performed so that the release of equipments and other resources is ready to begin. Redeployment involves usually appointing project materials and equipment to a next project (Gray & Larson, 2006).

2.5 Project selection

Effective project management begins with selecting and prioritizing projects that support the firm's mission and strategy. Successful completion and implementation requires equally technical and social skills. A project manager must have the capacity to plan and budget projects as well as orchestrate the involvement and contribution of the others. Gray & Larson (2006) argue that some selection and management of projects often fail to support the strategic plan of the organization because of the involvement of different groups of managers. For example, the strategic plans are written by one group of managers, projects are selected by another group, and then are implemented by another. Such situation can lead to conflicts and confusions making the final customers unsatisfied. Researchers state that 21st century wants an integrated project management system, that should be one in which all of the parts are interrelated as depicted below.

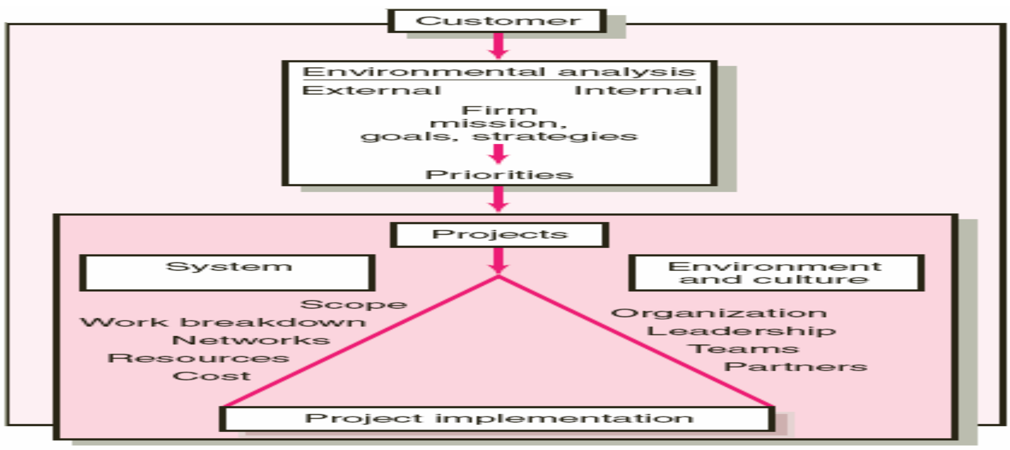

Figure 3: Integrated Management of Projects (Gray &Larson, 2006)

The mission, goals and strategies of one organization are established considering customers' needs but, developing these matters is totally dependent upon external and internal environmental factors. The external environmental factors are generally known as political, economic, socio-cultural and technological factors that are either offering opportunities or posing threats to the projects. The internal environmental factors might be management, facilities, core competencies, and financial condition that are also representing the strengths and weaknesses of the project (Gray & Larson, 2006).

Careful evaluation of environmental factors helps generating better strategies to meet the customer needs. Implementing the designed strategies need creative minds, people who can and should suggest more projects to choose from. The prioritization of projects should ensure the optimum use of scarce resources. Once a project has been selected for implementation, the focus switches to the project management processes which make sure the completion. Integrated management of project is essential as some project management systems fail to prioritize selection of projects by the importance of their contribution to the firm. As a result, they are not integrated throughout the project life cycle remaining a separate business inside the company. The specific literature gives examples of project plans not matched with organizational culture hence there are no appropriate adjustments in supporting project endeavors (ibid).

The priority team needs to not only scrutinize noteworthy projects in terms of their strategic value but also their fit with the portfolio of projects currently being implemented. Highly ranked projects may be postponed or even rejected if they disturb the current balance among risks, resources and strategic initiatives. Project selection must be based not only on the merits of the specific projects but also on what it contributes to the current portfolio mix. And this requires a holistic approach to aligning projects with organizational strategy and resources (Gray & Larson, 2006).

2.6 The role of project manager

Meredith & Mantel (2006) introduced "*the vital dozen for project managers*" which is actually dealing with what a project manager needs while managing projects. These twelve statements are aimed for better leadership and we present them below.

Understand the context of project management.
Recognize project team conflict as progress.
Understand who the stakeholders are and what they want.
Accept and use the political nature of organizations.
Lead from the front.
Understand what 'success' means.
Build and maintain a cohesive team.
Enthusiasm and despair are both infectious.
One look forward is worth two looks back.
Remember what you are trying to do.
Use time carefully or it will use you.
Above all, plan, plan, plan.

Figure 4: Twelve points to remember (Meredith & Mantel 2006)

The project implementation can be easier if these points are leading the attitude of the project manager. It is important for project managers to walk into their assigned role with their eyes wide open to the challenging nature of the task they are likely to face (Meredith & Mantel 2006).

Differences among functional departments invite conflicts and that is a matter of focused research. After analyzing the nature of conflict among team members a variety of conflict settling down methods can be used. Project manager is a leader with a demanding responsibility. Strong, effective leaders can go a long way toward helping a project to succeed even when they face numerous predicted or unpredicted problems. Any project is only as good as it is used; nothing matters if a system is not productively employed. Every effort in the project must be directed toward ensuring that the system fits with customers' needs. Developing and maintaining pleasant team relations and fostering a healthy inter group atmosphere often seems like a full time jobs for most project managers (ibid).

It has been said the project manager's job is to do whatever is necessary to build and maintain the health of the team. Asking 'what if?' questions are a good way of saying that one should never feel comfortable with the status of the project under development. A project should keep advancing and this is a demanding method to forward movement in most of the project. Project manager should always be aware of failing to maintain a view of what the end product is supposed to be. The essence of efficient project management is to take the time to get it as right as possible the first time. Planning is the prime responsibility of project managers, so as an entrepreneur they must plan, but sometime they should be sufficiently smart to recognize mistakes and change their strategy accordingly. The importance of planning is better emphasized by the truism "*those who fail to plan are planning to fail*" (Meredith & Mantel 2006).

2.7 Estimating Project Time and Costs

Quality time and cost estimates are the foundation of project control. Past experience is the best starting point for these estimates while their quality is influenced by factors like *people, technology* and *downtimes*. The key factor for getting estimates that represent realistic average times and costs is to have an organizational culture which allows errors in estimates without incrimination. If times represent average time, one should expect that 50 percent will be less than the estimates and 50 percent will exceed the estimates. Most of the authors agree that once work gets behind, it tends to stay behind. Using highly motivated teams can help in keeping task times and costs close to the average (Gray & Larson, 2006).

There are two methods for performing estimation of a project: *top-down and bottom-up*. The first method (macro level) is used for initial and strategic decision making or in situations where the costs associated with developing better estimates have little benefit. Micro level method is used in most of the cases being much more detailed and offering more reliable estimations per every package not only for the whole project. Estimating time and costs for each work package facilitates development of the project network and a time phased budget, which are needed to control schedule and costs as the project is completed. The level of time and cost detail should follow the old saying of "no more than is necessary and sufficient". Finally, how estimates are gathered and how they are used affect their usefulness for planning and control. The team climate, organization culture, and organization structure can strongly influence the importance attached to time and cost estimates and how they are used on managing projects (ibid).

2.8 Scheduling Resources

Handling and availability of resources are major problem areas for project managers. A careful examination of these issues in developing a project schedule can point out resource bottlenecks before the project begins. Project managers should understand the consequences of failing to schedule resources. The results of resource scheduling are often significantly different from the results of the standard CPM method (ibid).

Scheduling resources is a task that affects planning the time in a project network. The implicit conclusion is that resources will be available in the required amounts, when needed and to add new projects requires making realistic judgments of resource availability and project duration. When performing a schedule for the resources allocated to a project there are three types of constraints to be taken into consideration:

- **Technical or Logic constraints**. Is related to the networked sequence in which project activities must occur.
- **Physical constraints**. Represent the activities that cannot occur in parallel or are affected by contractual or environmental conditions.
- **Resource constraints**. The absence, shortage or complex interrelationship and interaction characteristics of resources that require a particular sequencing of project activities (ibid).

With the rapid changes in technology and the emphasis on time-to-market, catching resource usage and availability problems before the project starts can save the costs of crashing later project activities. Any resource deviation from plan and schedule that occur when the project is being implemented can be quickly recorded and the effect noted. Without these immediate update capabilities, the real negative effect of a change may not be known until it had happened. Fastening resources availability to a multi-project, multi-resources system supports a project priority process that selects projects by their contribution to the organization's objectives and strategic plan. Accommodating different people with different skills is usually organization's data software job but some authors argue that such selections should be assigned to the project manager (ibid)

The Norwegian market situation is nowadays affected by scarce human resources. We see that in most of the industries is a lack of specialized work force and that challenges every project manager when it comes about allocating and using organization's resources. Shipbuilding is one of the most affected industries when it comes about specialized workforce. The number of people to be used in a project is usually quite big (a few hundreds) and to plan these numbers is a challenging task. Due to the local market shortages, most of the shipyards import specialized workers from other countries and that make even more complicated the planning processes. In addition, our shipyard buys work modules from specialized suppliers who bring their own people on the ship. So, planning their own resources, the temporary (loaned people), suppliers' people and their variations it is a very complex task

2.9 Managing Risk

Project management in its essence is actually risk management. Every technique used by project management is a risk management method because each one of them tries to prevent something bad from happening. Project selection system try to reduce the likelihood that projects will not contribute to the mission of the organization. Project scope definition is designed to avoid costly misunderstandings and reduce scope creep. In order to avoid omission of some important parts of the project, the tool work breakdown structure (WBS) is used by all project managers. Teambuilding reduces the possibility of dysfunctional conflicts and breakdowns in coordination. All these techniques try to increase the stakeholder satisfaction and increase the chances of project success (Gray & Larson, 2006).

From such perspective managers are engaging in risk management in order to compensate uncertainty inherent in project management and those things which never go according to the plan. Risk management is a proactive and not reactive attitude. It reduces the number of surprises and leads to a better understanding of the most likely outcomes of negative events. Risk assessments and unforeseen events depend on subjective judgments even though project managers like to believe that their conclusions are based on objective analysis. The very process of identifying project risks forces some discipline at all levels of project management and improves project performance. Emergency plans increase the chances that the project can be completed on time and within budget (ibid)

As s conclusion, risk management is an iterative process that occurs throughout the life span of a project. When risk events occur or changes are necessary, using an effective change control process to quickly approve and record changes will facilitate measuring performance against schedule and costs. Successful risk management requires a culture in which threats are embraced not denied and problems are identified not hidden (ibid).

Many project managers feel the project network is their most valuable exercise and planning document: Project networks sequence and time-phase the project work, resources, and budgets. The majority of project managers use computers to generate these plans together with personal experience in the field. The main purpose of project networks is to ensure that there are no surprises and no activities are forgotten in the planning process (ibid).

2.10 Reducing Project Duration

The need for reducing the project duration occurs for a number of reasons such as imposed duration dates, time-to-market reconsideration, incentive contracts, key resources need, high overhead costs, or other unexpected events. These situations are known as *cost-time trade-off* decisions. But, crashing the project duration increase the risk of being late. How far to reduce the project duration from the normal time toward the optimum depends on the sensitivity of the project network. A sensitive network is one that has several critical or near-critical paths and to shorten such projects might actually increase the project risks. Project acceleration typically comes with at a cost of either spending more money for more resources, or compromising the scope of the project. When the latter is the case, then the stakeholders must accept the changes that have to be made. An important consequence of implementing time-reducing activities during the project execution is the reduced number of options a project manager will have (Gray & Larson, 2006).

Such situations are quite common in today’s shipbuilding industry. There are countless reasons which challenge a project manager to shorten the duration of a project. The delays are so expensive for shipyards that every possibility matters when it comes about shorter building interval. Another reason for attempts on reducing the project duration is given by the unforeseen problems delaying the scheduled project phases. And, in order to recover time and avoid too many extra costs, the project team will try to shorten the duration of a phase either by allocating more resources, or by cutting edges.

Chapter three: Project Management Tools

In the next we will describe some of the tools and their application in project management. We start by presenting the Theory of Constraints (TOC) which influenced both project management and lean thinking theories in their development. Then we present a description of the Work Breakdown Structure and few other tools that were mentioned along the theory review but not explained.

3.1 Theory of Constraints in a Project Setting

Application of TOC to project management is relatively new, but initial results are very promising: completion times have been dramatically shrunk for defense R&D contracts, aircraft repair, new product development and various types of constructions. Everyone involved is aware that virtually every business sector has become more and more competitive in recent years. There is cut throat competition both at home and abroad, and the need for improvement embraces virtually every aspect of business. The popularity of downsizing, rightsizing and re-engineering attests the need of change. There is no question that this need will grow stronger into the next century (Noreen et. al, 1995).

Dr. Eliyahu Goldratt, the father of TOC, coined the term “critical-chain” which recognizes that a project network can go through technical or resource constraints during a project life cycle. Each type of constraint can create task dependencies, and, in case of resource constraints, new task dependencies can follow (Gray & Larson, 2006). As a solution to managing these constraints Goldratt developed a five-step improvement process addressed to project managers dealing with such problems (Goldratt 1990). The five-steps are:

1. **Identify** the system’s weakest link (bottleneck) and leverage it
2. **Exploit** the weakest link and make it work at its best capacity
3. **Subordinate** everything else to the above decision (produce enough to keep the bottleneck busy and no more)

4. **Elevate** the bottleneck or eliminate them
5. **Go back to step no 1:** Do not let inertia become a constraint. Project managers need to be aware of that these five steps are a part of continuous improvement process and if they stop searching for improvements, than the interest is lost and inertia wins (Goldratt, 1997).

TOC introduces two important terms: *slack* and *buffers.* Slack refers to the spare time inherent in the schedule of non-critical activities; can be determined by differences between the *early start* and *late start* of a specific activity. Buffers mean dedicated time block reserved to cover most likely contingencies; are closely monitored so, if they are not needed, subsequent activities can proceed on schedule The main contribution of TOC and its Critical chain is that it brings resource dependency to the front position, stressing the modern ills of multitasking and forces project managers to rethink conventional methods of project scheduling (Gray& Larson, 2006).

Project managers can expect a number of benefits from the critical chain process for individual projects: Completion dates are more reliable due to the addition of buffers to the schedules; project times-to-complete are reduced by transforming the slack into buffers; costs typically go down as lead times go down; shorter lead times diminish the opportunity for customers to change so often the specifications, a common cause of uncertainty in projects. Then, people are not rigidly held to task start and finish times, so, they can feel comfortable taking the time to address quality problems without fear of missing their delivery dates. This reduces rework, a common and severe problem with defects discovered late in a project (Boehm, 1983).

The TOC improvement tools come with a warning: there is no single individual who can implement these concepts. In an individual project, the entire project team needs to understand what is needed while in a company, the entire organization must be involved. A successful implementation requires going from a cost-oriented approach that requires attention everywhere, to a throughput-oriented approach in which everyone must work together and focus on key leverage points (Goldratt, 1997).

3.2 Work Breakdown Structure

After identifying the project's scope and the milestones, its phases can be successively subdivided into smaller and smaller work elements. The outcome of this hierarchical process is called the Work Breakdown Structure (WBS) which is seen as project's map. It helps project managers to assure that all activities and work elements are identified and the project is well integrated with the organization current state. WBS serves also as a base for controlling the stage and evolution of each activity (Gray & Larson, 2006).

WBS was initially developed by the US defense establishment, and the Military standard 881 B in 1993 when they defined WBS as a deliverable or project oriented grouping of work elements shown in graphical display to organize and subdivide the total work scope of a project. A WBS is a corner stone of effective project planning, execution, controlling, checking the stage of completion and reporting. It is necessary that all the activities contained within the WBS to be identified, estimated, scheduled and budgeted. The WBS contains the project's scope baseline necessary to achieve the technical objective of the work described. Moreover, WBS it is in use as a management tool throughout the life cycle of the project in order to identify, assign, and track its total work scope since its beginning (ibid).

Defining the scope, the priorities and the WBS of a project are key steps to almost every aspect of managing a project. In order to stay focus and to emphasize the end of a project, a team has to clearly define the scope of the project from the beginning of it. Establishing the priorities of a project will help managers to choose appropriate trade-offs during the evolution of the project. Drawing the WBS helps managers to ensure that all tasks of the project are identified and offers a view over the organization responsibility and over the deliverables. WBS forces team attention to realistic requirements of personnel, budgets and hardware. Use of WBS provides a powerful framework for project control that identifies variations from plan, identifies responsibilities and spot the project areas for improved performances. WBS is also a database for developing a project network which establishes the timing of work, people, equipment and costs (ibid).

Managing project schedule is an important issue affecting the equipment suppliers. In creating the schedule, the first and most important input is the WBS document (APM, 2000). In the planning process, techniques like precedence diagramming method (PDM) and critical path method (CPM) are used to translate the hierarchical structure of WBS into a time-phased one (PMI, 2000). The schedule and duration estimates are sheltered from uncertainty by allowing certain slacks to each activity (Turner, 1999) or placing feeding buffers in front of the nodes of the schedule diagram (Leach, 2005). A different view state that slacks and buffers are useful but, they affect purchasing because precise materials-required dates may not be known for sure at the time when the orders are placed. The frequent adjustments, which often result from this, may seriously obstruct the efficiency of suppliers' production and delivery processes (Howell & Ballard, 1997).

The WBS provide also base for project planning and offers a good framework for tracking cost and performance. A project planning process will be more realistic with the help of WBS. Moreover, WBS integrates work and responsibility and, as a result, coordination takes place and a difficult situation can be properly tackled. WBS facilitates also cost, time, and performance evaluation at all levels in organizations throughout the life of the project. Smooth flow of information is possible only when WBS is recognized as a vehicle of project planning activities (Gray & Larson, 2006).

The figure below is an example of a WBS which groups activities (work) packages by type of work within a deliverable and allows assignment of responsibility to an organizational unit.

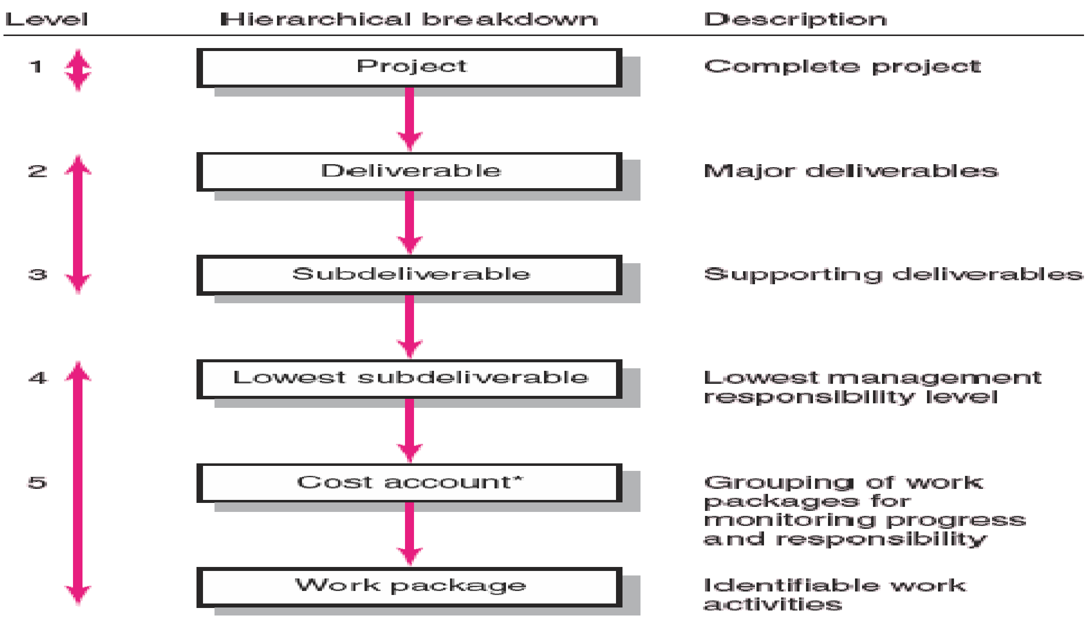

Figure 5**:** Hierarchical breakdown of the WBS (Gray &Larson 2006)

The figure shows that the work package is the lowest level of a WBS. Work package represent the tasks with the shortest duration, having a definite start and stop point, consuming resources and representing costs. Each work package is a control point which shows how effective the WBS is in one particular organizational setting. The cost account is also significant in understanding WBS as it belongs to the second last level of hierarchical breakdown in WBS. Cost account is related to measurement of different work packages which is essential at the time when performance evaluation is done. The information about all work components is generated from cost account (ibid).

The cost account and work package are the two working hands of WBS and it is said that there is a close association between them. It can be concluded that WBS is simply a vehicle which has to acquire several other accessories such as work package and cost account to start moving and contribute towards revenue maximization objective of the organization (ibid).

3.3 Use of PERT and CPM in Project Management

PERT (Program Evaluation and Review Technique) was originally developed as a risk management tool to plan and control the Polaris Submarine Project during late 1950's to be used for reviewing activity and project risk. A PERT network diagram may have multiple parallel or interconnecting networks of tasks. If the scheduled project has milestones, check points, or review points (all of which are generally found highly recommended in any project schedule), the PERT diagram will note that all tasks up to that point terminate at the review node. It should be noted that at this point the project review, approvals, user reviews, and so forth all take time. This time should never be underestimated when drawing up the project plan. It is not unusual for a review to take 1 to 2 weeks, sometimes getting approval from management and user may take even longer time span (Burke, 1999).

Critical Path Method (CPM) is similar to PERT diagram and sometimes is known as PERT/CPM. The critical path method offers a structured approach to project planning which has been designed to meet this need. Although CPM was originally developed to quantify the *time-cost trade-off*, the term is now used interchangeably with PERT as generic names to mean both time planning on its own or to incorporate the complete integrated planning and control cycle (ibid).

In a CPM diagram, the critical path is indicated. A critical path consists of a set of dependent tasks which together are using scarce resources and their completion is critical for the whole project. A delay on any critical path activity means a delay of the project. Now and then CPM diagram can define multiple, equally critical paths. Tasks following the critical path are getting always a special attention and they are well underlined on the specific documentation. The critical path can sometimes shift while the project progresses and this can happen when tasks are completed either behind or ahead of schedule, causing other tasks (which may still be on schedule) to fall on a new critical path (Gray & Larson, 2006). It is usually the transferred, carried over and reworks activities which are modifying the critical path. We see this happening in the project we analyzed for our research.

It is clear that PERT depicts task, duration, and dependency information. Each diagram starts with an initial node from which the first task or tasks originates. If multiple tasks begin at the same time, they are all started from the node or branch or fork out from the starting point. Each task is represented by a line which states its name or other identifier, its duration and some other information. The other end of the task line is terminated by another node which identifies the start of another task, or the beginning of any slack time, that is, time between tasks. Each task is connected both to its predecessor and to its successor forming in this manner a network of nodes and connecting lines. The network diagram is complete when all final tasks come together at the last node (the final phase of the project) as depicted in the figure 6 (Gray & Larson, 2006). Examples of PERT CPM and their results are presented in the appendixes.

3.4 Reforming vs. Performing

Our theoretical review of the Project Management (PM) concept and its tools tries to include some of the important issues used today by most of the project oriented organizations. However, as it is taught today, Project Management seems lack the necessary performances to adapt to more uncertain, complex and pressed for speed projects. Researchers like, Howell, Koskela, Ballard and Bertelsen started some years ago a reform of PM by introducing lean thinking tools or principles in the planning and controlling of activities (Howell & Koskela, 2000).

One of the solutions recommended by researchers and practitioners is to reform Project Management through Lean Thinking (ibid). After all, mass-production was reformed in a similar way and it works. The approach for such reforming is adapted to the business specificity given by the two well known features: one-of-a-kind and engineered-to-order. And, in order to present in a better way our line of thoughts, we make in the next chapter a review of Lean concept throughout its evolution.

Chapter four: Lean thinking

4.1 The roots: Toyota Production System

Evidence of meticulous process thinking in manufacturing can be found all the way back to Venice in the 1450s. But, the first person who truly integrated an entire production system was Henry Ford in 1913 at his first factory at Highland Park, MI. Through his vision he was able to connect the standard work and moving conveyance with consistently interchangeable parts creating what he called flow production. From a certain point of view his idea was perceived just as a moving assembly line, but from a manufacturing engineer point of view the breakthrough went much further (Womack and Jones, 2003).

Through aligning the flow of the production and assembly processes in a continuous line, the amount of time required to assemble a Model T was reduced by 90 percent during the fall of 1913. Ford managed to achieve a complete flow from the raw materials to the shipment of finished cars by aligning in a correct sequence all the machines needed to produce parts for Model T. But he only revealed the *special case*. Such a method works only when production volumes are high enough to justify high-speed assembly lines, the manufactured goods use the same type of parts and is produced for many years (19 for the Model T). The peak of production was achieved during early 1920s when Ford was producing in its plants around the world more than two million Model Ts per year (ibid).

But, as the customers' preferences changes, there was a problem with Ford's system and that was not the flow: this production system was able to turn the inventories of the entire company every few days. Rather it was its inability to offer variety and we are not talking only about its famous color limitation. The vehicle was also limited to one specification which meant that all Model T chassis were essentially identical during its life cycle, up through the end of production in 1926. Ford had available few customizations added at the very end of the production line but these were not significant (some drop-on features added from outside suppliers or five body styles). There were no changeovers for the machines which were producing continuously single part number of the vehicle (ibid).

Until after the WW II the results achieved by Ford were remarkable and admired by the whole world. But the evolution of the market shows that long model cycles were no longer a good policy. Ford seemed to loose his leading position while other cars manufacturers found a way to diversify their offer with new models each presenting many options. But important drawbacks of these offers were that the system used to produce them had long throughput times and it was designed with fabrication steps organized in process areas, the old way of American thinking (general-purpose machines gathered by process, which made parts that eventually found their way into finished products after a good bit of fitting in subassembly and final assembly). Over time the manufacturers filled their production houses with larger or bigger machines that run faster and faster, apparently lowering costs per process steps, but continually increasing throughput times and inventories. The time interval between the process steps, the increasing complexity of the machines and the sophisticated information management culminated with the introduction of an even more complicated system, the Material Requirements Planning (MRP) a system designed to control most of the supply chain operations (Womack and Jones, 2003).

During 1930s and after WW II Toyota Company sent some of its people to visit Ford's factories in order to see and understand how the mass-production system works. Analyzing the facts Taiichi Ohno together with Eiji Toyoda and Shigeo Shingo realized that with few innovations the whole system might be able to provide both a continuous flow of production and a wider variety in the product offerings (Womack et. al., 1990). They suggested a system which, by shifting attention from the individual machines and their utilization, was focusing on the total flow from one end to the other of the production process. Toyota concluded that right-sizing machines for the actual volume needed, introducing self-monitoring machine to guarantee quality, lining the machines up in the right process sequence, pioneering quick setups so each machine could make small volumes of many part numbers is the solution to follow. And, by having each process step notify the previous steps of its current needs for materials, it would be possible to obtain low cost, high variety, high quality, and very rapid throughput time, able to respond promptly to changing customers' requirements (Womack and Jones, 2003). Also, information could be made much simpler and more accurate.

And so the journey of TPS and then lean thinking started. There is little doubt that the TPS and its American derivate Lean thinking is the most dominant improvement program of our time. Unlike other management programs that have come and gone TPS has been developed and steadily improved since early 1950's in Japan for over fifty years. The astonishing results obtain by Toyota from 1950s onward demonstrate that such system works and it is trustworthy. Not too bad for a company that once went nearly bankrupt and had to lay off one third of its workforce. The figure below summarizes the differences between mass production and lean production[1] (Smalley, 2006).

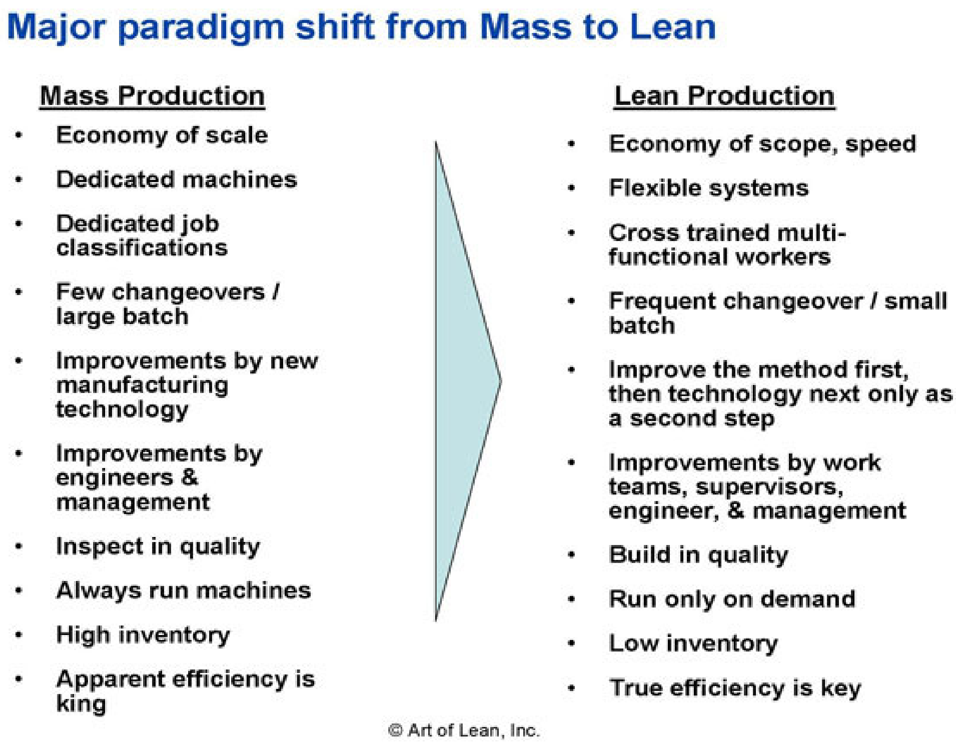

Figure 6: Major paradigms shift from mass to lean (www.artoflean.com)

[1] During our thesis we will refer to lean production, lean manufacturing or lean thinking in an alternative way because these are the term used by the researchers in the specific literature.

The figure above presents the major differences between the mass and lean production showing the two opposite lines of thoughts approached by these concepts.

Recently, lean practices have moved from manufacturing plants to operations of all kinds, in every type of industry including service: Insurance companies, government agencies, airline maintenance organizations, high-tech product-development, oil production facilities, publishing companies, retail buying groups, construction and shipbuilding. In each case the goal is to improve the organization's performances on the operating procedures that make a competitive difference, by drawing the workforce into the hunt to eliminate unneeded activities and other forms of operational waste (Corbett, 2007).

4.2 The four basic pillars of TPS/ Lean

The idea behind starting the TPS was to find a production way which could help Toyota to eliminate various kinds of waste that are so characteristics in every company. Such way of thinking proved its reliability when, during periods of slow growth, Toyota was able to make some profits by diminishing costs, eliminate excessive inventories and excessive workforce (Ohno, 1988).

The TPS is a practical method of making products for the reason that it is an effective tool for producing the ultimate goal – the profit. To achieve this purpose, the primary objective of TPS is to reduce the production costs or improve the productivity. And due to Toyota's founders simple and logic vision, the production costs are reduced and the productivity is improved through permanent focus on eliminating all kinds of waste along the whole production chain (Ohno, 1988). TPS refers to the costs not only for the production processes but also sales costs, administrative costs and even capital costs because in their conception this is the only way to have a clear picture about real productivity and profit (Womack et. al., 1990).

In his book, "*Toyota Production System*", Taiichi Ohno talks about the four most important key concepts guiding the whole system and about many of the methods used for realizing them. These concepts are:

1. **JIT** means practically to produce the necessary units in the necessary quantities at the right time.
2. **Autonomation** (Jidoka) can be translated as autonomous defect control. It supports JIT by never allowing defective units from a preceding process to flow into and disrupt a subsequent process.
3. **Flexible work force** is about multiskilled workers which allow Toyota to vary the number of workers and easily adapt to the demand changes.
4. **Creative thinking** or inventive ideas is based on a very active communication between people at every level. Toyota takes into consideration all suggestions coming from workers or managers and has a very special rewarding system where people get honors that are sometimes more important than money (Ohno, 1998).

To realize these four concepts, Toyota has established the following systems and methods:

- "*Kanban system*" to help and maintain the JIT production
- "*Production smoothing method"* in order to adapt to demand changes
- "*Shortening of the set-up time*" for reducing the production lead time
- "*Standardization of operations*" to accomplish line balancing
- "*Machine lay-out*" and "*multi-function workers"* for the flexible work force concept
- "*Improvement activities by small groups and suggestion system"* (Kaizen) to reduce the work force and increase worker morale. Through Kaizen, they are also able to improve some of the important value adding activities so important in the production process.
- *"Visual Control system*" to accomplish the Autonomation concept.
- "*Functional management system"* to promote company-wide quality control
- Etc. (ibid).

As a conclusion, TPS and Lean have in essence the purpose of increasing profits by reducing costs through completely eliminating waste like excessive stocks or work force. To achieve cost reduction, production must promptly and flexibly adapt to changes in market demand without having wasteful slack time (ibid).

4.3 Talking about waste

In order to understand TPS' and Lean foundation we must describe what their meaning is when talking about waste. According to Ohno (1998), in a production capacity context there are three types of operation categorized like this:

1. **Non-value adding** operation that are pure waste and involves unnecessary actions which should be eliminated completely (waiting time, double handling, etc).
2. **Necessary but non-value adding** operation may be wasteful but are necessary under the current operating procedure (unpacking deliveries, transferring tools from one hand to another, etc).
3. **Value-adding** operations involve the conversion or processing of raw materials or semi-finished products through the use of labor-intensive work (sub-assembly of parts, forging raw materials, painting body work, etc) (Ohno, 1998).

Through intense study and many experiments TPS has identified seven types of wastes that appear during production processes. These wastes are valid in many other types of activities not just in automotive industry.

1. **Overproduction** is one of the most serious wastes because discourages a smooth flow of goods or services and inhibit quality and productivity. It creates also the need for more storage place and excessive lead time. There are two types of overproduction: producing too much and producing too early.
2. **Waiting** is a waste which occurs when workers must wait to do their jobs due to different and predictable reasons. Whenever the goods are not moving or nobody works on them is called waste. Ideally a perfect state would be no waiting times

with a consequent flow of goods. Waiting time for workers can be used for training, maintenance or kaizen activities.

3. **Transport** is a waste involving the unnecessary transportation of the goods during the production time. Almost any movement could be seen as waste and so transport minimization rather than total removal is more appropriate. In addition, double handling and excessive movements can cause damage or deterioration which is not easy to repair due to so many additional activities required for that.
4. **Inappropriate processing** waste refers to applying complex production processes to simple procedures (a big and inflexible machine instead of several and small flexible ones). The over-complexity requires large investments which need to be recovered fast, so the overproduction is encouraged in order to minimize the cost per part of the product. Such an approach creates usually a poor layout, leading to excessive transport and poor communication. The ideal is to have the smallest and most flexible machines, capable of producing the required quality, located next to preceding and subsequent operations.
5. **Unnecessary inventory** create first of all significant storage costs and space. They have a tendency to increase the lead time, hinder rapid problem identification and discourages open communication. The solution proposed by TPS is to minimize the inventory by implementing the JIT concept.
6. **Unnecessary motion** refers to the ergonomics of production where operators have to stretch, bend and pick up when these actions could be avoided. Such waste is tiring for employees and can to lead to poor output or quality problems.
7. **Defects** are a direct waste in term of cost and time invested in that part. Toyota's philosophy regards defects as opportunities to improve rather than something to be blamed on management. Thus defects are seized on for the immediate kaizen activities (Ohno, 1988, Hines, 1997).

In systems such as the TPS or Lean, it is the permanent and iterative analysis of system improvements using the seven wastes that results in kaizen-style system. As such, the majority of improvements are of a small but incremental kind, as opposed to radical breakthrough type (Hines, 1997). We will describe the concept of kaizen in a later chapter, as one of the most important tools used by TPS and Lean.

4.4 Technical principles of lean thinking

Lean principles were originally developed in industrial operations as a set of tools and practices that managers and workers could use to eliminate inefficiency from production systems – reducing costs, improving quality and reliability, and speeding up cycle time. Toyota Motor pioneered lean practices, and much of their allure today stems from the fact that the phenomenal performance of this automaker, in one of the worlds most competitive sectors, rests to a considerable extent on its ability to develop and perfect these practices over the past five decades (Corbett, 2007).

In their research on Toyota's philosophy Womack and Jones (2003) try to find the essence of this system, the core ideas which help for a better understanding when it comes about implementing such system in a western culture. They came up with five important principles which are:

1. **Value**. Specify the value desired by the customer
2. **Value Stream**. Identify the value stream for each product providing that value and challenge all of the wasted steps (generally nine out of ten) currently necessary to provide it
3. **Flow.** Make the product flow continuously through the remaining, value-added steps
4. **Pull.** Introduce pull between all steps where continuous flow is possible
5. **Pursue Perfection**. Manage toward perfection so that the number of steps and the amount of time and information needed to serve the consumer continually falls.

4.4.1. Value

The meaning of value in the lean thinking is that of a term used to define a capability provided to a customer at the right time, right location and an appropriate price as defined in each case by the ultimate customer (ibid).

Modern non-lean enterprises are preoccupied today more and more on bringing financial satisfaction to its managers and to shareholders while the most important factor of an enterprise, its customers, is treated, more or less, as taken for granted assets. By contrast, a lean enterprise focuses on its core value defined by its customers. This core value is meaningful only when it is expressed in term of a specific product (a good, a service and often both at once) which meets the customers' needs in terms of quality, price, time and location. Creating the value of a product is every company's foundation because from the customer point of view this is why the producers exist (Womack and Jones, 2003).

Above all, lean practitioners must be relentlessly focused on the customer when specifying and creating value. Neither shareholders' needs, nor senior management's financial mind-set, nor political exigencies, nor any other consideration should distract them from this critical first step in lean thinking. The next passage from Womack and Jones shows how managers can easily choose the wrong path when they loose the focus on customer's preferences: *"Why is it so hard to start at the right place, to correctly define value? Partly because most producers want to make what they are already making and partly because many customers only know how to ask for some variant of what they already are getting. They simply start in the wrong place and end up at the wrong destination. Then, when providers or customers do decide to rethink value, they often fall back on simply formulas lower cost, increased product variety through customization, instant delivery rather than jointly analyzing value and challenging old definitions to see what's really needed"* (ibid).

4.4.2. Value stream

The value stream represents the specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer (ibid). Nave 2002, states that value stream is a Lean process-mapping method for understanding the sequence of activities and information flow used to produce or deliver a product. Lean enterprises use value stream to:

1. **Identify** major sources of non-value added time in a value stream

2. **Envision** a less wasteful future state
3. **Develop** an implementation plan for future lean activities.

The power of this mapping process lay in walking the production floor, talking to the workers and closely observes how a product is in fact made from start to finish.

The value stream represent all the specific actions required to bring a specific product through the critical management tasks of any business: the problem-solving task running from concept through detailed design and engineering to production launch, the information management task running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer. Identifying the entire value stream for each product is the next step in lean thinking, a step which firms have rarely attempted but which almost always exposes enormous, indeed overwhelming, amounts of waste (Womack and Jones, 2003; Nave, 2002).

4.4.3. Flow

Once value added activities and necessary non-value activities are identified, improvement efforts are directed toward making the activities flow. Flow means the uninterrupted movement of product or service through the whole system until the final customer. The most important inhibitors of flow are batch processing, transportation and work in queue. These are just buffers that are slowing the production processes, create inventory that uses money, space and need additional efforts for detecting defects (ibid).

Lean literature define flow as the progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials into the hands of the customer with no stoppages, scrap or backflows (Womack and Jones, 2003). Only after specifying value and mapping the stream can lean thinkers implement the third principle of value-creating steps: flow. Often, such change requires a fundamental alteration in thinking for everyone involved, because functions and departments that once served as the categories for organizing work must give way to specific products; and a "batch and queue" production mentality must get used to small lots produced in continuous flow. Interesting, "flow" production was an even more valuable innovation of Henry Ford's than his better-known "mass" production model (Smalley, 2006).

4.4.4. Pull

After eliminating waste and achieving a continuous flow, company's efforts are turned toward the final customers who learn to pull the product through the process. The company will have a responsive process able to provide a product or a service only when the customer needs it (Nave, 2002). This is the opposite of push system used in mass-production where products are sent on the market according to statistical forecasted demand (Womack and Jones, 2003).

As a result of the first three principles, lean enterprises can now make a revolutionary shift: instead of scheduling production to operate by a sales forecast, they can now simply make what the customer tells them to make. As Womack and Jones state, "*you can let the customer pull the product from you as needed rather than pushing products, often unwanted, onto the customer.*" In other words, no one upstream function or department should produce a good or service until the customer downstream asks for it (ibid).

4.4.5. Perfection

Through perfection, a lean enterprise is permanently focused on creating value for its customers by eliminating waste and improving its processes everywhere a better solution is initiated. In this way a lean enterprise is able to adapt faster and with lower costs to its customers' preferences. While lean focuses on removing waste and improving flow, it too has some secondary effect which is quality upgrading. The product spends less time in the production process, reducing the potential damaging risks or obsolescence. Simplification of processes results in reduction of variation. As the company looks at all the activities in the value stream, the system constraint is removed, and performance is improved (Nave, 2002). Looking at the results, "suddenly perfection, the fifth and final principle, doesn't seem like a crazy idea" (Womack and Jones, 2003).

These five principles pioneered by Toyota have confirmed during the last fifty years their validity and large applicability. Through lean thinking Toyota reinvented itself and is permanently improving its production processes. While many automakers (and many other industries also) are based mainly on outsourcing of the production capacities, Toyota continues to produce home (in a country with high wages) most of its products.

4.5 Tactical principles of lean thinking

Newer researches come to the conclusion that the five principles described in the previous subchapter are covering only the “technical” aspects of lean course toward continuous improvement and toward perfection. What is behind these technical ideas, what support their implementation and their success is identified by Liker (2004) as a set of 14 strategic principles (Liker, 2004). These are presented below as recommendations to managers interested in implementing lean thinking in their organizations.

1. Base your management decisions on a long-term philosophy even at the expense of short-term financial gain
2. Generate and then develop continuous flow in bringing problems to surface
3. Use “pull” systems to avoid overproduction
4. Level out the workload and eliminate irregularity in production schedule
5. Build a culture of stopping to fix problems, to get the right quality from the first attempt
6. Standardized tasks are the foundation for continuous improvement and employees empowerment
7. Use visual control so no problems remain unknown
8. Use only reliable, thoroughly tested technology that serves your people and processes
9. Grow leaders who meticulously understand the work, live the philosophy and are able to teach the others
10. Develop exceptional people and teams who understand and follow your company’s philosophy

11. Respect your extended network of partners and suppliers by challenging and helping them to improve
12. Go and see yourself to scrupulously understand the real situation
13. Make decisions slowly by consensus, carefully considering all options – implement these decisions rapidly
14. Become a learning organization through relentless reflection and continuous improvement.

All these principles emphasize the fact that Lean is generating, developing and customizing ideas that are fitted to a specific organization and systematically practicing them in order to achieve high performance that add value to customers and society.

4.6 Standardization as a key

Through standardization of work lean concept refers to a precise description of each work and activity specifying cycle time, takt time, the work sequence of specific tasks, and the minimum inventory on hand needed to perform the activity (Womack and Jones, 2003).

To implement this type of standardization is necessary to find the balance between providing employees with strict procedure to follow and stimulating the freedom to innovate and be creative when it comes about achieving tough targets for quality, cost and delivery. Successful keys for such balance are people who contribute to writing these standards and the way these are communicated to employees. First, the standard has to be specific enough to be a useful guide, yet, general enough to allow for some flexibility. Second, people performing their activities have to improve the standards (Liker, 2004).

In repetitive, manual work standards are quite specific. On the other hand, in engineering the standards it needs to be specified more variable since there are no fixed quantities. There is simply not enough time in a workweek for industrial engineers to be everywhere writing and rewriting standards. Nobody likes following detailed rules and procedures when these are imposed on them. Imposed rules which are strictly monitored can be a serious source of conflicts and tense relationships. People are doing a much better job when they have some flexibility in adding their own ideas to the imposed rules and practices. And is rewarding and motivating for an employee to see that some of his/her ideas are becoming a new standard for the organization (Liker and Meier, 2006).

Standardization can be achieved in three important parts of a production process: work time, work sequence and work-in-process. Due to the dynamic nature of lean thinking there are some significant aspects to clarify when we talk about standardization:

- **Standard work** is not a static process so, when a better way is founded, the procedure is updated
- **Standard work** supports stability and reduces variation because the work is performed the same way each time (defects are easier identified)
- **Standard work** is essential for continuous improvement (moving from a standard to a better one) (Liker, 2004).

Liker (2004) underlines the fact that standardization can be a useful tool in construction, design, service or senior management. Good, flexible maintenance and service work are built by combining various small standard work elements. Successful designs come out through creativity combined with standard methods and materials, adhering to standard procedures and gateways. Bicheno 2004, exemplified the idea of senior managers using standardization for meetings, communication, budget and other activities.

4.7 Human resources and Lean

It is important to specify that TPS and Lean are very preoccupied with their human resources in a very constructive way. As one of their first rule such systems do not lay off people unless it is absolutely necessary. People replaced by Autonomation are usually transferred to other departments or helped to get a new specialization. The employees are seen as the most ingenious resource of an organization because they are the ones who make sure that the quality of a product is the expected one (Womack and Jones, 2003).

Its focus on quality challenges a lean organization to guarantee all necessary tools and equipment to its workers who are multiskilled, ergo multifunctional. The employees are empowered to take decisions involving the production process. As an example, they have the authority to stop the production line whenever the quality of the product is not according to the standards. The idea behind such empowerment is that an overloaded information system will hinder the critical aspects of the production and communication issues (Ohno, 1988).

Lean thinking identified the main sources of problem occurrence regarding human forces. Analyzing the roots of these problems will offer solutions which enable a lean organization to improve its human resource potential. Liker and Meier (2006) identified as main causes the following:

- **Unbalanced work cycle times** which may be due to normal variations in work content, operator's skills or machine cycle time. Naturally, a person with extra time will loose easier his/her focus on the activities to be performed
- **Irregular work stoppages** due to lack of parts or operators leaving the work area to perform additional tasks, machine failures or correction of defects.
- **Intermittent work** delays due to struggles with machines, equipment or excessively difficult or complex tasks
- **Wrong ergonomics** influence not only the health of the employee, but also the time of performing an activity. Ohno was very preoccupied with studying and improving such ergonomics categorizing it also as an important source of waste (Liker and Meier, 2006; Ohno, 1988).

Taiichi Ohno understood the importance of free and open communication so he promoted a culture where people were challenged to find solutions to defects instead of blaming workers or managers (Womack and Jones, 2003). In the TPS or Lean culture it is impossible to achieve the expected results without a big consideration for the people, their safety and morale. As the most important resource of a company, people are willing to improve operations and eliminate waste only when they have the right incentives to do so. Improving workplace safety is an ongoing task for ongoing improvement and to reduce the work hazards is a proof of respect for people (Smalley, 2006).

A culture which promotes people's welfare at the working place is the type promoted through lean thinking. Every employee in a lean enterprise is expected to contribute to a creative, positive workplace. Since much of our personal identity is a reflection of work experience, pride and integrity are essential for a rewarding work experience. Through focus on continuous improvement, the problem-solving capacity and the creativity are recognized for all the people involved in this process. Every leader must learn how to use the creativity, the knowledge and the experience of his/her workers. Usually, the best solutions are there, among the workers and they feel more respect for the work they do when their ideas are heard. Creating an environment of mutual trust, respect, open communication and cooperation is a critical task for achieving a continuous improvement and maintaining the motivation (Smalley, 2006).

4.8 Summing up lean thinking

As a conclusion to our lean thinking chapter we can notice that lean thinking is a vast and complex manufacturing philosophy which covers every aspect of a business process. We choose to treat some important tools and techniques later in our thesis. From what we presented here it seems like TPS and Lean are specific to automakers and manufacturers. In the next chapters we will approach lean thinking in two of the most complex industries: construction and shipbuilding. These industries are well known users of Project Management theory and tools in their planning and controlling of activities.

Researchers and practitioners agree that there is necessary a reform of Project Management but they were excluding the ideas coming from manufacturing because of the differences between these two approaches. But, the reality appears to contradict such misconceptions. More and more successful stories come to prove that the theories and the principles drawn from lean thinking are indeed suited for a reform of PM (Howell and Koskela, 2000). And the concept resulted from this reform is called Lean Construction, the subject presented in the next chapter of our thesis.

Chapter five: Lean Construction

In our previous chapters we presented two very different lines of thoughts applied in, apparently, two very unlike businesses: Project Management (applied to project based industry) and Lean Thinking (applied to manufacturing industry). Therefore, this chapter is dedicated to the result (in our opinion) of the combination of these two theories, namely Lean Construction, a newer and continuous evolving concept.

5.1 Conceptual Evolution

By publishing their book "*The machine that changed the world*" (1990) Womack, Jones and Roos started a revolution in the way of thinking for many other industries in addition to automotive. And thus the development of lean construction began its journey toward continuous improvement. Lean construction acknowledged TPS and its principles as a standard of perfection while generally the construction industry has rejected many of the ideas coming from manufacturing because of the belief that construction is an unusual and special business case. Manufacturers make parts that go into products, but the design and construction of unique and complex projects in highly uncertain environments under great *cost, time* and *schedule* pressure is fundamentally different (Koskela, 1992).

As a term, lean construction was promoted by Lean Construction Institute (LCI) of Idaho in early '90s when a researcher began to investigate the performances of a planning system for a construction project. The conclusion of the research revealed that more than fifty percent of the planned activities were later than the planned date. The idea of finding and implementing better solutions to such delays came as a confirmation for the need of lean attitude (Egan, 1998).

The movement to apply the principles of lean thinking to the construction industry was initiated by several researchers. Among the pioneers Koskela started to study the application of lean in construction in early '90s. In 1992 Koskela argued that the traditional transformation used by the production system would be required to change to the new lean concepts of flow and value production systems because this would improve efficiency and control in the construction industry. Today, most of the researches about lean construction theory and principles are directed by two important institutions: International Group of Lean Construction (IGLC) founded in 1993 and Lean Construction Institute (LCI) founded in 1997 (Daeyoung, 2002). IGLC is focused on developing tools and principles necessary in implementation of lean construction concept, while LCI aim at reforming the management of production in design, engineering and construction for capital facilities. LCI developed Lean Project Delivery System (LPDS) which applies lean thinking principles to strengthen the planning and controlling functions throughout a project life cycle, ensuring value maximization and waste minimization (www.leanconstruction.org).

Koskela (1992) emphasized the importance of the production process flow, as well as aspects related to converting inputs into finished products as an important element to reduce wasted value in jobsites. Lean thinking captures attention on how value is generated rather than how any one activity is managed. Current project management practices see a project as a combination of activities to be performed, while lean thinking perceive the entire project in production system terms (Ballard and Howell 1998).

5.2 Special about Construction

What kind of production is construction? This is a question approached by most of the researches trying to recognize a correct definition of construction as a production system. Throughout years, the attempts to create the best definition cover a variety of attributes of the projects ranging from slow, certain and simple projects (stodgy) on one end, to rapid, uncertain and complex projects (dynamic) on the other (Ballard and Howell, 1998). The challenging tasks for a manager are to learn how to manage the dynamic projects and their characteristics within the specific circumstances of construction: *condition of site production, unique product* and *temporary organization* (Ballard and Howell, 1998).

Koskela (1992) took into consideration a forth important characteristic: *Intervention of Regulatory Authorities.* These specific characteristics of a construction are described in the following due to their importance in understanding the construction particularities. We adopt Koskela's (1998) lists with the four differentiating characteristics expressed as: *one-of-a-kind; site production; temporary multiorganization* and *regulatory intervention*.

5.2.1 One-of-a-kind

This characteristic is defined by two important issues coming from the customer's side. First of them is about the product design which is an integral part of production meaning that the product design or development is more than a simple selection of options or configuration design. The customer has an important decisional power to establish most of the details during the design process. This customer involvement leads most of the time to unique products which are built never again in the same way (Koskela, 1998).

The second characteristic of construction is the uncertainty, a critical aspect when it comes about customer order acceptance. This refers mainly to the final product when the customer still has the right to reject it. If the expectations are not fulfilled, the final product remains unpaid by the customer (Koskela, 2000).

5.2.2 Site production

The most specific attribute of construction is this site production. Among similar industries fellow members of "*fixed position manufacturing*" (shipbuilding or airplane building), construction is the only one which must happen at the place chosen by the customers. However, construction shares some of its characteristics with agriculture, mining or extractive industries in this site production issue. Koskela (2000) specify that the concept of construction refers to the term of site production when talking about:

- Site as a necessary production resource
- Space needed by the production processes where workstations move around the product. This spatial flow of workstations has to be coordinated emphasizing the difference from manufacturing where only the material flow through workstations.

- On the site is built the production infrastructure. The organization must plan and procure all the necessary machines, manpower, etc. and set them up on the site.

5.2.3 Temporary multiorganization

This aspect of construction is no longer so specific only to construction. The tendency to “projectize” appears to have no boundaries for applicability in other industries. But the specificity remains until some certain levels. There are many departments to be involved in a construction project. On the site, the people and machines are coming from different specializations and maybe different companies. At the mangers level, the planning and the controlling activities may need different specialists which are not always employed by the company which uses them (Ballard, 1998).

5.2.4 Intervention of Regulatory Authorities

This refers to the bunch of approvals and documentation needed by an entrepreneur before and during the construction process. From the design phase to the delivery are many uncertainties and constraints induced by rules and regulations. Authorities must check and inspect most of the processes and that can create important delays. The figure below summarizes the specificity of construction, the problems created by these peculiarities, and the solutions proposed by Koskela (1992).

Peculiarity	Process control problems	Process improvement problems	Structural solutions	Operational solutions for control	Operational solutions for improvement
One-of-a-kind	No prototype cycles Unsystematic client input Coordination of uncertain activities	One-of-a-kind processes do not repeat, thus long term improvement questionable	Minimize the one-of-a-kind content in the project	Upfront requirements analysis Set up artificial cycles Buffer uncertain tasks	Enhance flexibility of products and services to cover a wider variety of needs Accumulate feedback information from earlier projects
Site production	External uncertainties: weather etc. Internal uncertainties and complexities: flow inter-dependencies, changing layout, variability of productivity of manual work	Difficulty of transferring improvement across sites solely in procedures and skills	Minimize the activities on site in any material flow	Use enclosures etc. for eliminating external uncertainty Detailed and continuous planning Multi-skilled work teams	Enhance planning and risk analysis capability Systematized work procedures
Temporary organization	Internal uncertainties: exchange of information across organization borders (flow disconnects)	Difficulty of stimulating and accumulating improvement across organization borders	Minimize temporary organizational interfaces (interdependen-cies)	Team building during the project	Integrate flows through partnerships
Regulatory intervention	External uncertainty: approval delay			Compression of approval cycle Self-inspection	

Figure 7 Peculiarities of construction (Koskela, 1992)

To conclude with, we can define the construction as a complex production system which creates one-of-a-kind products undertaken mainly at the delivery point by cooperation between multi-skilled, ad-hoc teams (Bertelsen and Koskela, 2006).

5.3 Definition and Principles of Lean Construction

LC has been introduced to the construction industry as a new management approach in order to improve the productivity and to find a better way to control the process of construction. Much research is in progress to develop lean concepts and principles for better way to implement this mode of doing business and to get results of the successful adaptation of those ideas adopted from lean manufacturing (Daeyoung, 2002).

5.3.1. Lean Construction Characteristics

As a concept, Lean Construction is seen as a cocktail of ideas where the most important issue is to develop a continuous desire for improvement. A good team has to be focused on eliminating waste and on using all resources in an efficient way (Koskela, 1992). Another well-expressed definition of lean construction is given by Daeyoung (2002) who sees lean construction as a production management-based project delivery system. Such system calls attention to the reliability and to the speedy delivery of value and it challenges the generally belief of a trade-off between time, cost and quality.

The essential features of lean construction concept are:

- Clear set of objectives to be determined for the delivery process where the customers' needs and preferences are well understood
- Cross-functional design team is a common need of a construction project. Every member of the team tries to give more value to customer's preferences. Such attitude gives reliable relationships between entrepreneur and customer
- Changing the design work along the supply chain to reduce variation and to match the work content
- Work structuring of the entire construction flow increase the value and reduces waste at the project delivery level. Improving the planning process at every level will increase the performances at the project level (Chitla, 2003).

5.3.2 Lean Construction Principles

According to Daeyoung (2002), in the book "Lean thinking" (2003) Womack and Jones focused their principles (value, value stream, flow, pull, perfection) on reducing costs without considering the concept of generating value. That can be a valid strategy for manufacturing industry, but for one-of-a-kind production such as construction projects, was a serious mistake. The validity of Womack and Jones' formulation of lean principles was challenged by Glenn Ballard, who reformulated them as:

- Deliver the product while maximizing value by giving the customer what they want when they want it
- Minimize the waste by eliminating anything not needed for delivering value
- Pursue perfection by never stopping to search for achieving the lean ideal (Ballard, 1997)

This new view was further elaborated upon by Ballard and Howell in a number of principles for implementation of lean thinking not only in construction but in any other project delivery organization. However, in 2001 S. Bertelsen insisted that Ballard's formulation omitted a very important point: Continuous improvement. So, he proposed that lean construction principles should be based on: "*while delivering the project, an ongoing effort should be made to maximize the value and minimize the waste*" (Daeyoung, 2002).

For our thesis we consider eloquent the eleven lean construction principles acknowledged by Koskela in 1992 and then summarized in 1997.

1) *Reduce the share of non-value adding activities (waste)*. In his view, non value-adding activities are those that take time, resources and space but do not add value. The value-adding activities are the ones which convert materials or information toward the product desired by the customer.
2) *Increase output value through systematic consideration of customer requirements.* Fulfilling customers' requirements generates value for every project but, in many cases customers' preferences have never been identified or clarified.
3) *Reduce variability*. Koskela argued two reasons for reducing the variability. First argument was that customers like better uniform products and second was that variability increases the amount of non value-adding activities.
4) *Reduce cycle times*. Solutions to reduce cycle times are introducing JIT (just-in-time) principles in order to eliminate stock inventories. Another solution was to introduce a more decentralized organizational hierarchy (more decisional competence at lower levels).
5) *Simplify by minimizing the number of steps, parts and linkages*. Reducing the number of components in a product and the number of steps in a material or information flow will help to simplify the construction process.
6) *Increase output flexibility*. Using modularized product designs, reducing the difficulty of setups and changeovers and training a multi-skilled workforce help to increase the output flexibility.
7) *Increase process transparency*. This will facilitate a better control and will help improvements to all employees.

8) *Focus control on the complete process*. Koskela suggested that by allowing autonomous teams to exercise control over the process and building long term co-operation with suppliers will optimize the total workflow.
9) *Build continuous improvement into the process*. The effort to build continuous improvement into construction process is to reduce waste and carry out value-adding activities continuously.
10) *Balance flow improvement with conversion improvement*. Flow and conversion are complementary to each other because better flows require less equipment investments and have more control to implement conversion technology easier.
11) *Benchmark*. Benchmarking is about knowing the strengths, weaknesses, opportunities and threats of the organization. It is also about knowing the industry leaders and their best practices, incorporating these best practices into organization and finding a niche by combining existing strengths with the best external practices.

To conclude with definition and principles characteristic to lean construction we agree with the view articulated by Ballard and Woo Kim in 2007: *"Lean is a journey, not a destination"*. Lean construction is a business philosophy consisting of an ideal, principles and methods. Providing the customer with the required product at the perfect moment without creating any waste is the ideal of lean construction concept. This is an ideal which can be approached continually closer but never completely achieved, hence the dedication to continuous improvement associated often with lean thinking. Lean principles stated above are the rules to follow while pursuing the lean ideal. There are methods and tools which help implementing a lean thinking view in an organization. But these methods and tools need to be interpreted and adapted to different applications (Ballard and Woo Kim, 2007). We present some of the lean tools later in our thesis.

5.3.3 Transformation, Flow Value and Last Planner

Since 1993, two major lines of thinking have governed the work in lean construction theory and practice. One is the Transformation-Flow-Value (TFV) theory and the other is Last Planner (LP) method. Koskela, the father of TFV, argued the importance of flow and value-adding transformation process in construction. The LP method is used in planning and controlling the activities in the production flow (Daeyoung, 2002).

Ballard (2000) developed further the TFV theory creating the basis for the Last Planner tool. But he used the term “conversion” instead of “transformation” in his PhD research where he summarizes, in an easy and explicit way, the attributes and the usefulness of each factor of TFV/CFV.

	Conversion View	Flow View	Value Generation
Nature of Construction	a series of activities which convert inputs to outputs.	the flows of information & resources, which release work: composed of conversion, inspection, moving and waiting.	a value creating process which defines and meets customer requirements.
Main Principles	Hierarchical decomposition of activities; control and optimization by activity.	Decomposition at joints. Elimination of waste (unnecessary activities), time reduction.	Elimination of value loss - the gap between achieved and possible value.
Methods & Practices	Work breakdown structure, critical path method. Planning concerned with timing start and responsibility for activities through contracting or assigning.	Team approach, rapid reduction of uncertainty, shielding, balancing, decoupling. Planning concerned with timing, quality and release of work.	Development and testing of ends against means to determine requirements. Planning concerned with work structure, process and participation.
Practical Contribution	Taking care to do necessary things.	Taking care that the unnecessary is done as little as possible.	Taking care that customer requirements are met in the best possible manner.

Figure 8: Conversion/Flow/Value (Ballard, 2000)

The transformation part of this theory refers mainly to the traditional way of production in construction. Koskela (1992, 2000) and Ballard (2000) understood the production process from three different points of view. These three aspects are:

1) As a process of converting inputs to outputs

2) As a flow of materials and information through time and space
3) As a process for generating value for customers (Ballard, 2000; Koskela, 2000).

In order to create a lean organization in construction one need to see the construction process as a whole combining these three aspects mentioned above (CFV). Many researchers and practitioners doubted the application of flow in construction. However, the results show that it is not only possible but it is also very efficient (Ballard, 2000). The reason for this is that the production in construction is of an assembly type where different materials and resources are connected to the end product. The first task of the flow is to establish the site of the flow destination. A work assignment consists of a certain number of tasks to be performed in certain locations during a given time window. The figure below presents a comparison of flow in mass production and site construction as identified by Koskela (2000). A car seat and a window are used as examples.

Type of flow	**Car(mass) production**	**Site Construction**
Material flow (Supply Chain)	A seat is assembled in the seat factory, transported to the car assembly factory, transferred to the workstation and installed.	A window is assembled in the window factory, transported to the site, transferred to the place of installation and installed.
Task (elementary)	The seat installer mounts the seat at his workshop to one car.	The window installation team installs one window (sometimes two or more) to one window opening.
Location flow	The same as above (the seats of one car are mounted as one task at one workstation).	All window openings proceed through the installation workstation (in practice the team moves throughout the building).
Assembly flow	The car body moves through all workstations of the assembly line.	The building proceeds through all assembly phases (like window installation, partition wall construction, etc).

Figure 9: Comparison of flows in mass production and site construction (Koskela, 2000).

The third aspect of this theory is the value generated for the customers. This value has to be determined by the customer, understood and put on paper by the designers and made to a finished product by the constructor (Koskela, 2000).

As we see, this theory identifies three independent angles of production: the transformation perspective (T) (achieved by machines, tools, workers, etc), materials and information perspective (F) and customer perspective (V). Its aim is to provide a better understanding and to show the potential for improvement of construction theory and practice. Koskela state that, in order to effectively improve the construction by applying TFV, it is necessary that the discipline of construction engineering and management be reintegrated with the generic discipline focusing on operations, design, production and projects (Koskela et. al., 2007). This theory can be adopted by using proper and related tools where the most significant one is Last Planner to be discussed later in our thesis.

5.4 Lean Project Delivery System (LPDS)

This system introduced in 2000 by Glenn Ballard is based on lean construction method of doing business. It is promoted by LCI who conducts researches aimed at developing the knowledge regarding the management of project-based production systems in the construction industry. LCI is focused on three main research areas: The theory of project-based production; the production system itself; implementation of the system (www.leanconstruction.org).

The key theoretical questions to approach from LCI point of view are:

- To what extent is a project-based production system different from the non-project based production systems?
- To what extent can a construction project or a collection of projects be conceived as a complex, adaptive system, and what are the consequences (e.g. for distributed control)?
- To what extent are construction projects chaotic or confusing systems, and what are the implications for the project management?

An important task established by LCI is to develop a new and better way to design and construct capital facilities. The result of such focus of the research is called LPDS, now a trade mark of LCI. This current model of LPDS consists of 13 modules, 9 organized in 4 interconnecting triads or phases extending from project definition to design, to supply and assembly, plus 2 modules for controlling the production, both conceived to extend through all project phases, and the post-occupancy evaluation module, which links the end of a project with the beginning of the next (Ballard, 2000). The figure bellow present the phases summarized above.

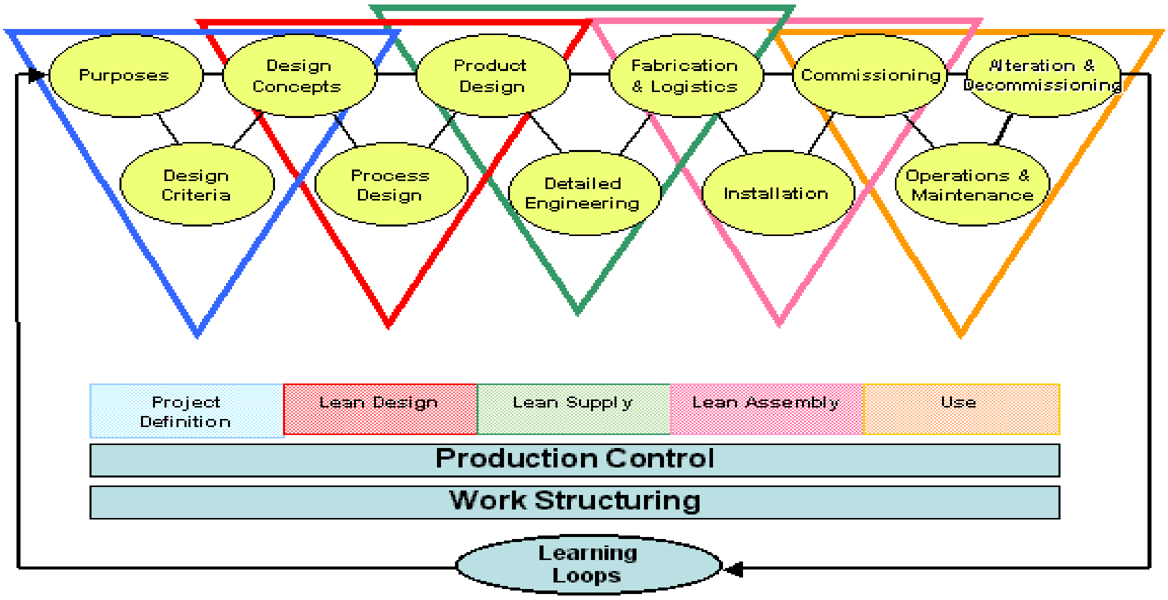

Figure10: Lean Production Delivery System (Ballard, 2000)

5.4.1 Phases' Contain

The five main phases of LPDS are identified by Ballard (2000) who sees the system to be developed as a philosophy, a set of interdependent functions (the system level), rules for decision making, procedures for execution of functions, and as implementation tools (including software when appropriate). The phases are:

1) The **Project Definition** phase with its modules: *Needs and Value determination; Design criteria; Conceptual Design*
2) **Lean Design** phase has the modules: *Conceptual Design; Process Design* and *Product Design*
3) **Lean Supply** phase consists of the following modules: *Product Design; Detailed Engineering* and *Fabrication/Logistics*
4) **Lean Assembly** which consists of: *Fabrication/Logistics; Site Installation* and *Testing/Turnover*

5) **Production Control**: *Work Flow Control* and *Production Unit Control*

Work Structuring and Post-Occupancy are so far, in the developing process, only single modules (Ballard, 2000).

5.4.2 Fundamental Characteristics of LPDS

The working area for the LPDS is defined by the meeting point between projects and production systems. LCI identified this area as project-based production systems. A number of LPDS' modules can be applied to projects which do no involve designing and manufactured articles, also, possibly to apply to some types of productions not performed through projects. As a whole, LPDS is applicable and specific to temporary production systems such as those used for new product development or capital facilities (ibid).

Ballard (2000) identifies the main characteristics of LPDS as being:

- The project is prepared and managed as a value generating process
- The planning and design phases are performed through cross-functional teams (every downstream stakeholder must send a team when these activities take place)
- Project control has the mean of execution as opposed to dependence on after-the-fact variance detection
- Optimization efforts are focused on making work flow reliable as opposed to improving productivity
- The flow of materials and information are governed (through networks of cooperating specialists) by pull techniques
- The variability is absorbed through capacity and inventory buffers
- Feedback loops are incorporated at every level, dedicated to rapid system adjustment.

5.4.3 Work Structuring (LWS)

This is a term created by LCI and indicates the development of operations and process design in association with product design, the structure of the supply, the allocation of resources, and design-for-assembly efforts. A main attribute of work structuring is to build a reliable and faster flow of the construction processes while delivering high quality to the customers.

LWS starts with the most basic level of process design answering the questions like: In what segments will work be assigned to specialist production units; How will work segments be sequenced through so many and different production units; in which segment will work be released from each production unit to the next, etc. All phases of a project contain some degree of LWS decisions. Some LWS decisions will be taken in the planning phase of the project while apparently small details (like selection of some specific components in detailed engineering) can impact the way work flows within the assembly process (ibid).

5.4.4 Production Control (PC)

This phase governs the execution of plans which starts from the planning phase and continues during the whole project. The tool used by LPDS to plan and control the execution of every task is called Last Planner. In the LPDS interpretation, the term "control" refers more to causing a desired future rather than identifying variances between plan and actual. PC means to control the performances of the work flow and the production unit. Last Planner controls the work flow through so called *Lookahead* process and the production units through *Weekly Planning* of work (Ballard, 2000).

The planning, from the start to finish of a project, is performed during the definition and design phases of a project. The result of such planning is called Master Schedule and serves specific purposes (like proving the feasibility of project completion by targeted date) without containing too many details (only the main phases –milestones – of the project). The phase schedules are produced by cross-functional team using pull techniques close in time to the scheduled start of the task. These phase schedules fit into lookahead planning usually 3 to 12 weeks in duration (ibid).

Lookahead planning prepares scheduled tasks for assignment and places them in Workable Backlog. A task can start to be performed at their scheduled time only if the planner is confident they can be *made ready* in time. To make ready a task means to check the constraints and by assigning actions to remove the constraints. Through lookahead planning is generated an early notice of problems and there is more time to find an appropriate solution (ibid).

Weekly work plans are formed by selection of tasks from the Workable Backlog and every effort is made to provide only quality assignments (to be well defined, secure, in the proper sequence and matched to the capacity). These weekly plans help to track the percentage of planned tasks completed (PPC) where the reason for incompletion are identified and analyzed to the root causes in order to prevent repetition (Ballard, 2000)

5.4.5 Project Definition

This is a phase managed entirely by the project manager who is assigned to be the link between the customer and the construction team. Usually, costing and project duration estimation are integrated with the project definition, rather than being performed after the definition is produced. When suitable, a target cost will be established for the facility to be design. If not, the customer makes a decision regarding costs within the definition phase. In this phase are produced the design criteria for the product and for the construction process. To generate multiple conceptual designs which are evaluated by the customer according to his/her requirements, Needs Determination and Design Criteria development (Ballard, 2000).

Collaborative production and decision making processes will include customers and stakeholders; suppliers of materials, suppliers of resources, equipment and service; facility operators, users, representatives of financiers, insurers, regulators and inspectors. In the project definition phase will be applied production control once the plan for the phase has been developed. The first plan might be no more than fitting the steps of the project definition process within the available start and completion date. Only if there is an appropriate alignment between: Customer’s needs and stakeholders demand; Design criteria for product & process; and Conceptual design then the transition to the Lean design phase can be done (Ballard, 2000)

5.4.6 Lean Design

In this phase, the conceptual design from Project Definition is developed into Product and Process Design, in connection with the criteria established in the Project Definition phase. Product and process design decisions are taken with a view to customer needs as well as to design criteria. An important issue here is that product and process design decisions must be made simultaneously rather than first producing a design for the product, then trying to design a process to match the design and the construction of that product. Maximizing customer value in the making trade-offs between needs and objective is a permanent effort of the decisional team. At this stage, a single conceptual design is normally selected even though some design decisions are postponed until the very last minute if that increase the value for the customer. In this phase of LPDS, specialty contractors will either serve as designers or will participate in the design process, assisting with the selection of equipment, components and with process design. The Lean Design phase can go the next step – Lean Supply – when the product and process design have been developed from the conceptual phase consistently with design criteria, customer requirements and stakeholders demands (ibid).

5.4.7 Lean Supply

This phase contains the detailed engineering of the product designed in the previous phase (Lean Design). The fabrication or purchasing of components and materials, the logistics management of deliveries and inventories are included in this phase of LPDS. Every decision is taken with an eye on maximizing the value defined by the customer. To integrate design inputs into a single model it is recommended to use collaborative design tools in this phase of LPDS. This phase of the project links the supply chains that exist independently inside of a project, with the production system. To map these supply chains is an important task of the project. When the chains are understood it is possible to find solutions for improving the process, for a better utilization of resources, for a shorter lead time and for cost reduction (Ballard, 2000).

5.4.8. Lean Assembly

From the first delivery of tools and materials at the site, until key delivery to the customers is called the Lean Assembly phase of LPDS. An important task of this phase is the coordination of deliveries in order to ensure the work flow and the scheduled program. An in-process inspection technique is adopted in this phase for both the site and in the shops. Changing the supervisors' function from the position of chief (who orders things to be done) to a coach who manages the improvements is another issue of LPDS. This Lean Project Delivery System promotes multi-skilled workers in shops and site installation as an indicator of a fine balance of the flow process. Such multi-skilled workers can easily help reducing some resource costs (ibid).

5.4.9 Implementation

The research on implementing LPDS is still ongoing and we have little literature to give more assumptions about the evolution of the system. LCI follows the companies implementing LPDS and the results achieved by now are promising (ibid).

5.5 Traditional vs. Lean in construction

This subchapter consists of a parallel between the project management and lean philosophy in construction. As we emphasized in first chapter, the most common way of managing a project today is Project Management theory and its tools. We will try to show how the concepts and tools inspired from lean thinking can enhance the Project Management concepts and tools obtaining what we know as Lean Construction theory.

Generally, Project Management understands the construction project as an ordered and simple (therefore predictable) event which can be divided into contracts, phases, activities, work packages, assignments, etc to be performed more or less independently. The project is also seen as a mainly sequential, assembly-like, linear process which can be planned in any degree of detail through a satisfactory effort and executed in accordance with the plan. The result of such approach is that the leaders act top-down, primarily by management-as-planning hence, the main role of managers is to plan the activities according to their own objectives (Bertelsen, 2005, Koskela and Howell, 2002).

5.5.1 What is traditional

The tools and techniques offered by Project Management are designed to help developing an overall plan, to define the scope of the project to be performed, to break the scope into tasks or deliverables, to help managing the time and costs for each task, and to manage quality and change. Special attention is paid to arranging the project activities in a logical sequence, usually the CPM (critical path method), timing the start of each task, monitoring the evolution of each activity and the larger network against the standards developed in estimating and scheduling, and taking corrective actions on negative variances from the plan. The plan is usually revised in order to reflect approved changes. Improvement or recoveries are typically a result of speeding activities or reducing their cost, or a result of changing the sequential logic of the network (ibid).

Howell and Koskela (2000) state that in practice, most of the project driven organizations are centered on the preparation, approval and application of CPM network. Construction companies using tools from Project Management manage a project as an assembly of contracts which determine what each company should do and then monitors the performances against the standards. But, the performances of the planning system itself is never measured or improved. The malfunctions are considered to be the results of someone or some company who failed to do what they should have done. Hence, every activity is the responsibility of some person or company. This could work if those responsible do in fact have the ability to make them happen. But the practitioners agreed that in reality it is that is not always possible. An example given by Howell and Koskela (2000) refers to the communication between the design team and workers who are rarely situated on the same place. Therefore, delayed answers and misunderstandings are common causes for late or wrong completion of a task.

To summarize the traditional project management few characteristics underlined. The project has a well-defined scope and can be understood as a sequential dependent series of activities. A central authority is designed to manage the project by controlling the achievements of schedule and budget targets. The relationship between activities is assumed to be simple and sequential. Control is understood as an act of comparing the variance from the plan and taking action (attempt to return on schedule or manage the change). There is a constant pressure to reduce time and cost of a project although there are no negative variances because the project manager try always to “meet or exceed” the requirements (Howell and Koskela, 2000; Bertelsen, 2002).

5.5.2 Deficiencies in current PM

According to most of the researchers, PM is deficient in most of its assumptions and the clarifications of these assumptions are described in the following.

PM assumptions	**Reality according to practitioners**
Low uncertainty of the scope and methods	Often very high and subject to almost continuous change.
Relationships between activities are simple and sequential	The reality is more complex. Activities are often interdependent which means that action in each affect the other. Resources shared between activities are the most noticeable form of interdependence. Pressure for speed increase interaction as the number of activities in progress at the same time increases.
Activity boundaries are rigid.	In reality downstream activities are rarely completely restrained from starting before upstream are finished. Upstream activities are often not completed when downstream begins. These fictions are useful for managing payments.
Control against standards for activities will assure outcomes which can be enhanced by improving activities.	In practice such form of control causes people to do their work with little consideration for how it might affect others. Work is selected to assure the cost or schedule reports look good even if that means doing first the work which earns highest value but is of no use downstream. It is a work done for “show” as opposed to achieving real progress in supporting objectives.

Figure 11 Assumption vs. reality in PM (Howell and Koskela, 2000).

One more deficiency is that the production management is not a project management concern. Daeyoung (2002) state that the traditional construction is too activity centered, controls begins with tracking cost and schedule, and efforts to improve productivity lead to unreliable work flow, further reducing project performances. Protecting activities leads to adversarial relations and planning system can not coordinate the work between crews.

5.5.3 Constructing through lean

Major aspects which emphasize the differences between PM and lean construction include control, performance optimization, scheduling perspective, production systems and process, performance measurements and customer satisfaction. The definition of control in PM is monitoring against schedule and budget projections, while lean construction defines control as causing events to conform to plan. Traditional construction chases the optimization of a specific activity, while lean construction optimizes the entire project (Howell and Koskela, 2000, Daeyoung, 2002).

A fundamental difference between lean and traditional construction come from the planning aspect of a project. In planning, lean uses “pull” work schedule as opposed to “push” schedule used by PM. Pull initiates the delivery of input based on the readiness of the process into which the resources will enter for transformation into outputs. Push releases materials, information, or directives possibly according to a plan, but without consideration to the downstream process which may or may be not ready to process them (ibid). The figure below summarizes the main characteristics of lean vs. traditional construction.

Lean Construction	Traditional Construction
Control	
Causing events to conform to plan – Steering	Monitoring against schedule and budget projections – Tracking
Optimization	
The entire project	A specific activity
Scheduling Viewpoint	
• "PULL" work schedule • Based on when its completion is required by a successor activity	• "PUSH" work schedule • Based on emphasizing required start dates for activities
Production System	
Flow production system	Conversion production system
Production Process	
Effectiveness	Efficiency
Performance Measurement	
Percent Plan Complete (PPC)	WBS, CPM, Earned Value
Customer Satisfaction	
Successor process satisfaction	Owner or final consumer satisfaction
Planning	
Learning	Knowing
Uncertainty	
Internal	External
Coordination	
Keeping a promise	Following orders
Goal of Supervision	
Reduce variation & Manage flow	Point speed & Productivity

Figure 12 Comparison of Lean and Traditional (LCI seminar, 2002)

Koskela (1998, 2000) defined the traditional transformation production system as a task management approach. In his view, a project is a series of tasks which transform inputs into outputs. The project is composed of a hierarchy of chronological dependent activities. The tools used in traditional transformation production system are: Work Breakdown Structure, Critical Path Method and organization charts. Koskela state that the flow production system help eliminating waste by organizing interdependence, improving reliability, reducing uncertainty, and integrating production management.

The lean construction emphasizes effectiveness measured by cycle-time, defection rate, variation and reliability, and completion of planned work per week while PM measures productivity to obtain efficiency. Measurement tools are PPC (Percent Plan Complete) in lean construction while WBS, CPM and Earned Value are specific PM (Daeyoung, 2002).

In PM the customer is consider the owner or the final consumer while in lean construction, the customer is the downstream process. The upstream process has to fulfill the requirements needed by the downstream process. In addition, coordinating activities through pulling, decentralization and continuous flow is supreme, as opposed to the traditional schedule-driven push with its over-dependence on the central authority. To decentralize in lean means to provide the project members with information on the evolution of the production system and authorize them to take action without orders from upper level management (Ballard and Howell, 1997; Daeyoung, 2002).

LCI seminar (2002) shows two figures which present the work flow in PM and in lean production. Lean management has fluency in work flow, while PM has segmented work flow. PM produce a lack of a common language, lack of production knowledge, lack of team commitment, and pay no attention to variability.

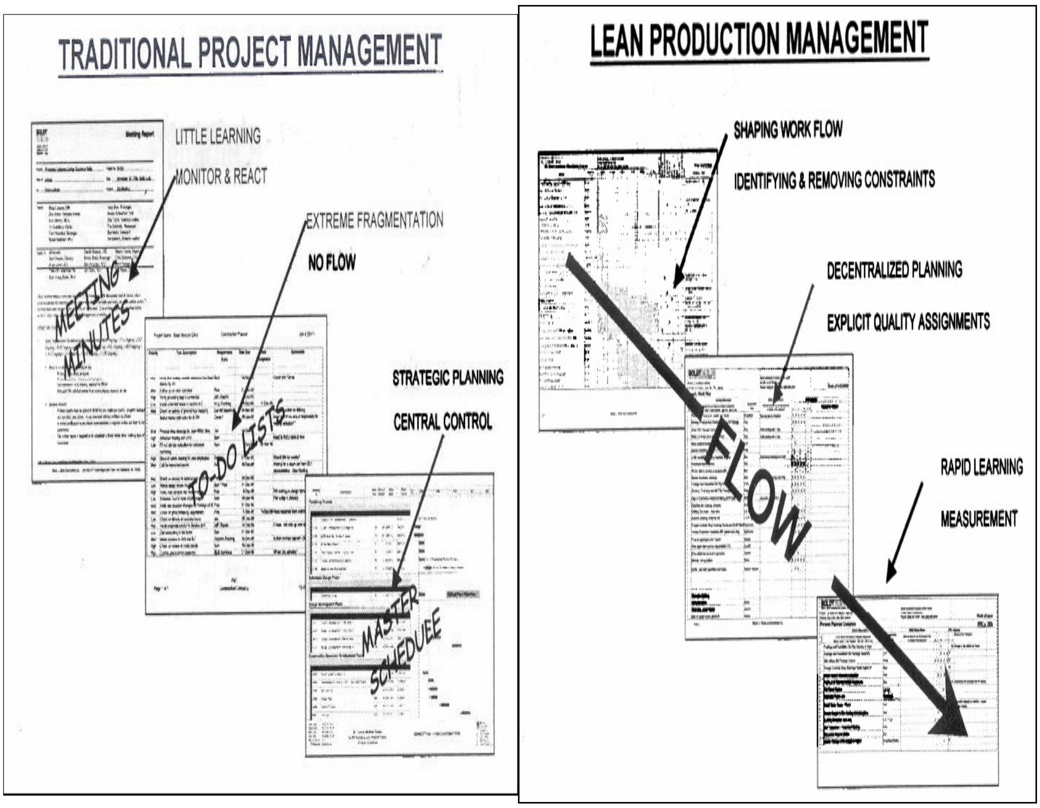

Figure13. The two work flows in PM and Lean (LCI seminar, 2002)

On the other hand, lean management can build reliability, manage work flow, improve the production management system and achieve collaborative team commitment. An important issue of lean construction is to learn through planning in order to avoid repetitive failure. Lean construction considers uncertainty as caused by internal factors rather than an external problem as in PM. Therefore, the main goals of supervision in lean are to reduce variations among internal factors and to manage the production flow. Keeping a promise attitude is emphasized in lean thinking. And such attitude among the project participants can improve coordination and commitment (Daeyoung, 2002).

5.6 Value Creation and Lean

Value defined by the customer is the central philosophy in lean thinking. Due to its improvement over the years, value creating became a state-of-art in many manufacturing areas. But it took many years until construction started to accept and introduce such concept in its daily routines. The value creation approach in doing business facilitates value maximization. Value is generated through a process of negotiation between customer ends and means (Ballard and Howell, 1998).

Koskela (1992) identified four activities which influence the value creation and disturb the production flow in construction creating waste: waiting, moving, processing and inspection. After a proper analysis Koskela came to the conclusion that the only value adding in the production activity is processing. To optimize the value adding in construction one must eliminate or at least diminish the non-value adding activities like waiting, moving and inspection. In order to improve the value-adding processes and to eliminate waste, several techniques are emphasized:

- Stop the line whenever defects are spotted
- Procure materials by a JIT (pull-type) system
- Reduce lead time by increasing flexibility against variation
- Design pre-planning to prevent delays and to provide buffers
- Decentralize the decision making process by applying production system process transparency (Koskela, 1992, Ballard, 2000, Daeyoung, 2002).

5.7 Construction as a Process

Through a careful analysis of the construction environment, Koskela (2000) observed that there are seven important pre-condition for a construction project to be sound. Through a sound project Ballard (2000) means that a project can be undertaken without any delays, an important aspect of Last Planner. The seven preconditions identified by Koskela are: Construction design (information), Components and Materials, Workers, Equipment, Space, Connection (previous work) and External conditions. A graphic representation of these elements is presented in the figure below.

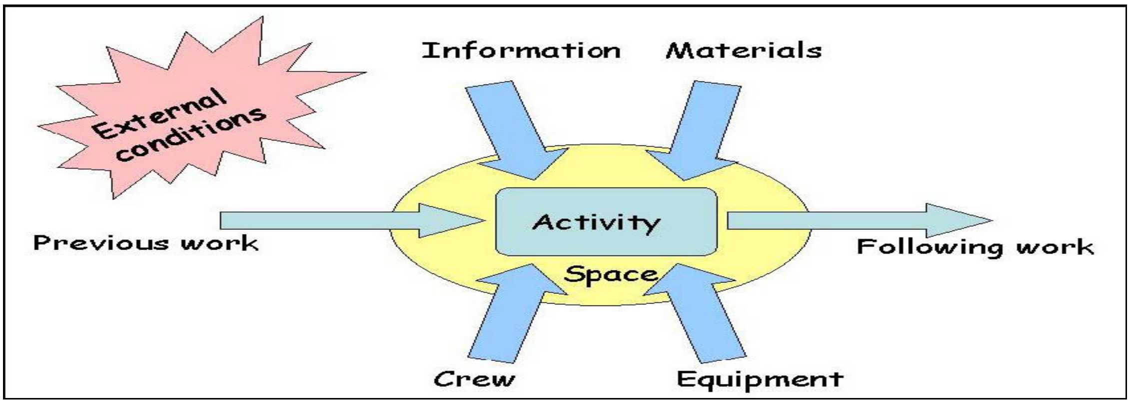

Figure 14: The seven flows (Koskela, 2000)

The interesting discovery made by Koskela was that a reliability of 95 percent for each of the seven flows would cause a reliability of only 70 percent on the soundness of the whole project itself. Through this analysis Koskela wanted to demonstrate the impact of variability in the flows of the process itself only and he was not aiming at explaining the nature of the flows (Bertelsen et. al. 2007).

Ballard (2002) came with another solution which by analyzing the nature of the preconditions groups them into three main types: Directives, Previous work and Resources. Into the Directives groups are introduced the guidelines of the means through which the output is to be produced or assessed (assignments, design criteria and specifications are some examples of directives). The Previous work group acknowledges the substrate on which work is done or to which work is added. Some example would be the materials in the decisional process (the raw materials and the work-in-process must be analyzed when a decision is to be taken). The third group, Resources, refers to the labor, the instruments used by the labor and the conditions in which labor is performed. Resources can bear load but have a finite capacity (Ballard et. al. 2002). A graphic is presented below showing the combination of Koskela and Ballard's views.

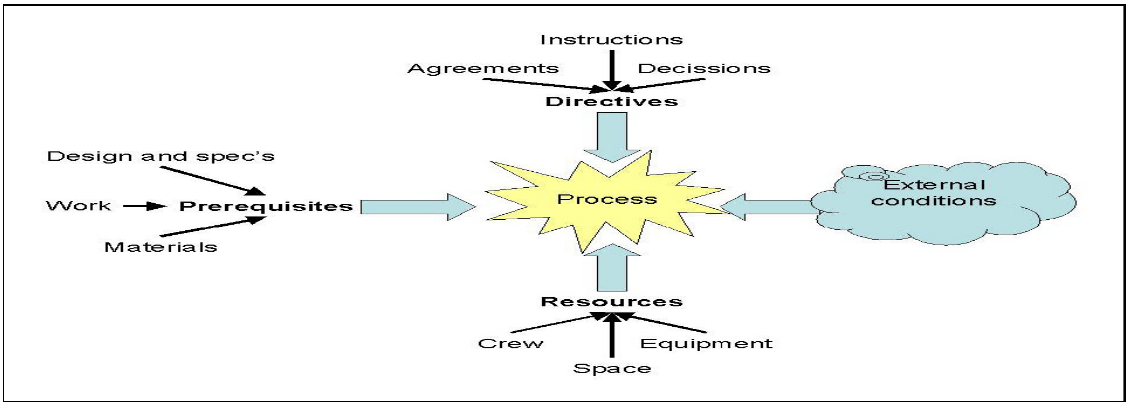

Figure 15: The three type model (Ballard, 2002)

The aim of this grouping is to help for a better understanding of the nature of the flows in constructions but not through an operational management perspective as much as the floe themselves. Looking at this grouping it is simpler to understand the nature of the processes. It is obvious that the Directives group is not under the control of a project manager but gives the framework within the project has to be conducted. Previous work gives the view about what the project have at hand to work with at a certain moment if the directives and resources are available. The Resource group includes, in addition to crew, space and equipment, the capacity of middle management, an important aspect of managing a project. Resources preconditions have limited capacity and if not used at the moment when these are available, these can be just wasted or lost (ibid)

Managing the flow in construction is not an easy task and do not happen as often as it should. But the seven flows and the three groups can be used in managing the flow. These seven flows can be easily transformed into check lists to be used in Lookahead plan of Last Planner. Using them will help to make certain that work packages are sound.

Furthermore, in the weekly work plan of LP these seven flows can be used to check the factual reliability. Ballard's groups can be use as frameworks for project coordination. Bertelsen et. al. (2007), state that the flow reliability should be the focus of management not which model is used for calculating that reliability (Bertelsen et. al. 2007).

These explanations and descriptions of flow in construction offer a new view for understanding project management and its tools. It can be tempting to try managing by flow, but, according to practitioners, the problem is that the critical flow is hard to identify and may change from day to day or even from hour to hour. There is a need to develop tools for managing the flows of information, crews, materials, space and equipment.

5.8 Lean Construction Summary

The roots of Lean Thinking are in the manufacturing industry but people with vision understood that its interpretation into construction might be the so needed reform of traditional practices in this industry. Continuous enhancement, elimination of waste, flattened organization structures, teamwork, efficient use of resources and cooperative supply chains are only few of the issues approached and developed by lean concept. It has been argued that construction is very different from other industries and that affects the extent to which new production processes can be deployed. Most important characteristics are the size of the final product, the immobility of the product, the high complexity (large number of components and relationships) and the high prices to pay for a good quality of the parts. But, these characteristics do not stop construction to develop new techniques and tools for improving its performances (Daeyoung, 2002).

Our next chapter is dedicated to shipbuilding industry. We try to document the applicability of Lean Thinking and Lean Construction concepts into shipbuilding. The area is not yet so much explored by the academicians but recent practical results give as the support we need for proving our assumptions.

Chapter six: Lean Shipbuilding

6.1 Introduction

Shipbuilding is among the oldest occupations in the human being history. The art of manufacturing ships evolved continuously during the centuries being quite often a promoter of new and complex technologies. In the same time, it is one of the industries challenged continuously throughout the history. Increasing speed, capacity, robustness, economy of transportation or reducing the ships' exhaust are among the reasons determining an attitude of searching for continuous improvement so characteristic to shipbuilders. Today's challenges are given by an unstable market, growing competition, many environmental rules, labor costs and technological developments. There are shipyards who understood the need for a change and the fact that in order to survive on today's market they must find feasible solutions. And one of the solutions is a new way of seeing things, a concept which can make the difference between just surviving and making a profit i.e. Lean Shipbuilding.

6.2 Toward the Concept

As a concept, lean shipbuilding is still under development. Skeptics, forgetting the history, argue the specificity of shipbuilding and the fact that the differences between it and automotive industry are too many therefore it can not use the same production principle. One does not see a ship coming off the assembly line every few minutes with relatively standard configuration. Today, shipyards engineer-to-order, one or few at a time, very high customized ships, over few months. And to the question if the concepts of lean manufacturing or lean construction are applicable to shipbuilding, there are many researchers who answer yes (Liker and Lamb, 2000).

The basic idea of giving to the customers exactly what they want, in the shortest lead time possible by eliminating waste is applicable to every industry. Examining construction models in shipbuilding industry, Liker and Lamb (2000) came to the conclusion that there are many similarities between the adopted philosophies and TPS. Same authors state that even though the automotive is different from the shipbuilding industry, the Japanese shipbuilders developed some of the lean principles at the same time as Toyota, and they probably learned from each other. A major factor in such evolution was the involvement of every employee in the continuous improvement effort, not just management and some technical employees. Some important common characteristics were the use of standardization, one piece flow, focus on elimination of waste, group technology and part families, continuous improvement, multi-task jobs for employees and application of 5S to a certain level (ibid).

Pleading for lean thinking implementation in the shipbuilding industry in USA, Liker and Lamb (2000) use an interesting example of efficiency between the Japanese and American shipbuilders. By comparing the productivity metric based on Compensated Gross Tonnage (CGT) they found out that a Japanese shipyard (Hyundai) delivers 74 ships per year, while an American one (Newport News) deliver one every five years. Both shipyards have approximately the same number of employees. The high complexity of American ships can not be an excuse for such long lead time (ibid).

The researchers anticipate an important improvement in the building process of a ship (by at least 50%) and a shorter lead time by implementing the lean way of doing business (Liker and Lamb, 2000). This way might be the solution for the shipyards around the world. A short look at the global situation with its challenges in terms of competition on the market, building prices and raw materials location can easily show a need for a change and radical improvements. And these are available through lean thinking.

6.3 A model of Lean Shipbuilding

Mass production and Project Management concepts are both focused on cost reduction through individual efficiency gains within individual operations. But lean thinking comes with a focus on quality – doing it right from the first time – and that will help reducing costs and lead time. TPS takes a value stream perspective which means a focus on the total system (Liker and Lamb, 2000). And, by seeing the whole system, the planning and the controlling processes are more transparent and easier to perform.

The two pillar of the system are JIT and Build-in-Quality which are mutually reinforcing each other. If the quality is not right from the first processing, then a lot of interruptions will disturb the system and a JIT approach is no longer a solution. So, these two pillars are important to each other and important for a reliable lean implementation. It is also important to start a lean implementation with a strong and stabile foundation. All the processes presented in the house above have a central role from the first step toward lean implementation. But, as TPS and Lean emphasize, the core of such systems is their people who can bring the system to life by continually improvement. Without committed people there is no way of implementing such systems (Liker and Lamb, 2000).

To make things easier to understand, Liker and Lamb (2000) put lean core components in a picture of Lean Shipbuilding applied to the shipyard situation.

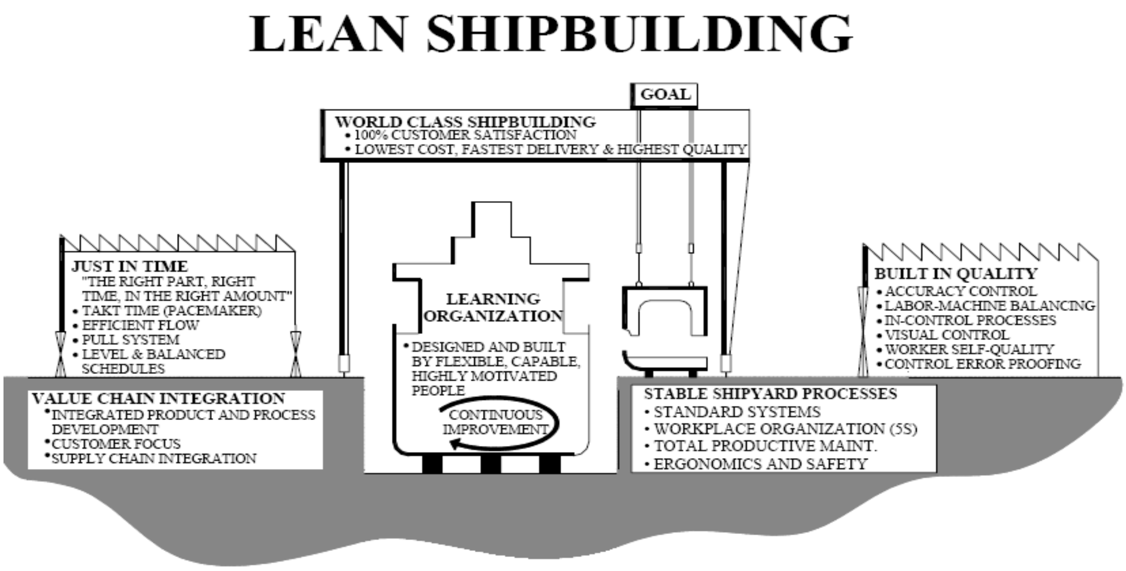

Figure 16: Lean Shipbuilding house (Liker and Lamb, 2000)

All the TPS elements are included in this house but shown within a shipyard with a dry dock as a center piece. A main strength of the TPS house versus this shipbuilding model is that the house depicts a system where any missing part will collapse the house. The ship model does not reflect it so clear. What is important to emphasize is that the lean system and its elements cannot be cherry picked one at a time (ibid).

6.4 Lean Construction and Lean Shipbuilding

Most of the theoreticians consider lean shipbuilding as "one of the extensions" of lean construction. This is probably one of the reasons stopping it to become a concept in the academic world. Both branches – construction and shipbuilding – are project-driven, deliver one-of-a-kind products and share many other similarities in the production processes. Bertelsen (2007) sees Lean Shipbuilding as a concept between lean manufacturing and lean construction, having a totally new production concept and being inspired by sources like: Shingo, Toyota, Goldratt, Womack, Jones, IGLC and not least the experienced practitioners and theoreticians

Dugnas and Uthaug (2007) take into consideration the lean construction principles defined by Koskela in 1992, and try to apply them to the lean shipbuilding concept. The authors consider all fourteen principles as applicable to shipbuilding even though some of them are slightly altered to better address the specific characteristics of shipbuilding.

PRINCIPLES	
LEAN CONSTRUCTION	**LEAN SHIPBUILDING IN NORWAY**
Reduce the share of non value-adding activities (waste).	Reduce the share of non value-adding activities (waste).
Increase output value through systematic consideration of customer requirements.	Increase output value through systematic **and continuous** consideration of customer requirements (**Awareness of 'change orders', Agile production**).
Reduce process variability. Consider process interdependency and isolate supply-related variation.	Reduce process variability. Consider process interdependency and isolate supply-related variation.

Reduce cycle times. Eliminate inventory stock and decentralize the organizational hierarchy.	Reduce cycle times. Eliminate inventory stock and decentralize the organizational hierarchy.
Simplify by minimizing the number of steps, parts and linkages **in a product** and the number of steps in a material or information flow.	Simplify by minimizing the number of steps, parts and linkages in a material or information flow. **The product's complexity is a competitive advantage in Norway: gain more control in this area.**
Increase output flexibility. Use modularized product designs, reduce the difficulty of setups and changeovers and train a multi-skilled workforce. Increase process transparency.	Increase output flexibility. Use modularized product designs, reduce the difficulty of setups and changeovers and train a multi-skilled workforce. Increase process transparency.
Focus control on the complete process. Allow autonomous teams to exercise control over the process and build long term co-operation with suppliers.	Focus control on the complete process. Allow autonomous teams to exercise control over the process and **gain more involvement in often temporary** co-operation with suppliers **chosen by the end-customers.**
Incorporate the best practices into the organization and combine existing strengths with the best external practices.	Incorporate the best practices into the organization and combine existing strengths with the best external practices.
Build continuous improvement into the process.	Build continuous improvement into the process.
Balance flow improvement with conversion improvement.	Balance flow improvement with conversion improvement.
By improving performance at the planning level increase performance at the project level. The Last Planner method is an appropriate alternative.	By improving performance at the planning level increase performance at the project level. The Last Planner method is an appropriate alternative.
Shift the design work along the supply chain to reduce the variation and match the work content.	Shift the design work along the supply chain to reduce the variation and match the work content.
Benchmark.	Benchmark. **Take advantage of knowledge-transfer within the Norwegian Maritime Cluster and beyond.**

Figure 17: Developing the principles of Lean Shipbuilding (Dugnas and Uthaug, 2007)

After outlining the main features and principles, a framework for ideal lean shipbuilding was established. The authors (Dugnas and Uthaug, 2007) believe that this framework can serve as a tool for best practice evaluation (internal benchmarking) and become a kind of "idealistic guide" for shipyards pursuing lean thinking.

Molde Research Institute developed a Lean Shipbuilding "house" which shows the principles and the tools applicable to shipbuilding. In this house we see an ideal combination of concepts specific to both Lean Manufacturing and Lean Construction.

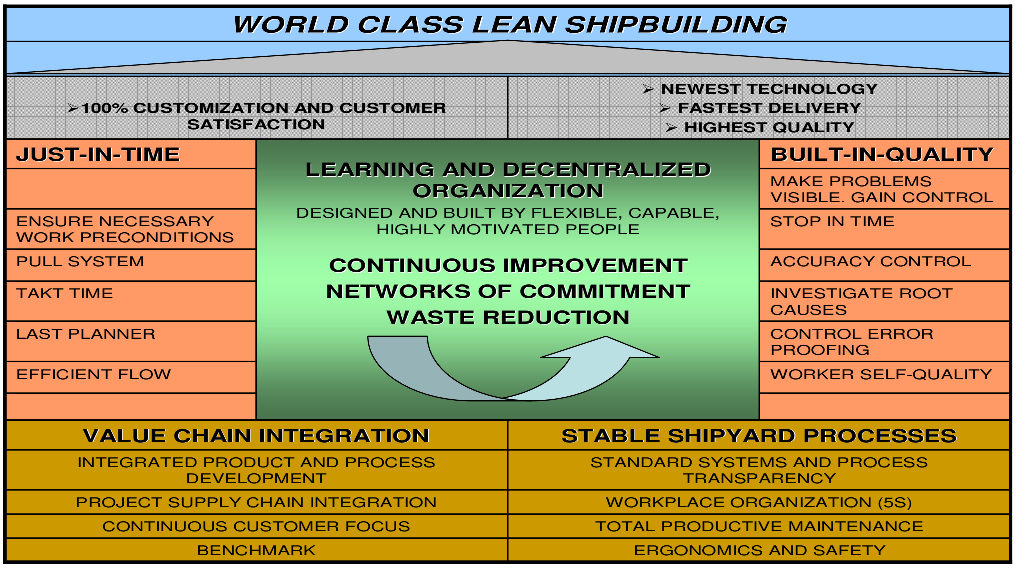

Figure 18: World Class Shipbuilding (Dugnas and Oterhals, 2008)

The evolution of the Lean Shipbuilding in Norway concept can be influenced in a constructive manner by the figure above. In our opinion, such house confirms Lean Shipbuilding as a separate concept from Lean Construction.

6.5 What is Different

Although the two industries share many essential production characteristics, the shipbuilding practice has some differentiating features as well. And those are important issues in the research toward establishing lean shipbuilding as a concept itself. The differences are:

- Design, Supply Chain Management and production activities are integrated and carried out simultaneously – it is rather a rule than exception in shipbuilding
- Production facilities are the same and their layout is “generalized” in order to be optimal for different projects
- Significant prefabrication and pre-outfitted units and modules off-site
- Significant customization and innovation – also during the construction phase
- Capacity constrained industry (lack of qualified workforce, critical lead time)
- There is less randomness in shipbuilding projects’ organization when compared with construction
- Even if shipbuilding belongs to “one-of-a-kind” industries, there are some features similar with mass-manufacturing, i.e. line for pipe fabrication.

All the mentioned features make a background for analysis toward a clear definition of Lean Shipbuilding Concept (Dugnas and Oterhals, 2008).

6.6 Implementing Lean

The current business model used in shipbuilding is very much inspired from the construction industry. Project Management tools like WBS, Production Schedule and CPM are applied by most of the shipyards in the process of managing their projects. Dedicated project teams follow a project and try to deal with delays from the design team, from the suppliers or with unforeseen problems like new requirements from the customer side. All these aspects are common to both construction and shipbuilding industries. For that reason it was easy to adapt most of the PM tools, hence to see Lean Shipbuilding as an extension of construction. After introducing the Lean Construction concept and after the improved results obtain by those constructors, the shipyards started to import tools and ideas from the same concept.

In most of the situations where shipyards tried to implement lean thinking, they choose to implement tools or principles inspired from successful lean construction cases. But, it soon became obvious that shipbuilding differs from construction in some aspects. Every shipyard has its own strategy, its own organization and facility layout which make difficult benchmarking even among national competitors that are planning to implement lean principles (Dugnas and Oterhals, 2008). Hence, there are a few important questions a shipyard should try to answer when it starts implementing lean tools and techniques. Some general questions are suggested by Quarterman (2007) for every business which tries to implement lean thinking. These questions should be addressed in the beginning of the importing tools and techniques process.

- Do we need the entire list of tools and techniques?
- If not, which do we employ?
- Which elements come first?
- What brings quickest benefits and build up motivation immediately?
- How does kaizen fit into the picture?
- How detailed should the plans be?
- How do we know when we are really lean?

The feasibility of implementing lean tools will be better emphasized by analyzing the answers to the questions above (Quarterman, 2007).

6.7 Lean Shipbuilding in Norway

During centuries, the Norwegian shipping industry has been based on rich fishing resources along the coast of Norway. Most of the ships were build in the same region and have crew from the same area. Over time, the competition of cheaper boats and crews came to reduce dramatically the Norwegian fishing industry. And then, the oil industry came as a new fresh start for most of the shipbuilders in Norway. Increase demand for offshore vessels, new and attractive technologies offered by the Norwegian engineers and the geographical location made Norway an attractive place for shipbuilding.

There are some noticeable factors influencing to a great extent the development of shipping and shipbuilding in Norway. One of them is the traveling instinct characteristic to the Nordic people which help them to develop a great understanding of the sea and transportation on the water. Another reason for developing such great maritime skills was the fishing needs where, by understanding the needs for safety and speed, the Norwegian shipbuilders were able to build not only good ships but also a very good reputation. The importance of being first at a fishing location encouraged the design of fast boats while the importance of not drifting away from a good location encouraged the development of good propulsion systems (Dugnas and Uthaug, 2007). Permanent improvement of technological devices is the most important competitive advantage gained by Norwegian shipbuilders over the years.

But, the technological advantage is not enough to maintain a prosperous situation for the shipbuilding industry. There are several institutions and researches institutes who started a research program for implementing lean thinking in the shipbuilding industry. Some of the parts involved are: FAFO, MFM (Molde Research Institute), the University of Molde and the DTU (Danish Technological University). The Norwegian shipyards involved in the project are: Ulstein Verft, Kleven Maritime shipyard and Aker Yards (Brattvåg and Langsten). All three companies have decided to approach and start implementing tools and techniques characteristic lean thinking. Together, they constitute app.75% of the total Norwegian shipbuilding capacity (MFM, 2007).

The shipyard which started first such implementation was Ulstein Verft who began to use the Last Planner tool from last year. The results show an important improvement in the planning activities, increased transparency and better management of variability. Continuous improvement is emphasized in the daily activities (Toftesund, 2007).
However, there are many more tools and techniques that would help Ulstein Verft to achieve a robust lean implementation. Examples are: project supply chain integration, social logistics (managing multinational workforce) and process standardization. The sequence of their implementation is dependent on the following issues: a) current situation; b) speed of positive results' delivery; c) employee motivation; d) defectiveness on applying Lean ideas; e) resource availability. The managers at Ulstein Verft are making considerable efforts to ensure smooth implementation process and continuity of improvement leading toward a goal named Ulstein Production System (Dugnas and Oterhals, 2008).

The other shipyards involved in the lean shipbuilding project are in the early phases of Lean implementation and there are some visible trends of their journey toward perfection. There are many differences between shipyards and their strategies but, in the same time, they outline similar project issues that need immediate attention like: project process variability and transparency, project planning and root cause analysis. Nevertheless, not every shipyard chooses Last Planner as the first priority. Both Aker Langsten and Kleven yards are interested in improving the Phased-based Project Management while Aker Brattvåg starts implementing Last Planner tool (MFM, 2007).

6.7.1. Transferred, carried over, rework

Phased-based project management is a tool used by most of the shipyards in Norway where the production is based on differentiating and dividing project phases to a higher extent. Due to specific competition conditions, the key-trend is now to outsource the construction of the hull and some primary outfitting phases to low labor cost countries. The remaining work like outfitting, testing and delivery are performed in Norway. In the management process the shipyards use four main production phases: 1) Hull production; 2) Primary outfitting; 3) Final outfitting; 4) Testing (Dugnas and Oterhals, 2008).

The current challenge is to find a solution for diminishing the "carried over", "transferred" or rework activities from the hull and primary outfitting phase to the final outfitting phase. Carried over are the activities which from one or another reason are not completed or wrong performed in the allocated time. The downstream processes are not informed and hence not prepared to deal with these missing or defect links. For identifying these carried over activities the shipyards organize dedicated inspection teams who go on board and inspect the stages of the building process for each component of the ship. These inspections together with the extra work are affecting the project in a negative manner not only on the total costs but also in the planning process for the extra time and resources to allocate for the project.

Transferred activities are announced by the upstream processes of the project in good time and that gives some planning and preparation time to the downstream team. These transferred activities are also influencing negative the evolution and the cost of the project. One of the most negative effects is the increasing cost per building process. The prices per activity to be performed (in our case in Romania) are much lower then the prices of performing same activity in Norway. The same situation is applicable to the carried over or reworking activities. A characteristic of transferred activities is that they give some planning time to the activities downstream while carried over are ad-hoc findings. Having in mind the complexity of such one-of-a-kind projects which contain thousands of work packages (1011 in our case), the control of every activity and their transition is a challenging task (ibid).

The third category of activities influencing the costs and the duration of the project are the reworking activities generated by change order from the customer side, late revision or new requirements from the classification societies and design team. The costs for some of these reworking activities are supported by the customer while some by the shipyard. However, these activities can influence the duration of the project to a certain extent especially because when happen in Norway, the cost for the extra work can e very high.

The involved shipyards and the researchers emphasize the importance of tracking the reasons for these transferred and carried over activities in order to prevent the same mistakes from reoccurring. How these non-completed tasks are managed in Norway is another important issue for establishing a learning curve and for sustaining motivation and positive results. All these elements can be placed within Lean thinking framework and help Phase-based PM become a specific Lean shipbuilding methodology (Dugnas and Oterhals, 2008).

Our case study is based on the researches we performed at Aker Yards Brattvåg and Langsten. The study is focused on the usefulness of Lean thinking and its techniques on these two shipyards. And, in order to offer a better argumentation we will first study some of the most important tools and techniques applicable from both Lean Manufacturing and Lean Construction to shipbuilding industry.

Chapter seven: Lean Tools

After describing the Lean Thinking, Lean Construction and Lean Shipbuilding concepts without explaining any of their tools, we now reserve a whole chapter for that. We will illustrate and explain some of the tools originated by Lean Manufacturing, improved by Lean Construction and fitted for Lean Shipbuilding.

7.1 Kaizen

Kaizen is the Japanese name for continuous improvement and it has a central role in lean thinking. Underlying the Kaizen strategy is the acknowledgment that management must seek to satisfy and serve the customers' needs if it is to stay in business and make a profit. Kaizen is a customer-driven strategy for improvement and it brings together several tools and techniques. Some of them will be described in this chapter, mainly the ones appropriate to shipbuilding industry. Even though the word itself is very much used in Japan, it became famous in USA and Europe after the book "Kaizen" written by Masaaki Imai, was published in 1986 (Bicheno, 2004).

According to Imai, Kaizen consists of two main elements: the philosophy and a set of tools. The philosophy of Kaizen state that the quality begins with the customer. But, customers' preferences are continuously changing and standards are rising, so continuous improvement is essential. Kaizen is dedicated to continuous improvement in small increments, at every level, forever. Everyone has a role, from top management to shop floor employees. Imai argue that without active attention, the gains made will simply depreciate thus he emphasizes the importance of building on these gains by continuous experimentation and innovation (Imai, 1986).

The Kaizen guiding principles defined by Imai include: Questioning the rules (standard are necessary but work rules are there to be broken and must be broken with time); Developing resourcefulness (it is a management priority to develop the resourcefulness and participation of everyone); Try to get to the Root Cause (do not solve problems superficially); Eliminate the whole task (question whether the task is necessary at all); Reduce or change activities (search opportunities to combine tasks) (ibid).

The table below summarizes the involvement and the attitude necessary from every organizational level in a kaizen business.

Top management	Middle management and Staff	Supervisors	Workers
Be determined to introduce Kaizen as a company strategy	Deploy, and implement Kaizen goals as directed by the top management through policy deployment and cross-functional management	Use kaizen in functional roles	Engage kaizen through the suggestion system and small-group activities.
Provide support and direction for Kaizen by allocating resources	Use kaizen in functional capabilities	Formulate plans for kaizen and provide guidance to workers	Practice discipline in the workshop
Establish policy for kaizen and cross-functional goals	Establish, maintain and upgrade standards	Improve communication with workers and sustain high morale	Engage in continuous self-development to become better problem solvers
Realize kaizen goals through policy deployment and audits	Make employees kaizen conscious through intensive training programs	Support small group activities and the individual suggestion system	Enhance skills and job-performance expertise with cross-education
Build systems, procedures and structures conducive to kaizen.	Help employees develop skills and tools for problem solving	Introduce discipline in the work shop	

Figure 19: Hierarchy of Kaizen involvement (Imai, 2004)

7.2 Just-In-Time and Shipbuilding

Although having no inventory is a goal which can never be achieved, inventory is the enemy of quality and productivity. This is so because the inventory tends to prevent rapid identification of problems, increase the lead time and the need for space thereby discouraging communication. The true cost of extra inventory is very much in excess the money tied up in it. The specific literature identifies three types of inventory: raw material, work-in-process (WIP- the only one under a real control) and finished goods. The existence of any of these is regarded as waste, but their root causes and priorities for reduction are different (Bicheno, 2004).

JIT manufacturing has taught that inventory deliberately hides problems by covering them up. So, perhaps, a quality problem is not considered important because there are always extra parts available if one is defective. JIT encourages deliberate inventory reduction to uncover this kind of problems. Cutting the safety inventory will help the organization to operate with a leaner system. If problems occur is good because the organization can recognize and solve the problem from its roots (Bicheno, 2004).

7.3 Takt Time and Work Flow Leveling

Takt time is the German word for meter and in lea thinking is the targeted pace of production. It is also known as “Customer Demand Rate” and is measured as the total available production time per total customer demand for some period of time. Running faster than the takt time will generate the need for accelerated production, overtime and/or excess inventory. Applying takt time is not so evident for the shipbuilding process due to, first of all, the longer time needed for building a ship. A takt time of e.g. six month is difficult to be used as a means of breaking up tasks to set a tempo of production. There are many differences between ships in term of size, complexity and the number of parts needed for each, thus a different takt time for every project (Liker and Lamb, 2000).

But, in order to make the stages of ship production flow it is necessary to define the takt time. One need to know how often a part needs to be completed to fit the overall schedule for the final ship construction and ideally all parts of the shipbuilding process should move through the yard in the same tempo. Different takt times can make one department very efficient while the others are affected by the irregularities and extra work load, resulting in bottlenecks.

Takt time can be used to set a pace of the production and to alert workers whenever they are getting ahead or behind (Liker, 2004). If we imagine a ship as a collection of smaller units, we can make more sense in using takt time in shipbuilding. Considering the ship delivery schedule as an average of six month, the conclusion will be that all components need to be built JIT for this to happen. Next, is necessary to identify when each part need to be completed in order to meet this delivery schedule. For example, there are many blocks which make up a ship and they obviously need to be built in parallel and in a shorter time than the time it takes for final construction of the ship. In consequence, a takt time for blocks can be calculated backwards from the ship delivery schedule and the time the ship will be on dry dock. The table below shows the differences between unequal process time and takt time scheduling.

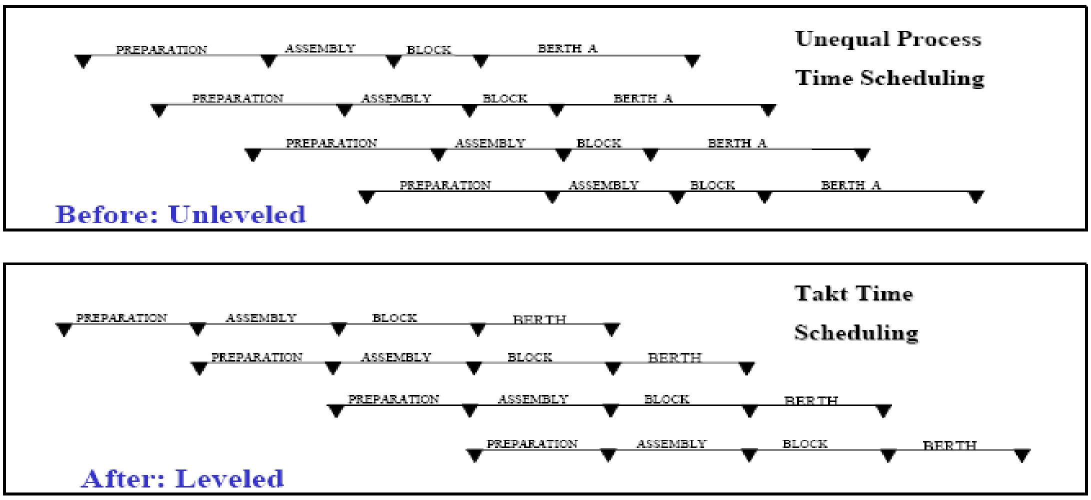

Figure 20: Balancing overall Shipyard Schedule to Takt Time (Liker and Lamb, 2000)

The top part of the figure 22 shows unequal process time scheduling where none of the temporary products are ready just when needed by next process. This will lead to bottlenecks and queues of material waiting to be processed in later stages. In the lower part of the figure above, through takt time planning, all parts of the process move in synch, allowing for flow production and JIT (Liker and Lamb, 2000).

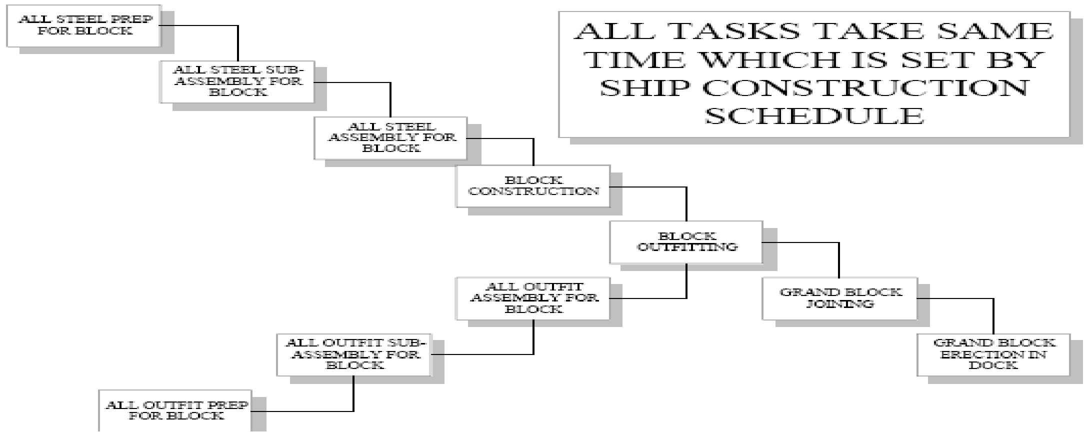

Figure 21: Block construction to takt time (Liker and Lamb, 2000).

There are several alternative ways of leveling the flow in shipyards. A few are feasible in some circumstances, while others are better in different circumstances. These alternatives can be: Using temporary workers; Cross-training employees; Careful planning, as standardized time for processes, standardized design and balanced processes across the shipyard (ibid).

7.4 Stable Shipyard Processes

Implementing lean means working without the safety net of large inventory buffers and that requires very stable and reliable operations. One of the most important keys of stability is standardization which represents also the current best method of doing things, but should continually be updated by the learning process. So, standards go hand in hand with continuous improvement and starts at the worksite. There are a number of key processes at the worksite which lead to stability: Standardized work; efficient workplace design and layout; 5S; ergonomics (Liker and Lamb, 2000, Ohno, 1998).

A very important characteristic of TPS and Lean is the emphasis on a well organized workplace. Having clear standards for where things belong makes possible visual control and enables the spotting of deviations from the standard much faster. The tool for achieving such well organized working place is called 5S. The Japanese words are: Seiri, Seiton, Seiso, Seiketsu and Shitsuke. Creating a clean and organized workplace in five steps means to:

- **Sort** – Sort through tools and keep only what is needed while disposing the unnecessary ones
- **Stabilize** (orderliness or simplify) means to have a place for everything and everything has its own place
- **Shine** (sweep or cleanliness) means to inspect and expose the abnormal and pre-failure conditions
- **Standardize** (create rules) means to maintain and monitor the first 3S
- **Sustain** (self-discipline) means to maintain a stabilized and clean workplace permanently as a process of continuous improvement (Bicheno, 2004)

Figure 22: The 5S (Liker and Lamb, 2000)

An alternative to 5S is CANDO (Cleanup, Arrange, Neatness, Discipline and Ongoing improvement (Bicheno, 2004).

7.5 Lean Value Chain

Lean thinking does not stop inside the shipyards. It comprises also the integration of its suppliers becoming in this way a value chain proposition. Without a good collaboration with the suppliers it is difficult to introduce JIT and thus to eliminate unnecessary inventories. Steel, pipes, raw materials are a few examples of possible JIT systems if the relationships with the respective suppliers become lean. But, such relationships requires a high level of trust and a high degree of mutual learning between customers and suppliers to understand program timing and how to adjust to the inevitable changes and setbacks which happen so often in a shipbuilding project (Liker and Lamb, 2000).

7.6 Last Planner

This is one of the most important tools coming from the Lean Construction concept. It was created by Glenn Ballard in 1994 and then developed further in collaboration with Lean Construction Institute. Its implementation began in 2006 and the results are more than promising. Last Planner is a system for collaboratively managing the network of relationships and communication required for production planning, coordination and delivery of a project (Mossman, 2005).

A suggestive definition of the Last Planner System (LPS) is given by Mossman (2005) who states that LPS enables programme and production planning decisions to be made collaboratively from the lowest possible working level in a whole range of unusual production setting. It is a system fitted for areas like: Software development; Shipbuilding; Yacht fit-out; atypical Manufacturing; Construction. By promoting communication between trade foremen and site management at appropriate levels of detail before issues become critical, LPS creates significant improvements in programme predictability, productivity, profit, safety and feelings of welfare among project participants (Mossman, 2005).

An important source of frustration, uncertainty and waste in projects is waiting – waiting for access, materials, plant waiting for the upstream process to complete its work. When a team is late with delivering its work, follow-on teams are impeded from starting when they planned to and hence work ceases to flow. This is one of the main reasons which make impossible for any function or system to manage a project by centralized planning.

Through LPS projects became more predictable and the chances that work will flow and projects can be completed in time increases (Ballard, 2000; Mossman, 2005).

In Last Planner (LP), it is the *last planners* who work together to plan the production week by week and ensure that work is made ready before it is planned to do it. The last planners use continuous improvement for both planning and production. They together with project managers produce the overall project programme collaboratively so that everybody understand the overall process before they begin to work (Mossman, 2005).

LPS has four main elements:

1) **Programming Workshop** – collaboratively creating and agreeing the production sequence (and compressing it if required). It is about regular meetings with duration no longer than an hour, involving all last planners (design team leaders, and/or departments' supervisors on site). Such meetings are called Production Planning Meeting (PPM) and their purpose is to plan the work that will be done in the next period taking into consideration the previous period and the knowledge of the work that is made-ready to be done. An important aspect of this element is that the foremen can only reasonably commit their teams too deliver a particular piece of work only if it **can** be done. LPS has a systematic Make Ready process to ensure that when work is programmed for production it CAN be done.
2) **Make Ready** – Making tasks ready so that they can be done when people want to do them. It is a process which systematically checks that everything is in place for each of the tasks in the Lookahead part of the plan.
3) **Production Planning** – collaboratively agreeing production tasks for the next day or week. LPS is a tool for coordination and production control designed to ensure the achievement of agreed goals. Those goals are set in collaboration so that all the main suppliers and specialists contractors are engaged right from the start in developing and signing up to the master programme for each phase. Clarify criteria for release of work to others sooner; Builds the team; reduces the need for progress chasing, etc.

4) **Continuous Improvement** – learning about and improving the project, planning and production processes. Only by adding continuous improvement process people will systematically learn how to work more effectively together and to make the work programme ever predictable (Mossman, 2005).

7.6.1 Pull vs. Push

The traditional planning system is a push system – it pushes work into production based on pre-determined start and completion dates, without regard to whether the work is ready to be performed or not. If this system worked, there would be a high coincidence between *should do* and *done* (Mossman, 2005).

LPS changes the way the programme is arrived at and adds critical step designed to ensure that only work which CAN be done id scheduled for production. When includes in the current planning system, LPS would first transform what SHOULD be done into what CAN be done. A reliable assignment, one that gets done at the required time, determines what WILL be done, after considering both what should from higher level plans and what can be done based on the situation at hand (Ballard, 2000).

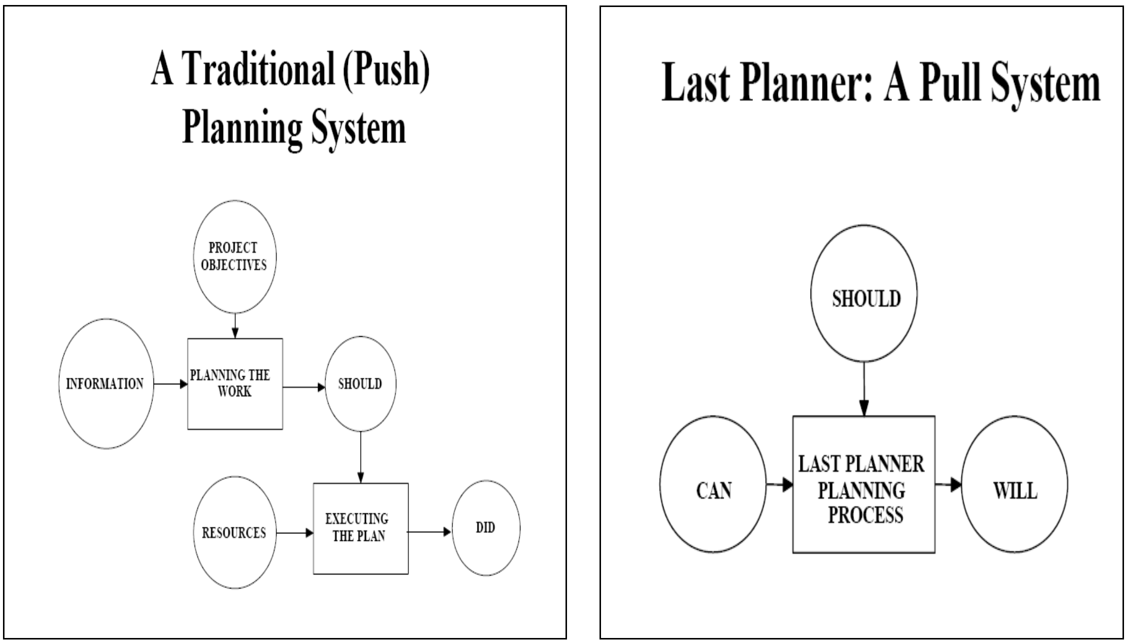

Figure 23 Push vs. Pull planning systems (Ballard, 2000)

Stabilizing the work environment begins by learning to make and keep commitments. The last planners can be expected to make commitments (WILL) to doing what SHOULD be done, only to the extent that CAN be done (Ballard and Howell, 1997.

7.6.2 The LPS Planning Process

The LPS is divided in few important planning phases: Master Pulling Schedule, Phase Schedule, Lookahead and weekly schedule. An overall project schedule is the *Master Pulling Schedule* and is developed from the design (which supports customer's requirements) to the delivery phase. It is determined by breaking the project into pieces and establishing their sequential relationships. The detail level is resumed to key milestones and develops phase schedules as the milestones approach. Milestones are determined by using a pull process from successor phase, starting with the project completion date and working backwards to the beginning of the project (Ballard, 2000).

The next level of planning is *Phase Schedule* which is prepared by the team that manages the work in the phase. Master schedules can be seen as an assembly drawing of the project showing how the big pieces come together over time, while Phase Schedule is prepared in finer details than the master schedule. It must be ready at least six weeks prior to the first activity. Phase Schedule displays the way work will be done to complete the work within each piece or to coordinate the details of assembly. The main scope of Phase Schedule is to produce the best possible plan by involving all those participants with relevant expertise. Planning near action is a way to ensure that everyone involved in the phase understands and supports the plan by developing the schedule as a team (ibid).

The *Lookahead Plan* puts the workflow into the best achievable sequence while rate and matches labor and related resources to the production flow. It provides the workable backlog of assignments for each supervisor and crew, screened for constraints. Operations are planned collaboratively by multiple departments and the work which is highly interdependent is grouped together, so the work method can be planned for the whole operations. The *Weekly Work Plan* (WWP) identifies make-ready-actions, assesses their feasibility prior to making assignments, identifies the best use of the crew or team's capacity, and acknowledges individuals differences in the light of the scheduled loads. The assignments for the workers are made on the quality criteria: Definition; Soundness, Sequence and Learning Ballard, 2000, Daeyoung, 2002).

Definition means that work is ready to start; soundness is resources readiness (design, components and materials, workers, equipment, space, connecting work, external conditions). Sequence means the work is well sequenced according to the tasks orders. Learning is for continuous improvement and adjustments (Ballard, 2000, Koskela, 2000).

Figure 24: LPS (Ballard, 1999)

7.6.3 Percent Plan Complete (PPC)

A main feature of LP is to allow the last person in the authority line to plan and decide the assignment to be done. And, in order to assess the quality of the performed assignment, LPS uses a simple metric called PPC. This PPC is calculated by expressing the number of completed tasks as a ration of the total number of tasks planned for a particular production team in a given period of time. PPC can have a value between 0 and 100 % where every number under 100 means a failure in the production planning process. It is important to specify that PPC does not provide a measure of how efficient the tasks were conducted, but it measure the reliability of the production system. Furthermore, while PPC is calculated, a re-programming is made, indicating the executed tasks and those forecasted but not completed. The result of this re-programming is the calculation of a new date for finishing the project (Chitla, 2003, Daeyoung, 2002). The figure below shows an example of a PPC.

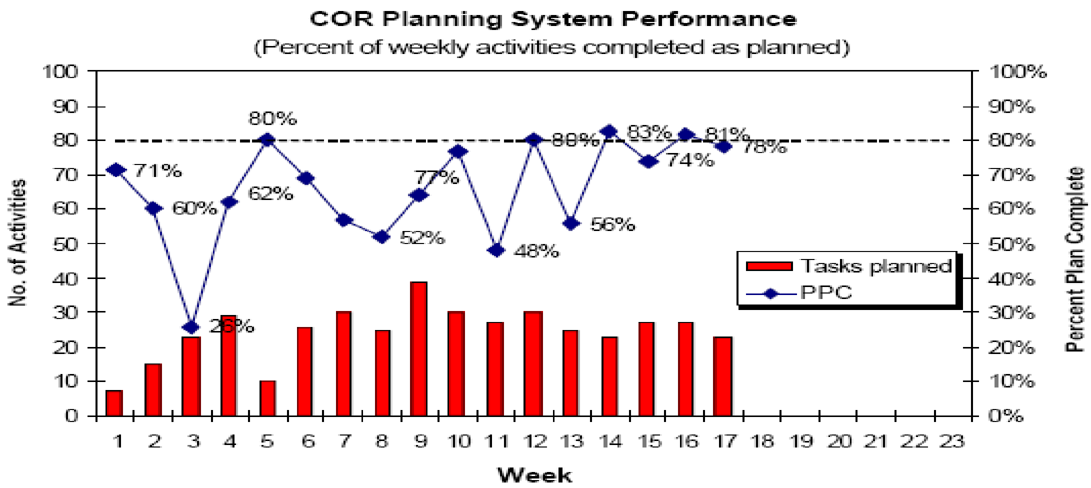

Figure 25: PPC (Daeyoung, 2002)

7.6.4 Planning and Process Reliability

After PPC is calculated, and the current situation is visible, it is important (together with re-programming) to pay attention to planning reliability indicators and perform a root cause analysis. The planning reliability takes into consideration the fact that plans can change and materials are often late and that influence the whole project. When planning is unreliable, bottlenecks occur and are pushes downstream. Through modifying the planning system, the work environment becomes more stable, and it is possible to reduce variation in flows and work behind the shield to improve downstream operations, hence improving the whole system. Koskela (2000) suggest the necessity of locating the source of variability in order to launch corrective actions and monitor their success (Ballard and Howell, 1994, Koskela, 2000).

LP combines effectively control and improvement to fight back against variability and the waste caused by it. Minimizing the variability is important for the planning process which is reliable when the variability is close to zero. A reliable planning process is also vital for the labor productivity unit and for the duration of the project which can be affected by a low planning reliability (Ballard, 2000).

The process reliability is affected by two aspects: A self-inflicted one which is about the way organizations control their resources – people and equipment. Balancing the resources is possible only after creating a reliable planning process. The other aspect influencing the process reliability is given by the external variability which is mainly related to the customers, suppliers and the product variation (different types of ships with different complexities). External variability may not be within the organization's ability to change, but a system to manage them can be found through a lean value chain (Liker, 2004, Ballard and Howell, 2000).

7.7 Root Cause Analysis

The importance of "root cause" problem solving is fundamental in lean thinking. It means solving problems at the root rather than at the superficial or immediately observable level. One of the most used technique is the "*5 whys*" which ensure that the root causes of the problems are sought out. It basically requires that the user asks "why?" a few times over again. This simply but quite effective technique sums up to a questioning attitude. The first reason is never accepted and the answer is always explored deeply. It goes along with the idea that a problem is something valued; not to be wasted by merely solving it, but taking full advantage by exposing the underlying causes that have led to it in the first place. Many believe that is this insistent searching for the root of the problem that gave Japanese industry the edge on quality, reliability and productivity (Bicheno, 2004).

Discussing the root causes it is important to define also the criteria of a well-defined problem: It focuses on the gap between what is and what should be; It states the effect; It is measurable; It describes the pain; It avoids "lack of" and "no" statements (that imply the solution); It highlights the significance of the effects (Bicheno, 2004).

Barrier Analysis is another tool used to analyze the root of a problem. It is useful in the situation where the implementation problems are being experienced. It amounts to a straightforward set of questions which should be addressed to an unwanted event or problem:

- What are the threats, hazards or potential problems that can influence the situation? Threats can be physical, psychological, or influence status or security.
- Who or what are the "targets" for change? In any change there will be victims and beneficiaries, some maybe unintended. It is useful to list these.
- What are the barriers? These might be physical, geographic, communication, language, culture, administrative, organizational.
- What are the safeguards that are supposed to be in place to make the change easier or more acceptable, and if these are not in place, why are they not? Should the threat or the target be isolated or both?
- What is the "Trace"? It means to identify the sequence of the events or history which caused the situation (Bicheno, 2004).

The last tool recommended by Bicheno (2004) is called "**six honest working men**" and it refers to the six types of question one can address to identify the root problem: What, Why, When, Where, How and Who. Their scope is to define the customers, their requirements and what is really valued.

Every shipyard is unique and has its own specific strategy. The tools or techniques should be selected by the management according their needs, without loosing the road to the final scope. We will now try to apply the theoretical base accumulated during our research to the case study of the project: Aker Yards, Langsten.

Chapter eight: Aker Yards

"Preferred for Innovation"

8.1 Acknowledgement

As we state earlier, our research paper is a part of one bigger research project organized by FAFO, Molde Research Institute and Danish Technical University in collaboration with some of the most important shipyards in Norway. For our part of research, we have had the task to gather some of the available data, to analyze them and hopefully to contribute to the development of lean shipbuilding concept. However, our focus is mainly on the academic side of the case study and very little (none) on the implementation part. We have tried to bring into attention the lean thinking principles and tools which we considered fitted to our case study. The shipyard we focus our study on is Aker Langsten which allowed us to follow the evolution of the Maersk (A.P. Møller-Maersk AS Denmark) project for which they will build three specialized ships. But, due to the project division in two shipyards and Langsten's team interest in studying the sister-ship effect, we need to take into consideration some data and facts from Aker Brattvåg who will build seven out of the ten AHTS Maersk ships.

In the first part of the analysis we present several facts about the whole company Aker Yards ASA. Then, we describe the standardized business process used by every shipyard belonging to the group. A brief project description is presented in the subchapter 8.4 after which we present the collected data and the results we were able to synthesize from those data. In the data results subchapter we divided the findings into qualitative and quantitative results in order to emphasize the different types of available data for our case study. The managerial implication subchapter presents our view about lean tools and principles applicable to the project. Our suggestions are based on the theoretical studies inspired from lean thinking, lean construction, lean shipbuilding and some case studies we met along our research period. We conclude the case study with a brief outline of the most important aspects of the case.

8.1.1 Types of Data

Our interviews and discussions were oriented toward acknowledgment of weaknesses in the current business process used for the project we studied. Using specific features from project management theory, lean thinking, lean construction and lean shipbuilding we tried to portrait an overview of the project. However, we were limited to a small part of a big project divided in different circumstances, different internal cultures and different regions. We are aware about these limitations and we acknowledge the reader to take this limitation into consideration when reading the conclusions of our research.

During our research period we conducted several types of interviews for the qualitative side of analysis. The thirteen interviews conducted from January to beginning of May are organized in categories like: 3 Open interviews and 10 structured interviews. Inside of the structured interviews we have 10 direct interviews, 3 correspondence interviews (e-mail) and 2 parallel interviews. The addressed questionnaires are attached in the thesis appendix. We interviewed people at different managerial levels starting from the project manager level, middle and lower management levels to team leaders. With the Project Manager we have had two open interviews and he gave us most of the quantitative data we were allowed to study. Two Project Coordinators, two Planners, one Purchaser, the Technical engineer and four foremen are the people and their project position we could interview during our research.

Our questionnaires are approaching issues which are at the core of lean thinking concept:

- Flow of information
- Waste in the building process and adjacent activities
- Bottlenecks in the system
- Challenges in the planning system
- Suppliers - shipyard relationships, etc.

The quantitative analysis is based on the documents we collected direct at the shipyard or through correspondence from authorized people. We analyzed the following documents:

- Production schedules for each of the three ships at different stages in the production process
- The Master schedule of the project
- Commissioning document for the first ship
- Docking plan for the first ship of the project
- Production plan per construction hours for the first ship of the project
- A sequential plan for outfitting second ship
- Non-conformity plan for the ship no 2 (one month)
- HAT commissioning plan for ship no 2 (contain the WBS of the project)
- Milestones per every ship of the project
- An official project management presentation describing the business processes
- A map of project organization

Due to the confidentiality agreement we do not attach these documents to the thesis.

8.2 State of affairs

Aker Yard Langsten (AYL) is recognized as one of the most modern shipyards in Norway. Situated in a fjord - called Tomrefjord - with good access to the North Sea and then to the ocean, the shipyard gained its good reputation over the years by building high quality ships. From the beginning in 1945 "*Langsten Slip & Båtbyggeri AS*" was recognized as a local shipbuilder and a problem solving oriented shipyard. Today, the knowledge base the good competence, the know-how and long traditions, put the shipyard on the list among the best in the World. A side of the important competitive advantages of AYL is the hall for shipbuilding which saves them many waiting hours caused by unfavorable whether (www.akeryards.com).

Langsten shipyard is a part of Aker Yards ASA, a company who provide work for 21 000 employees on 18 shipyards spreaded in 8 countries around the world.The main types of ships produced by Aker are categorized in three main groups: Cruise & Ferries; Merchant Vessels; Offshore & Specialized Vessels.

According to the report for the first quarter in 2008, the results achieved by the whole group are quite significant: Seven ship deliveries in the first quarter; Solid order backlog gives strong, long term perspective; Organization focused on operation; Partnership to expand in Russia is established. Most of the positive results are a combination of factors like: Maritime cluster and tradition; Innovative solutions; High product quality; Flexible cost base; Leading position in niche market segment. As its main competitive advantage, the company has leading position on the market of build prototypes, niche products and sophisticated ships with high technological content (www.akeryards.com).

The eighteen shipyards belonging to Aker Yards ASA are spread on three continents and eight countries: Norway, Germany, Finland, France, Romania, Brazil, Vietnam and Ukraine. The figure below presents the group's shipyards and the business segments they are assigned to.

Figure 26: Aker Yards business departments (www.akeryard.com)

Inside the three main business areas, Aker Yards offers the following ships types:

- **Cruise and Ferries** primarily built at Aker Yards' five locations in Finland and France. The offered ships include: Post-panamax cruise ships; Cruise ferries, etc.
- **Merchant Vessels** built at Aker Yards in Germany, Ukraine, Romania and Norway. The range include: Bulk carriers; Product tankers; Juice carriers, etc.

- **Offshore & Specialized Vessels** built mainly in Norway, Finland, Romania and Brazil. The offers include: PSV; AHTS (Anchor Handling, Towing and Supply); Field support; Subsea support; Icebreakers; Arctic vessels; Fishing vessels; Naval craft; Research ships; Coastguard ships.

The ships we studied are part of the third category of vessels - Offshore & Specialized vessels which are usually built in collaboration between Romanian and Norwegian shipyards. In our case, the three shipyards are: Langsten, Tulcea and Brattvåg with emphasis on Langsten, the starting point of our project. Aker Langsten management team is currently interested in getting an overview of the planned activities versus those that are actually transferred or carried over to be completed in a late project phase. An important task is to investigate the reasons for delayed activities completion and establish more distinctive phase overlap margins. The main focus is on studying how the transferred and carried over activities are affecting the economy of the project and its scheduled delivery.

Figure 27: Aker Langsten (www.akeryards.com)

Reasons leading to the occurrence of such problems are a matter of concern for the leaders at both Langsten and Brattvåg. Management team at Langsten is preoccupied - besides the already mentioned problems - about the learning curve and the sister-ship effect in the Maersk project while Brattvåg is preoccupied about improving the planning system in the same project. And, in order to analyze the transferred and the carried over activities, we need to introduce the business process applied today at the two shipyards.

8.3 Business Process

Ships for the offshore industry and specialized market segment are built mainly in Norway, Finland and Brazil. Aker Yards' shipyards in Romania produce hulls for the Norwegian yards, as well as complete offshore ships. Due to their size, the company is able to offer a flexible cost by assigning production phases to one or more of the group's shipyards. At Aker, state-of-the art expertise is a priority in the construction of specialized and offshore service ships. They build a significant share of the world's current orders for platform supply larger-sized AHTS which is also the type build in the project we study (www.akeryards.com).

Building a ship is considered today as an engineering-to-order project where every ship to be built is seen as a project in itself and it is managed on its own. The project management team assigned to a project is usually composed by 17 to 30 people ranging from the design team to project manager, planner, purchaser, production coordinator, departments responsible an so on. All members of the leading tam team try to focus on the following common project management objectives: *On time; on budget or better; on specifications* (www.akeryards.com).

A standardized model which identifies the main phases of a shipbuilding process is used in planning and managing a project at Aker Yards. These phases are representing the milestones throughout the life of a project and the figure below presents their sequence:

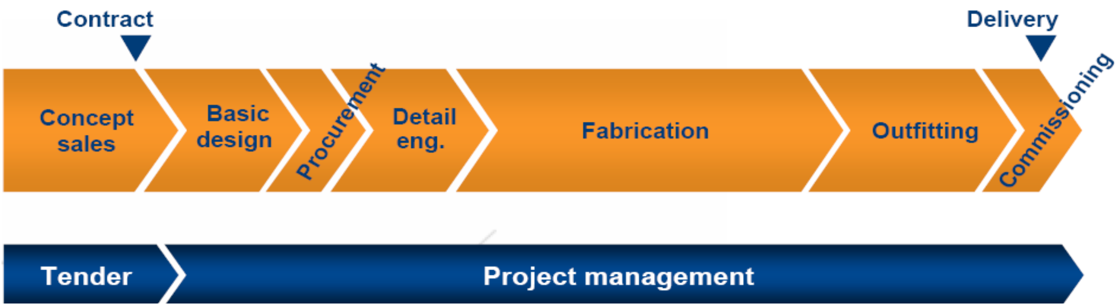

Figure 28: Business Model at Aker Yards (www.akeryards.com)

The above model represents the Work Breakdown Structure (WBS) of the project. Every milestone contains some specific phases and work packages. Even though these phases are presented as clear divided, they are overlapping especially after the concept sales and contract phases. As an example, we understood that basic designs can happen during the procurement and other downstream phases; or some fabrication activities are transferred or carried over to outfitting phase.

In the **sales phase** are included the building specifications and the general acceptance of the contractual agreement. Deciding which suppliers to be used, some basic aspects of the design and the beginning of purchasing major equipment are also parts of the sales phase. In our case, the shipyard's responsibility starts mainly from the procurement phase of the project. They must build ten similar ships following a design concept created by an independent Norwegian company, chosen by the customer.

The **basic design phase** starts with agreeing on the shiplines and with testing the proposed models. In our case, the design team is not a part of the case company hence most of the negotiations here did not involve the shipyard. These negotiations took place mostly between the customer and the design team. For the shipyards, in this phase are established the dimensions of the equipment to be purchased, the milestones of the project and what resources are needed (people, equipment, capacity, etc).

Procurement phase is about finding the right price, quality and suppliers' reliability. It is considered that about 80% of the value of the ship is based on purchases. What general equipment to be ordered and purchased is an important issue for receiving documentation for the next phase - detail engineering. In our case, the customer decided which main suppliers to be used for all the important components thus giving more negotiations power to latter.

Detail engineering phase has a great importance for the project. The design team starts delivering the necessary documentation according to plan. The coordination between departments (steel, piping, electro, etc) begins here also. Ensuring binding documentation from the suppliers, getting the approvals from the owners, class, authorities, classification societies and sub suppliers are also happening in this phase. According to our data, the design team generated some delays and some errors in delivering the drawings.

The **fabrication phase** is about building and pre-outfitting the hull of the ship. Due to economical reason, this is a phase outsourced to countries which can perform this phase for a better price. As a consequence, the need for a good flow of communication between departments is increased. An important issue of this phase is the delivery of the documents and components on time, according to plans. Late deliveries of the drawings have a negative influence on the hull construction and outfitting phase. For the shipyards it is important to avoid transferring activities to Norway hence, much effort is made to decrease their percentage and negative aspects on such divided project.

Outfitting, testing and delivery phases are usually performed in Norway due to the ability to provide high technological complexity and necessary expertise. Following the plans, securing the right resources and finishing all detail engineering are the main issues performed in this phase. This phase can be influenced by deliveries of the key-components as well as by the access to specialized work force. We did not study this project phase due to the research delivery time limitation. However, the collected data shows some difficulties created by transferred, carried over activities and rework during the outfitting phase. A positive and noticeable aspect of the project is the time recovered at Langsten who managed to achieve a big step forward due to their building hall.

8.4 The 10 AHTS Maersk

Aker Yards decided to allow us access to data and information regarding one of their biggest projects at a time Molde Research Institute (MFM) approached them. This project is about building ten similar AHTS ships for the Danish customer- A.P. Møller - Maersk. The ten sister-ships started to be built in the beginning of 2007 and they are supposed to be finished by November 2009. The customer selected a Norwegian design team to be in charge of delivering the technical drawings for the whole project. All ten hulls are planned to be built and pre-outfitted at Tulcea Yard in Romania and then final outfitted at Brattvåg (seven of them) and Langsten (three of them). Because of our research delivery date, we were able to gather data just for the first three hulls which came to Norway in time for our analysis.

The figure below summarizes the business phases assigned to each part involved in the project. Our data collection is centered on three segments of the project: the hull construction, pre-outfitting and the beginning of outfitting parts of the project.

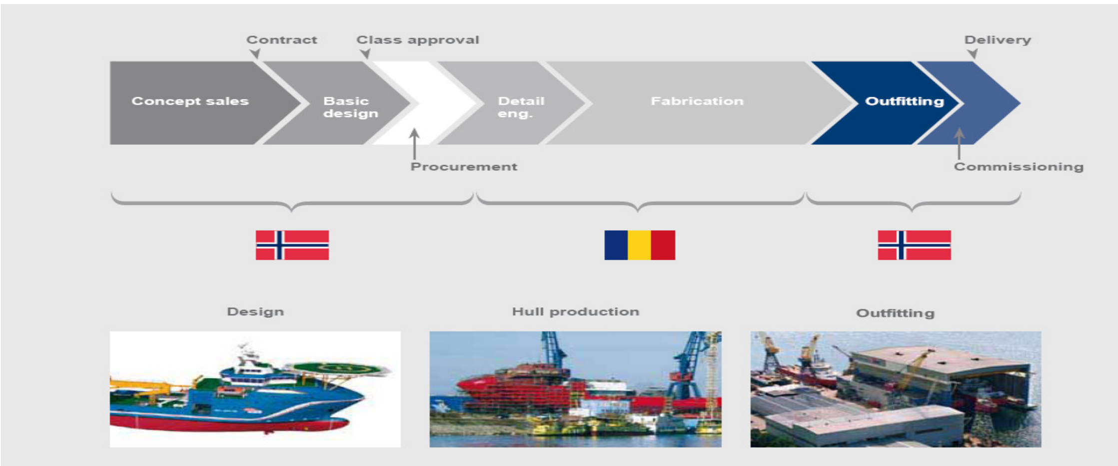

Figure 29: The project phases (www.akeryards.com)

It is important to mention that although these phases are presented in a sequential order, there is a certain overlapping and over return to earlier issues. And that can be a matter to be analyzed through lean thinking lens where the division of the phases is applied from a slightly different angle, taking into consideration aspects like continuous enhancement.

8.5 Data on the Building Process

We need to emphasize an important managerial aspect regarding the relationship between the three shipyards involved in this project. All these shipyards share the same managerial team which is located at Brattvåg and, for our research that meant organizing the collecting data process in two different locations. It also gave us the possibility of performing parallel interviews between similar positions in the project organization plan..

This subchapter is based on the quantitative and then qualitative date we were able to collect during our interviews at the shipyards and through internet correspondences. We start with a presentation of the available data about each of the three studied hulls. Then, we present some general data collected through interviews with people from the middle and lower levels of management, as well as with some of the foremen assigned to this project. Most of the direct interviews took place at Langsten while from Brattvåg we have two direct and three indirect interviews. The latter were given through correspondence by the people who could not participate directly at the discussions. Most of the interviews were structured, containing about 10-20 questions regarding activities causing transferred and carried over activities. We need to remind here, the lack of direct data from the Romanian shipyard.

The identification number for each hull is different from one shipyard to another. We specify the number for the hulls we studied from the beginning of their description.

8.5.1 The first hull # 119 Brattvåg

According to our data, the building process started in January, 2007 at Tulcea Yard in Romania. The hull building period was planned to take eight months and to start towing it to Norway in the beginning of September, 2007. From late September 2007 to the end of March 2008, the outfitting phase was planned to be performed and completed at Aker Brattvåg in Norway. But an updated plan shows that, after reanalyzing the current situation, the whole building process was delayed with almost three months. Building the first hull took eleven months instead of eight and the December weather delayed also the towing period. But, the team at Brattvåg tries to recover the delays with extra workers and constant work. The updating of the building process shows that the delivery date is moved to June, 2008, if everything goes well from now on.

According to the Production Schedule, when this hull came to Brattvåg, the Norwegian team knew that there were about 35 % of transferred activities from Romania to Norway: 1% of the hull; 11% for the pre-outfitting phase; 2% of the piping phase and 21% of the painting phase because these were not completed before the towing phase. All these activities had to be performed at Brattvåg in parallel with the other earlier planned tasks. Planning and fitting these transferred activities in the scheduled building process takes time, money and resources which are not forecasted in the beginning of the project. However, the inspection performed after arriving to Norway revealed some unreported faults discovered on the hull construction. These carried over activities must be completed in Norway but the problem is that they are not planned in terms of time schedule and necessary resources. Then, planning them is a challenging task for the middle-level management team of the project, especially when some of these activities require specialized or customized resources.

8.5.2 The second hull # 214 Langsten

As planned, the building process stated in March, 2007 but, instead of being completed by the end of November, same year, the hull was ready to be towed at the end of January, 2008. Again, bad weather delayed the towing period. However, the team at Langsten set up the delivery time just 15 days later than the actual planned delivery. They are confident that the advantage of having the hall, together with a well sustained work will give them the possibility to recover a big part of the delayed time. At the time we collected our last data, the shipyard was satisfied with the fact that they were on schedule with most of the activities and there was a great possibility to deliver the ship in the beginning of July, 2008.

We can not compare the results between the first hull and the second due to the lack of accurate data on the percentage of transferred activities.

The production schedule we were allowed to study was issued one and a half month before the towing phase. We consider the completed and non-completed (possible transferred) activities at the time given by our data.

According to our documents, the most significant percentages of non-completed activities for the second ship were registered at the propulsion system and the alternate mechanical work. But, the interval to the towing phase could have changed significantly these percentages. From our interviews we know that on the second ship was a significant percentage of rework activities do to late revisions. Some last minute change orders or revisions coming from the customer, classification society or from the design team, created the necessity of replanning and redoing some activities considered as completed. And, this is not specific only to the project we studied for our research.

8.5.3 The third hull # 215 Langsten

This hull came to Langsten in the end of April after a significant delay due to bad weather during the towing activity. The building process started as planned, but it took almost three months extra until the hull was delivered to Langsten (the towing time included). The delivery date was therefore moved from end of August to end of September. It is worth to notice the one month common vacation for almost all employees at Langsten during July and a part of August. That means an outfitting process shorter with a month. Again, sustained work and the hall are a big advantage in establishing such high targets.

We were allowed to analyze the production schedule issued one and a half month before the towing phase. Therefore, we take into consideration the completed and non-completed activities specified in these documents at that time. Then, the transferred works seem to be, according to our data, even a higher percentage than for the second hull. Available data are computed later in this chapter but, we need to specify the lack of information about carried over or rework activities. The ship arrived too late for our data collection and analysis processes.

8.5.5 General data

We conducted a few interviews with people involved in the project. From the project manager level to the foremen, we tried to draw a comprehensible view of the current project situation. Most of our questions were related to lean thinking specific topics. Identifying bottlenecks and the way to deal with them at every level of the project; measures to improve the building process; understanding the work assignment process; how the planning and replanning system works; understanding the information flow; the challenges of the project; relationships between departments; estimations processes; root causes and management of the transferred and carried over activities are issues we tried to approach in our thesis. The opinions are occasionally different for some of the issues due to the respondent position in the project processes.

8.6 Data Results

We approached the available data from two points of view: Qualitative and Quantitative analysis. The qualitative part based on what we have found through interviews and direct discussions will be presented in the first part of our analysis. The quantitative part of our analysis is the last part of this subchapter.

8.6.1 Qualitative results from the interviews

The findings are presented under every generalized issue we were interested in.

Information flow and communication

This was one of the first questions we addressed to our respondents. It is an issue emphasized by lean thinking as a core concept. No lean attitude or principles can be implemented without a proper flow of information and open communication.

Most of the respondents were satisfied with the communication inside their shipyard and inside their working team. However, the information flow is disturbed by some variances. Many delays are caused by the design team and this is a problem encountered at every level of participation in the project processes. Everyone is affected by delayed drawings, by countless revisions or by wrong specifications in the drawings. Some of the drawings revisions are decided by the classification societies – DNV in our case. The design team holds a weak collaboration with the main office at Brattvåg and that makes the information flow longer than usually. Therefore there are project participants who consider that the organization of the information flow should be improved.

The lack of direct communication between project participants has also a negative impact on the building processes. We understood that most of the information flow between the project participants happens through the main office and the technical department both located at Brattvåg. Very little direct communication between Langsten and Tulcea can be a cause of avoidable delays. A specific aspect of the project we study is given by the management team which is located mainly at Brattvåg. Such centralized organization has some certain advantages and disadvantages as we understood from the interviews we performed at the two shipyards.

- Pros:
  - One project management team instead of two (less people in charge for the decisional process)
  - More ships to be built at Brattvåg (seven out of ten)
  - Simple flow of communication between the customer and the shipyard
  - Better overview of the whole project at the management level
- Cons:
  - Difficult to get all the needed information due to longer course to follow
  - Easier to blame errors on other people
  - Frustrated people who must wait for the necessary information and who consider that there is very little open communication
  - Difficulties in approaching some of the project leaders due to extra working load
  - Difficult to send in time the information required by other people involved
  - Too much correspondence for people responsible for resource and material planning.
  - Extra work load for some project participants.

These are some of the aspects we noticed during our interviews but we have to remind our limited sample of interviews: No data from Tulcea, only one direct interview at Brattvåg, no data from the design team, etc.

Another negative aspect influencing the flow of communication is given by the IT systems used by the shipyard. We understood that every shipyard has its own data base system and to transfer them from one system to another it is time and resources consuming. Such transformations are not mistakes free and that can create problems like delays in delivering the information and in some cases the need to rework some tasks.

Some people argue that this centralized information system does not offer a complete or correct view on the situation regarding material consumption for people involved in the process of resources, material or equipment planning.

Transferred activities

It is the focus of our thesis to identify such activities, their occurrence reason and to suggest eventual solutions for diminishing the percentage of transferred activities. These are the activities which are not completed at the scheduled time and they have to be re-planed at a later time and phase of the project. In our case, these transferred activities refers at the reported as non-completed issues from Romanian to Norway. Therefore, we asked our Norwegian respondents about how they are affected by these extra activities. We asked them also to make some approximates on the number of hours used to perform them. The numbers are used later, in our quantitative analysis.

Transferred activities can not be performed in the scheduled time due to reasons like: delayed drawings, late deliveries of materials and components, lack of specialized work force, errors in the planning system and last minute revisions. The Romanian shipyard sends to Brattvåg a list with all non-completed tasks when the towing process starts. That gives to Norwegian shipyards about three weeks to plan and find the necessary resources in order to complete these tasks. Both Langsten and Brattvåg, use the solution of increasing the number of the workers on the hull. But, finding specialized personnel is not always easy due to a tight market which makes difficult finding such workers.

Most of the people we interview acknowledge the problems created by transferred activities: stress in finding the necessary resources, extra work load for the human capacity, crowded working areas and daunting attitude among colleagues. Hence, for the shipyards it is important to analyze the root causes of these transferred activities in order to reduce or eliminate them.

Carry over activities

The carried over activities are those non-completed and unreported tasks identified after the ship arrived in Norway. Langsten shipyard management team is interested in improving (diminish) the rate of these carry over activities. Thus, we asked in every interview how are people influenced by these activities and how they deal with them.

For the shipyards, these unplanned and unforeseen tasks are most of the time creating a chain of negative reactions. These carried over activities are found usually after the inspection performed in Norway either by the classification company or by the shipyards' own inspectors. Reasons for those problems can be: late or incorrect drawings, lack of specialized work force, misunderstandings of the drawings, unreported mistakes or late revisions. Planning and finding the necessary resources for these activities is even more challenging than for the transferred activities, especially when they need high skilled workers. This short notice makes also difficult to negotiate prices and use of the resources.

An interesting aspect is that most of the carried over activities are not registered in a common document. Sometimes, people find ad-hoc solution and then the problem is forgotten. If the problem is too big, then the situation is reported and decisions are taken at a higher level. The influence of these carried over activities is negative not only for the scheduled delivery, but also for the people assigned to the project. Extra work load, a stressful and daunting working environment are few of the effects noticed by the people.

Reworking activities due to change orders

We were not very much aware about the size and the influence of these reworking activities, so we did not prepare specific questions for this issue. However, it came again and again in our discussions and then we discovered its influence in our analysis. It is a discussed term in the lean construction literature.

These are activities mentioned in every conversation or interview we have had at the shipyards. New revisions from the classification society or from the design team, new requirements (change orders) from the customer, are reasons for redoing activities which are completed from a previous phase of the project. We imagine these reworking activities as in the figure below which presents the whole building process considered as 100 % completed. But, out of these 100% completed activities, a certain percentage was transferred, another percentage was carried over. The rework activities are represented in such way due to the fact that these can happen throughout the life cycle of the project.

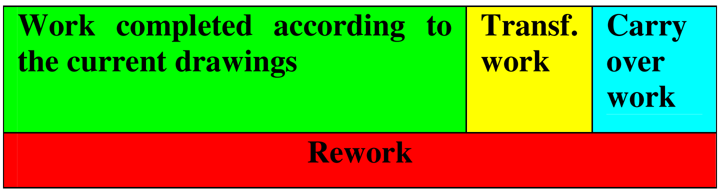

Figure 30: A complete building process

It is important to note that both transferred and carry over activities can lead to rework and they usually do. However, in our case we will refer at rework activities as to the rework caused by change orders, new revisions and changes in the specific drawings. Their impact on the project participants is identified through: Stressful working environment, frustration and tensions between the workers who must redo an activity considered completed, difficulties to find the time and necessary resources. The chain of reactions is usually complex and not so easy to manage and control. As an example, moving a window or a pipe will require new painting or new route for some electrical cables. Such rework would involve two or three departments and a part of their resources planed for other tasks. Some of the rework is paid by the customer but we do not have more data about that.

Planning and replanning – estimating

The importance of planning system is very much emphasized in the lean construction literature. We prepared specific questions regarding planning of a project but also questions about the influence of transferred and carried over activities on the replanning system. The findings suggest mostly an unconstructive influence and growing complexity in dealing with these problems.

It is indeed a challenge to plan the large number of activities included in a shipbuilding project. There are about 1011 drawings for each one of the ships in our project. Then, the task of finding and planning all the necessary resources and materials requires not only good estimations, but also a continuous flow of communication. Late deliveries of the technical drawings are affecting to a great extent the planning system because such delays create idle time for workers and unnecessary increased project cost. The transferred, carry over and rework activities create the inevitability of replanning equipment, materials and people which are not always under the control of the leaders involved in the planning process.

An additional issue regarding planning is the way estimates are calculated for a project. We have in mind the estimates of cost per activity; starting and ending dates; number of necessary people; amount of materials to be ordered. These estimates are mainly based on previous similar projects and some of the calculations are performed by people without access to real data. Looking at the dynamic evolution of the market, such estimations may usually create problems later in the project process in terms of renegotiations with the suppliers and with the customer. Some of the negotiations with the suppliers are tough from the beginning and a renegotiation may not be possible. Then, again, a chain of reactions affecting people and departments is starting to influence the duration and the final costs of a project.

Waste

The production waste, which is at the core of lean thinking, was also a specific question we addressed in our interviews. We asked in most of our interviews if people involved in the project can identify waste in the following: Transportation; waiting; unnecessary work; unnecessary material handling; unnecessary motions; overproduction; defects. What was the most common waste identified by the people we discuss with, was the waste of time waiting for drawings. It happens quite often that the design team delivers the drawings at the very last moment or so late that the work is started, or even closed to completion.

Some of the people responding to our questions identified also the waste of unnecessary work due to lack of discipline and specific routines, mistakes in the drawings or language misunderstandings. Defects are produced by workers who are unskilled or slow in performing their tasks and that cause waste of time and resources.

Bottlenecks

Lean thinking deals with bottlenecks by trying to eliminate them and ensure undisturbed workflow, not just improving the situation. Our interviews contain questions about bottlenecks of this project and about the way people are managing them.

We try to identify some bottlenecks in the project we study and there are some noticeable ones. The first bottleneck is the lack of skilled personnel able to work independently and do a good quality of work from the beginning. The market of skilled workforce is tight and the situation is common to whole Europe. High skilled people are sought after so the competition makes difficult to find and recruit experienced workforce.

Another important bottleneck is the lack of support from the design team. It is not so easy to communicate with them and that creates tensions and frustrations among the project participants. Some of the suppliers create another bottleneck by delaying key-components or materials deliveries. Too often, the flow of communication is interrupted or delayed creating another type of bottleneck in the building process. Project leaders turn into bottlenecks due to extra working load and the impossibility to physically perform all the required tasks.

Special named bottlenecks are the ones coming from the physical capacity of the two shipyards. The docking space and crane capacity create sometimes bottlenecks in the system and in the building process. An issue considered as bottleneck is the lack of a hall at Brattvåg. Factors like weather and water temperature create often the waste of idle waiting. People can not perform their tasks until proper conditions are met. The results obtained by Langsten confirm the comparative advantage of owing a building hall.

Suppliers' relationships

Addressing questioning about relationships with the suppliers is due to the importance of a well integrated supply chain and collaboration between suppliers, focal company and consumer. Lean thinking focuses on the whole chain not just separated tiers.

We mentioned few times by now the problems created by some of the suppliers. The situation of our project is special -in some ways- due to the implication of the customer in choosing the suppliers. Maersk decided from the beginning most of the suppliers to be used for all ten ships of the project. That gave suppliers some extra negotiation power in their relationship with the shipyards. Some suppliers do not deliver in time major components or materials and that result in transferred activities to later phases of the project. It is also happening that wrong materials and components are sent to the shipyards leading to waste of time and resources. Fail markings on the packages is another issue which results in unnecessary motion, time and resource consuming.

Challenges

We asked in our interviews what challenges are people dealing with in this project. The answers are mainly connected to the people and their behavior. The first challenge is to improve the economy of building the ship. With so many variation and aspects influencing the building process, it is a challenge to overcome them and to make a reasonable profit. Most of the leaders struggle to keep up the people's motivation especially when it comes about rework. People feel daunted by reworking again and again parts which were completed for long time ago. Another issue to deal with is to overcome the frustrations given by the crowded working space when the shipyard must use extra workforce in order to recover time and match the delivery date.

A challenge is also finding and mending all the building defects before the ship is delivered. The effort should be general but sometimes lacking motivation, people do not report the defects in time to be fixed. It is taking extra efforts from team leaders to check and confirm the completion of every assigned task. The challenge is to convince all people to get involved in the building process, to collaborate with the other groups and not working only as individuals.

Despite all these findings we saw how through dedication and hard work the products delivered by Langsten and Brattvåg are recognized among the best in the world.

7.6.2 Quantitative Analysis of Production Schedules

In this section we present the available data we have collected during our interviews at the shipyards. The data are taken mainly from the production schedules for each of the three ships we could study. The first ship has the number 119- outfitted at Brattvåg, while ships 214 and 215 – are outfitted at Langsten. We acknowledge the lack of accurate information regarding which are the transferred activities in our data. Therefore, we use the term *non-completed* instead of transferred for all the activities in the production schedule.

The production schedules present the percentage of the completed and non-completed activities planned to be executed at Tulcea. For the information purpose, they contain also some milestones planned for the last part of the project planed in Norway. However, the specifications are quite generally and do not show details of the activities to be completed in Norway. We took into consideration this percentage per completed activity (PCA) and we computed it in some bar charts and diagrams in order to visualize the situation of the building process at the given stages. This PCA represents the completion stage for each activity (we found them in the production schedule) at a point in the production system.

For the first hull we have collected combined data from the production situation three weeks before towing and at the towing moment. At the beginning of the towing phase, the general situation is presented through 4 main milestones: Hull 98% completed, Outfitting 89% completed, Piping 98% completed and Painting 70% completed. We need to specify that all these percentages are considered from the total work assigned to be performed by Tulcea shipyard and do not include the total working hours to be performed in Norway. For the second and third hull we have representative data from the building process at the point one and a half month before starting the towing phase. Therefore, our assumptions and comparing analysis will contain mainly the data from these two ships.

Emphasizing the sister-ship effect

In order to identify the project's learning curve we wanted to present a chart showing the available data. But, due to the lack of necessary data for all three ships, we choose to compare only the second and the third ships which have the appropriate data. Both ships have their Production Schedules issued one and a half month before the towing phase. For a reasonable comparison between the levels of completed and non-completed activities we selected seven representative milestones and computed them in a bar chart. At this stage in the production schedule we see that the third ship was less completed then the second one.

Table 2: Comparison completed and non-completed for 2nd and 3rd ships

Comparison between completed and non-completed activities					
ID	Activity name	Maersk 214		Maersk 215	
		C	NC	C	NC
2	**Fabrication**	**91**	**9**	**84**	**16**
33	Fabrication of independent units	98	11	89	11
49	Mounting the hull	88	12	13	87

55	Mechanical works	49	51	35	65
56	Alternative mechanical works	40	60	3	97
57	Electrical works	97	3	88	12
58	Final painting	9	91	0	100

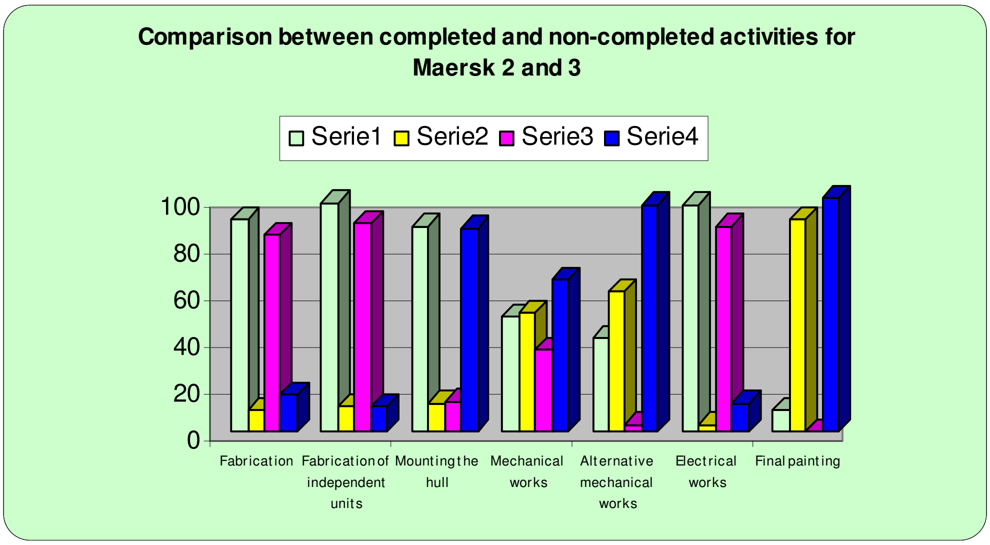

Figure 31: Bar charts comparing Maersk 2nd and 3rd

The bar chart presents a decreasing learning curve at the same building stage for the ships two and three of the project. We do not analyze in depth the evolution of the learning curve due to our research limited time. From the data in the bar chart we see that the percentage of completed activities at the same stage in the building process is lower on the third ship than on the second. The available data do not show how the situation evolved until the towing phase and if such big gap was totally recovered.

Presenting planed vs. achievements # 119

In the production schedules of the first ship we found the data at the beginning of the towing phase. These data show the hull's completion percentage expressed through four big milestones: *Hull construction, outfitting, piping* and *painting*. For understanding of planning reliability we have presented the phase based plan versus achievements for the major activities on first ship. We observed that the planning reliability is weakened by the non-completed activities in the shipyard. The table and figure below depict this situation. Painting and outfitting work packages show high percentage of non-completion.

Table: Planned vs. actual - Maersk 1st ship (Brattvåg 119)

Phases	Planned	Achieved	Non-completed
Hull Construction	100%	99%	1%
Outfitting	100%	89%	11%
Piping	100%	98%	2%
Painting	100%	79%	21%

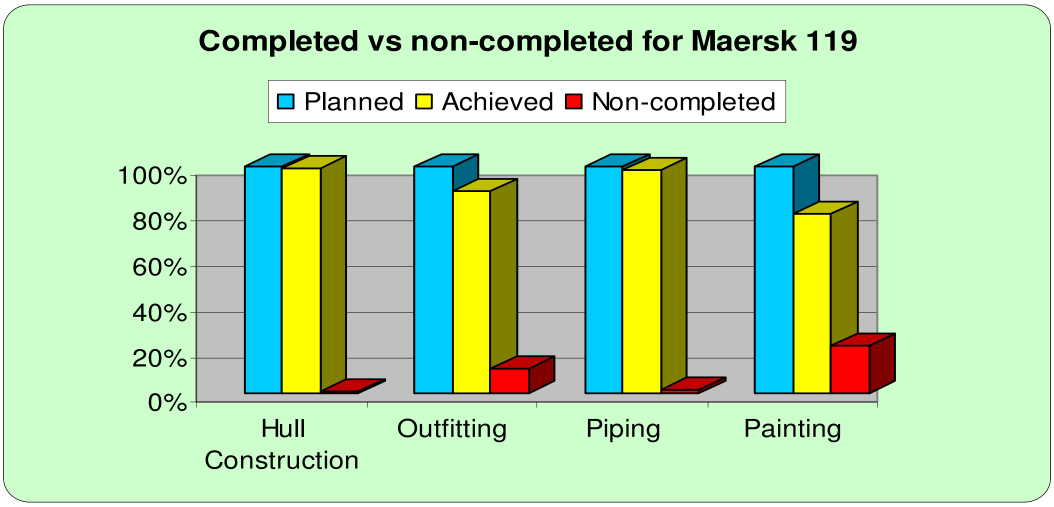

Figure 32: Planned vs. actual Maersk 1st ship (Brattvåg 119)

There are situations when some of non-completed activities are larger than reported, so they become carried over in the planning system which must deal with even more extra work.

Carried over activities from AYT Romania

Together, some of the carried over and rework activities are registered in a "*Non-conformity*" form at AYL. Such non-conformity registration starts to be filled after the hull arrives in Norway noting both carried over activities, order changes, new revisions and their duration. We have a few information regarding carryover activities from Maersk 214 which is now in the outfitting stage at AYL. The table below shows a part of the available data about non-conformity registration starting from 22nd Feb to 25th March

2008 which means that the non-conformity identification is not finished yet. From a similar form issues to a previous ship, we see that the process of identifying them is itself time consuming.

Table 4: Records of non conformity registration

Works ID	Reasons for non-conformity	Responsible for non-conformity	Man hours non-conformity
577	Late sent revisions to Ro	AYT	195
815	Not performed in Ro	AYT	5
211	Revisions from DNV	Design team	12
211	Revisions from DNV	Design team	10
341	Revisions from DNV	Design team	8
304	Late revisions	Design team	18
582	Don't mach standard quality	Design team	243
582	Not drawn	Design team	6
582	Not well fitted	Supplier	232
582	Not performed	Technical	55
515	Drawings changed	Technical	66
	Total hours non-conformity reported in between 22nd Feb – 25 March 2008		**850 man hours**

The table above shows a glance of non-conformity that was found within the first month of inspection. We understood from the shipyard that finding and fixing carried over activities can go on up to the time before delivering the ship.

Seeing the table above we understand some of the main factors leading to carried over activities. The design company V&S seem responsible for a big portion of the non-conformity and rework activities. We can see that 297 man hours (out of 850 collected in just one month) were carried over just because of technical support from design team (that means 35% of the total). If we see further, some carried over activities are due to suppliers responsibility - 29 % and then Tulcea shipyard with 22%. The technical factor seems responsible for 14 % of the carried over activities. Now, with the help of available data, we can see three major factors responsible for the carried over activities: Technical drawing, critical component from suppliers and quality work force.

Analyzing the percentage extra work occurrence

During our interviews we noticed that most of the people were not aware of the whole picture created by the transferred, carry over and rework activities. For measuring the extent to which every one is affected by the transferred, carried over and rework activities we used *men working hours* counting. We have got some data and numbers given by every ones point of view. Summing them up and then estimating for the departments we haven't interviewed, the numbers were around 45 000 to 50 000 men hours.

But, at a second attempt to understand the implications of these extra hours, we look to the numbers and data on the production schedule (and on the internet page of the shipyards). Most of the data are taken from the production schedule for the first ship. The numbers we have got are in working men hours.

In Romania:

- Eleven months for a hull to be build before towing
- App. 25 working days per month
- App. 8 working hours per day
- App. 200 workers (there are 5000 workers in two Romanian shipyards – we assume 2000 worker at Tulcea; We assume that they deliver a hull per month and then we have about 180-200 workers per hull)
- App. 35% transferred activities on the first production schedule ship # 119

In Norway:

- Six months for outfitting
- App. 25 working days
- App. 8 hours per day
- App. 200 workers (from interviews and visits at Langsten)
- Our estimation: 20% change orders and revisions (in Norway)

Table 5: Men working hours (mwh) per ship

In Romania	In Norway
11 x 25 x 8 x 200 = 440 000 (mwh) 35 % = 154 000 (transferred)	6 x 25 x 8 x 200 = 240 000 (mwh) 20% = 48 000 (rework)
A total shipbuilding process of **680 000** total working hours per ship	
A total of **202 000** (transferred plus rework) extra men working hours for the ship after arriving in Norway.	

The result is about 440 000 working hours per hull in Romania and 240 000 working hours for the outfitting phase in Norway per ship. An approximated number on the total building process is 680 000 men working hours. If we consider the results from the ship # 119 we see 35 % non-completed activities hence, we have about 154 000 extra working hours in Norway. And then, we have to consider the mistakes, the late revisions or change orders in Norway and we see a great amount there too. We use the same logic and with the help of the Master Plan we find some of the data. And if we assume that there are about 20% of reworks due to change orders, late revisions or drawings updating, we have a result for about 48 000 extra men working hours. Adding the two results from transferred and rework we have a result of 202 000 extra men working hours per ship. For us, looks like the shipyard build one and a half hull in one project. It is then a big figure which is probably a matter of frustration for most of the people involved in the project. These are problems to which lean shipbuilding can offer some feasible solutions.

We acknowledge the reader about the chain of assumption we made above. All the data are taken from both the Production Schedule per ship, the Master Schedule, from the interviews and visits at Langsten. The model we use is for the purpose of emphasizing the extent of extra working hours per ship. Data are not necessary very accurate but they serve the academic purpose of our research

The shipyards do not have any statistics with such differentiation between the terms transferred, carried over, rework. Without such statistics is quite difficult to get a real picture on the causes and possible solutions.

A graphical presentation of the accumulated man working hours is presented in the following. The graph presents the increasing project costs due to the additional resources assigned for the project.

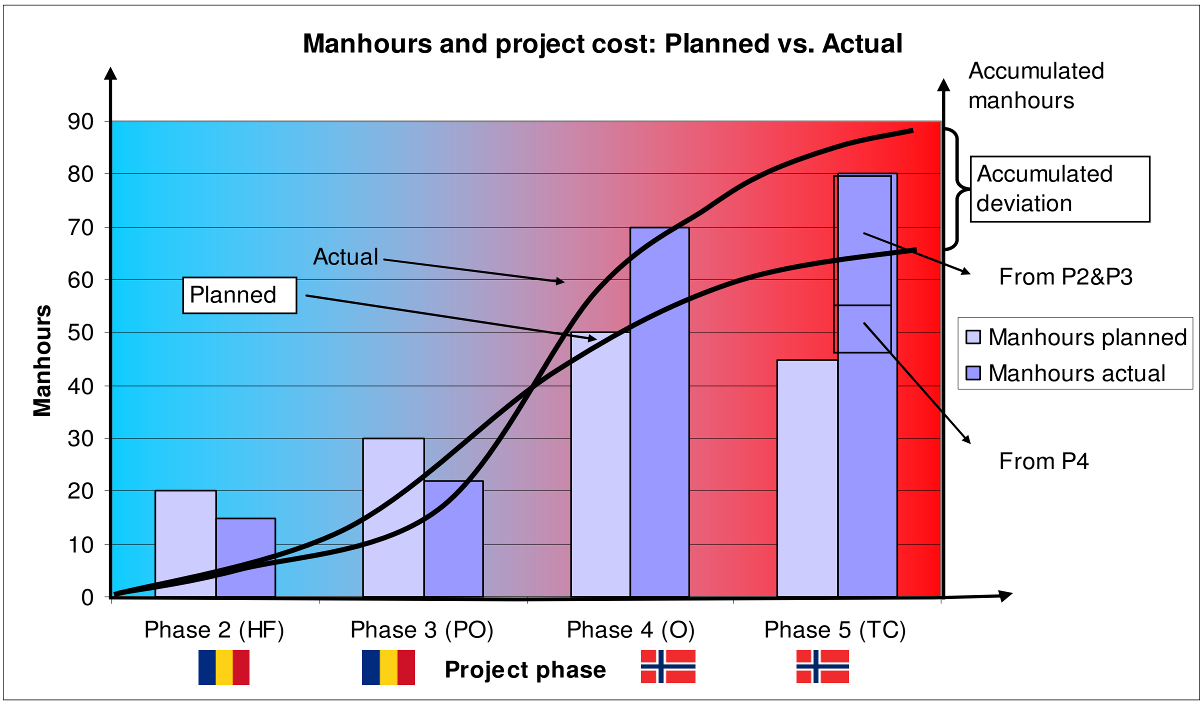

Figure 33: Man hours and project cost: Planned vs. Actual

8.6.3 Summing up the findings

In order to create a concise view of our findings we present the table below. These are in our opinion main causes for the transferred, carried over and reworking activities.

Table 2: Possible problems causes

Category	Findings
Information flow	➢ many change orders ➢ difficult to keep track of the changes ➢ poor communication with the design team ➢ too many and different IT and data base systems ➢ language based misunderstandings ➢ poor communication between the shipyards' teams
Bottlenecks	➢ technical drawings ➢ suppliers capacity ➢ too long communication path ➢ better tools in some departments ➢ lack of high skilled people ➢ lack of crane capacity ➢ the ship is cramped for space
Planning system	➢ difficult replanning process due to lack of control and necessary updating ➢ lack of real data regarding the extra hours needed for performing the carried over and rework activities ➢ lack of clear overview and control of the processes ➢ lack of discipline and routines ➢ stress and extra working load ➢ too many ways to perform the same activities ➢ planning process delayed by the communication path ➢ longer working hours ➢ too many change orders
Challenges	➢ too much waiting ➢ lower motivation for people ➢ some small defects can not be fixed before the delivery due to the time pressure ➢ about 50% of extra work in Norway ➢ chain reaction of delays ➢ wasted time in finding the correct drawings ➢ tensions between working teams due to reworking ➢ careless workers damaging expensive equipment ➢ poorer economy ➢ much higher costs in Norway for the transferred, carried over and rework activities
Improving relationships	➢ inadequate negotiation power with suppliers ➢ errors in deliveries ➢ delays in delivery

8.7 Managerial Implications

In this subchapter we present our opinions and ideas about possible improvements to the findings we made during our research. Through applying ideas and principles from both lean manufacturing and lean construction, we are convinced that the current system, used by the shipyards we studied, can be enhanced to a very high degree.

We noticed people’s dedication and passion for their work at both shipyards while making efforts to recover time and to deliver as promised. Another observation is the fact that some of the people we interviewed are suggesting simple improvements which are very much similar to the ones emphasized by lean thinking. And that is because lean is a philosophy build on common sense and simple line of thoughts. At both shipyards we found willingness to improve and that will, undeniably, create the path toward lean thinking attitude there and in some other places. It is important to mention the necessity of a sustainable process for all the phases of the project. The improvement process should start at the very beginning of the building process and should include every participant at the project. In the following we will try to apply the lean tools or principle we think are offering a feasible solution for improvement.

8.7.1 Improving the communication

As we see in our findings the communication flow is quite critical and people are frustrated and unpleased about the faults of the system. The lean concept is focus on improving the information flow along the production process from the suppliers to the customers’ sides. It is most likely that a more open communication with the customer will help planning activities to get enhanced. The project we studied seems to have met astringency in the relationship with Maersk who uses a selected design team and selected suppliers without giving too much negotiation space to the shipyards. A clear customer value definition might give more freedom and equal negotiation power.

The relationship between shipyards is a matter which can be improved through introducing what is called *kaizen*, one of the core tools of lean thinking. Organizing meetings and open discussions with people participating in the project it is a way to improve continuously the project activities. We have noticed some good improvement ideas among the people we discuss with. Kaizen suggests different methods for gathering such valuable information like: Go and see yourself; boxes for gathering suggestions, etc. Closer to the core of the building process is easier to identify what can be improved when performing a work. A system to reward best ideas would be a motivation for finding and proposing improvements.

Root Cause Analysis (RCA) which is recommended by the lean construction concept might helps to obtain an open and trustful communication between project participants. The five whys technique used inside RCA can create a shorter and faster path (vs. accepting any first coming explanation which do not show the actual situation and when the real cause is identified some bigger than expected problems might appear) on identifying problems, their roots and then proper solutions. RCA can be a solution for diminishing the transferred activities, carried over or rework. Asking why questions would reveal sometimes very simple and avoidable causes of the problems.

We have to remember that the shipyards work with few different nationalities and this RCA can be sometimes difficult to apply. However, the lean concept is not far from any cultural background. The Norwegians' creativity and respect for individual freedom will find a way to perform RCA without making people to feel enquired and judged before even talking.

All five principles defining the lean concept: Value; Value Stream; Flow; Pull and Perfection are useful in improving the flow of information at Aker. By giving some more decisional power to people at lower levels of management and to team leaders might actually improve the motivation, collaboration and the quality of the work.

8.7.2 Eliminating bottlenecks

It seems like the design team has and important contribution on the negative evolution of the project. We did not have access to interview people from the design company thus we can not make appreciation for eventual improvement in their communication system which affects so many people and activities. But, maybe some meetings and kaizen activities organized in collaboration between shipyards and the design team might improve the relationships and the collaboration willingness.

As we see in the theoretical part of our thesis, lean concept tries to eliminate the bottlenecks, not to just improve or upgrading them. Transferred activities, carried over and rework can be all results of bottlenecks in shipbuilding efforts because they demand extra time, resources and money. Therefore an approach for diminishing and, in time, eliminating them, could be the Last Planner tool. By letting the last person in the authority line to plan and decide the activity completion, can motivate them to find and apply the best solutions in their working processes. This responsibility might be also a way to improve the quality of the work diminishing the number of defects. In the same time, by spreading the responsibilities, the level of working load per leader will be lower and more stable, giving them the possibility to have a better control of the situation.

A better collaboration between teams will also help diminishing the need for rework and the frustrations around redoing things over and over again. The bottleneck given by the lack of high skilled workers can be eliminated by improving the steps above. Without so many transferred or carried over activities there will be no need for so many extra workers on site.

8.7.3 Improving the planning system

One-of-a-kind is a well known feature of shipbuilding and construction industries. In our case we see that even though these ships are all same type, they are not identical. Between the first and the last ship of the project, many things will evolve and change due to technological development, customer requirements or other unpredictable factors. However, there is a sister-ship effect and by the last ship to deliver, a lot of things can be improved by learning from experience. The planning system could -in our opinion- be improved by standardizing the planning tools used by shipyards in such combined projects. To keep track of the extra work to be planned and the work load of planning them, should be a standard task because in this way similar problems could be avoid in the future by eliminating their cause. Such registration would be a good controlling tool especially if the division between transferred, carried over and rework can be clearly emphasized in these registries.

Standardization as a key in the planning system at the shipyards refers to the planning, reporting and organizing activities during the building processes. These three features can offer a better overview of the situation if there is no need to translate them from one system to another. Every person involved in the decisional process will save time and efforts by looking at papers easy to understand.

Last Planner (LP), the tool used so much in lean construction, showed good results when used in shipbuilding (Toftesund, 2007). We see that there are interesting possibilities in using such tool for the rest of the project. It can give a better possibility of managing the risks and controlling the situation by assigning responsibilities to a larger group in people. LP uses root cause analysis and that gives leaders the possibility to eliminate the bottlenecks and to enhance the project activities. Through its Lookahead and weekly plans LP gives a better overview on the resource planning system.

Lean project delivery system (LPDS) presented in our theoretical review seems to offer some proper solutions to the planning system. Being managed as a value generating processes it is easier to eliminate wastes and defects. By implicating cross-functional teams (with delegated people from all teams involved in the project) it will be easier to plan and adjust everyone to the common goals.

8.7.4 Responding to challenges

Value, Value stream Mapping, Flow, Perfection, and takt time are all - in our view – principles which can enhance the project activities by preparing its participants for better response to the challenges of a project. It is much easier to prevent the occurrence of the negative events if people involved in the project have a way to keep track and control the evolution of the activities.

Stable processes mean in lean thinking a clean, tidy and easy to control working space. We know that both shipyards have assigned one day per week for cleaning activities on the ships and that works most of the time. However, there are some problems given by the pressure of meeting the delivery time which make people pay little attention to this aspect of the project. A standardized cleaning process which could run every day and become a working norm would help diminishing the waste of defects or carried over activities.

Eliminating waste is a challenge in itself when running such one-of-a-kind projects due to chaotic factors and events influencing the activities. It seems difficult to control all the factors at all times. But, inside both shipyards are unused resources which can help enhancing the control of such chaotic events. Some people are ready to accept the challenges of eliminating waste while some need to be guided toward such simple way of seeing things. An attitude toward eliminating waste should start from the top where leaders give positive signals by appreciating and implementing any suggestion and action which can diminish waste.

8.7.5 Improving relationships

The supply chain can be improved in every type of activity and industry because there is always an evolution toward perfection. This evolution is emphasized by lean concept as a method of achieving continuous improving processes. However, there is not that easy to improve only your part of the business. Enhancing the whole chain means to create good collaboration with suppliers and customers by sharing necessary information and by being open and honest in these relationships. We did not study the suppliers' point of view in our thesis but, we understood that the market situation is quite special and the needs for new ships give suppliers a strong negotiating power. Therefore, we think that through some kaizen activities the relationships could be enhanced and waste can be, reduced or eliminated.

The theory of Lean value chain argues that there are many possibilities on reducing the amount of unnecessary inventories through improving the relationships along the building chain. There are probably many things to be enhanced at the Romanian shipyards and one of them could be their relationships with local suppliers and with Norwegian suppliers and shipyards. Just in time approach together with other lean principles applied there could make a difference in the whole picture. But, for such approach all project participants must keep an open mind and fulfill their part of agreement. That can be achieved through a lean attitude enhanced along the business process from the first to the last project task and participant.

8.8 Summing up the case study

Today, we see that the organization of a shipbuilding process follows the structure we described in the chapter one. There is a distinct life cycle for every project which is organized as an entity of its own. It has a Work Breakdown Structure (WBS) which depicts every important phase of the project and their work packages, well established starting and completion dates. We see that most of the estimations at the shipyards are made using methods from project management approach which means based on previous experience and some other calculations. Scheduling the resources is a process happening at a certain level of management, taking into account the needs of the project and the estimated starting or completion time. All of these features of a shipbuilding process can be improved through lean thinking.

Using Value Stream Mapping to understand the life cycle and the main phases of the project can be a way to enhance the planning and controlling of project evolution. Kaizen, Root Cause Analysis, Last Planner, 5S and LPSD are only some of the tools we can see as responding to the focus problem of our thesis: transferred and carried over activities. However, the limitation of the collected data might have hindered us in identifying the best solution.

Our case study shows that there are some problems which could find many possible solutions inside Lean concept. Introducing approaches inspired from lean might begin with a focus on waste and kaizen activities. Human resources are the most important asset of a company and motivating them can be the first step toward continuous improvement. Listening to and applying people's suggestion can be a motivation toward diminishing waste in most of the activities and project phases.

We truly believe that a lean concept approach would enhance some of the sensitive areas we met in our case study. An in-depth analysis of the three shipyards involved in the project might give even more reasons to enhance the system through lean principles and tools.

According to our collected data, some of the most common accepted reasons are: Faulty design basis; unrealistic plans from the beginning; unclear specifications; late design deliveries; late revisions from the classification companies; changes at late stages, design, equipment; difficult relationship with the customers, etc.

Quite often problems like transferred or carried over activities appear and create delays along the phases of the project or at the delivery. According to our collected data, some of the most common accepted reasons are: Faulty design basis; unrealistic plans from the beginning; unclear specifications; late design deliveries; late revisions from the classification companies; changes at late stages, design, equipment; difficult relationship with the customers, etc

Chapter nine: Conclusions and Limitation

Studying lean concept from the beginning to nowadays it is an interesting experience. It does not change only your academic understanding but also shows you the way out of the box. From its roots the concepts show a great deal of common sense and right focus. And, the more we study, the more we find its challenges and applications.

9.1 Conclusions

The methodology approached in this research started by presenting the most common practice in managing industries like shipbuilding and constructions. The transition to that part of lean managing the same industries was made through presenting the roots of this concept. Lean Construction and Lean Shipbuilding are products of people who understood the need for a change before is too late. These two concepts reveal the wide range of possibilities offered by lean thinking. As a concept, Lean Shipbuilding is on a developing phase but that can not stop us to see its future potential.

We hope that our research contributed somehow to the development of the Lean Shipbuilding concept. Our opinion is that shipbuilding can become a new lean concept due to the industry specificity. One of its main characteristic features contributing to our opinion is the high degree of interest and intensive research in advanced technology. The market evolution and the increasing environmental rules, challenge the shipbuilders to come with solution unconceivable for just some years ago. And, the time to market with such solutions can make a huge difference for a shipyard especially in countries like Norway with a high cost on the labor market. Asian countries are competing more and more on the shipbuilding market and it may not be so easy to respond to such competition.

For revitalizing the Norwegian shipbuilding industry, Lean Shipbuilding could be the nowadays solution because his concept can improve the building process, the planning process, the design and the rate of bringing on the market new technological developments.

9.2 Limitations and Further Research

Our research was limited by time and by the evolution of the project. The delays in hulls arrival in Norway hindered us in getting the significant data for an in-depth research. Also, the lack of statistic data or other significant data from the shipyard led to a rather simple quantitative analysis based more on our assumption and qualitative data collected at the shipyards. Another limitation of our project was the division of the project. The sister-ship effect was not so obvious because each shipyard involved in the project has its own strategy, own organization of activities and their own organizational culture. Some activities are performed in a very different manner from one shipyard to another i.e. the different data software used by each shipyard in its planning system.

An interesting area of future research could be the possibilities of implementing Lean Shipbuilding at the Romanian shipyards. Their influence on the building processes is big, so an enhancement of their planning system would have a positive effect in Norway. Another research area could be the relationship with the design team when this is not a part of the shipyard. Through a lean analysis, the major problems can be identified and a win-win solution would be easier to spot.

The Maersk project is scheduled to last until 2009 and that give an opportunity for a further research. After some more hulls will arrive in Norway and some will be delivered, the evolution of the learning curve can be easier emphasized. It is also an opportunity to study the scale of transferred, carried over and rework from the first ship to the last. An eventual statistic divided per category will help in finding the adequate solutions. This project can be a confirmation of the enhancement in the building process due to introducing tools and principles inspired by Lean Shipbuilding.

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Appendixes

Maersk AHTS, 2008

Interviews

Most of the questions are directed related with the Maersk project.

Questions used in interviews:

Q1. Which activities were planned but not fulfilled in Romania for the construction no. 2

a) for the hull construction phase
b) for the preliminary outfitting phase
c) for the piping installation phase
d) for the painting phase

Q2: Are the above mentioned delays specific just for the construction 214/120? Q3: How many extra-hours are necessary in order to complete these carried over activities from Romania to Norway? Please estimate the number of working hours for the construction 214/120:

a) hull construction
b) outfitting (components)
c) piping
d) painting
e) other

Q4: Which activities are mostly transferred into the testing phase even though they should be completed during the outfitting phase? The question applies to similar projects also.

Q5: Are you expecting any delays from the outfitting phase to the testing phase regarding the construction 214/120?

Q6: Do you keep any statistics about the reasons for delays/ uncompleted activities? Q7: What measures are taken in order to complete the carried over activities in parallel with the work which is already planed for a specific phase? Are you keeping a record of these measures?

Q7: What measures are taken in order to complete the carried over activities in parallel with the work which is already planed for a specific phase? Are you keeping a record of these measures?

Q8: Which are the negative effects expected to appear due to carried over activities and its extra load on the workers?

Q9: Who has the main responsibility for managing the carried over activities and their replanning? Is this a person or group responsibility? Who gets involved if this is a group responsibility?

Q10: Which are the most critical bottlenecks in the production process?

a) the working force
b) the necessary machines
c) the suppliers' delivery of A- components
d) the display of the shipyard
e) the technical support
f) the flow of communication
g) others

Q11: How many hours are necessary in order to identify and check all the carried over activities?

Q12: How and how early is the shipyard informed about the coming problems? What does the shipyard do in order to avoid repetition of the same problems over and over again?

Q13: Do you have any available statistics about all the extra-hours used to complete the carried over activities?

Q14: Which activities were planned but not fulfilled in Romania for the ship # 119?
a) For the hull construction phase
b) For the preliminary outfitting phase
c) For the piping installation phase
d) For the painting phase

Q15: Are the above mentioned delays specific just for the construction no. 119?

Q16: How many extra-hours are necessary in order to complete these carried over activities from Romania to Norway? Please estimate the number of working hours for the construction no 119.

Q17: Which activities are mostly transferred into the testing phase even though they should be completed during the outfitting phase? The question applies to similar projects also.

Q18: Are you expecting any delays from the outfitting phase to the testing phase regarding the construction no. 119?

Q 19:Do you keep any statistics about the reasons for delays/ uncompleted activities?

Q20: What measures are taken in order to complete the carried over activities in parallel with the work which is already planed for a specific phase? Are you keeping a record of these measures?

Q 21: Which are the negative effects expected to appear due to carried over activities and its extra load on the workers?

Q 22: Who has the main responsibility for managing the carried over activities and their replanning? Is this a person or group responsibility? Who gets involved if this is a group responsibility?

Q 23: Which are the most critical bottlenecks in the production process?

a) The working force
b) The necessary machines
c) The suppliers' delivery of A- components
d) The display of the shipyard
e) The technical support
f) The flow of communication
g) Others.

Q 24: How many hours are necessary in order to identify and check all the carried over activities?

Q 25: How and how early is the shipyard informed about the coming problems? What does the shipyard do in order to avoid repetition of the same problems over and over again?

Q26: Do you have any available statistics about all the extra-hours used to complete the carried over activities?

Q 27: Can you identify the three biggest challenges for your department?

Q 28: Which are the three biggest problems of the production process?

Q 29: Can you identify waste in the production process you are coordinating? Like:

a) Waiting..
b) Transport.
c) Unnecessary work.
d) Unnecessary material handling.
e) Unnecessary motions.
f) Overproduction.
g) Defects (redo activities)..

Q 30: What do you think about the Project Management tools used by your planning system? Can they be improved?

Q 31: Where do you see most waste in the building process?

Q 32: Which are the most critical bottlenecks in the planning system?

a) Technical support
b) Workforce
c) Working tools
d) Materials

e) All the ongoing work to be completed
f) External relationships

Q 33: Are there any statistics about all the hours used to get in time with the transferred or carried over activities?

Q 34: Are there any activities difficult to replan? We think about the activities which were not completed in the normal allocated time?

Q 35: Do you have any statistics about the reasons for delays from the Romanian shipyard? Is it difficult to get the necessary information from the Romanian side?

Q 36: How many hours do you use to replan the transferred or carried over activities?

Q 37: Is it easy to communicate your plans or ideas to your co-workers?

Q 38: Which are the three biggest challenges (problems) in your work?

Q 39: What do you think about the information flow between you and the foremen from the other departments?

Q 40: Is it difficult to keep track of all the details which need to be changed during the process of building a ship?

Q 41: Can you give as some estimation of the hours spent by your team to redo or complete the last minute changes in the project's details?

Q 42: How and how fast are you informed about the activities to be redone or completed?

Q 43: Is it difficult to cooperate with the technical department at Tulcea?

Q44: State the three major challenges in the relationships with the suppliers.

Q45: Are you experiencing the so called sister-ship effect for this project in your department?

Data from the Production schedules

The data are presented with the informative purpose due to the fact that we are not allowed to attach the original.

	Completed (C) and non-completed (NC) percentages						
		Maersk 1st		Maersk 2nd		Maersk 3rd	
ID	Task Name	C	NC	C	NC	C	NC
1	**VS 472 AHTS-N362, N363, N364**	**95**	**5**	**91**	**9**	**84**	**16**
2	**Fabrication**	95	5	91	9	84	16
3	**Fabrication of BLOCK 1**	98	2	95	5	90	10
4	Manufacturing of hull units BLOCK 1	100	0	100	0	100	0
5	Assemblage of Hull Units BLOCK 1	100	0	100	0	100	0
6	Assemblage of BLOCK 1	100	0	98	2	98	2
7	Manufacturing of secondary steel works Block 1	100	0	99	1	99	1
8	Mounting of secondary steel works BLOCK 1	91	9	98	2	89	11
9	Manufacturing of Pining BLOCK 1	99	1	100	0	99	1
10	Mounting of Piping Block 1	99	1	96	4	87	13
11	Ftd. Steel Remd. Tight ness test BLOCK 1	96	4	99	1	90	10
12	Blasting and painting of BLOCK 1	88	12	63	37	33	67
13	**Fabrication of BLOCK 2**	97	3	95	5	92	8
14	Manufacturing of hull units BLOCK 2	100	0	100	0	100	0
15	Assemblage of Hull Units BLOCK 2	100	0	100	0	100	0
16	Assembling of BLOCK 2	100	0	98	2	95	5
17	Manufacturing of secondary steel works Block 2	97	3	88	12	89	11
18	Mounting of secondary steel works BLOCK 2	93	7	96	4	92	8
19	Manufacturing of Pining BLOCK 2	99	1	100	0	99	1
20	Mounting of Piping BLOCK 2	99	1	98	2	97	3
21	Ftd. Steel Remd. Tight ness test BLOCK 2	100	0	100	0	91	9
22	Blasting and painting of BLOCK 2	86	14	74	26	50	50
23	**Fabrication BLOCK 3**	98	2	89	11	86	14
24	Manufacturing of hull units BLOCK 3	100	0	100	0	100	0
25	Assemblage of Hull Units BLOCK 3	100	0	100	0	100	0
26	Assembling of BLOCK 3	100	0	98	2	98	2
27	Manufacturing of secondary steel works Block 3	100	0	100	0	99	1
28	Mounting of secondary steel works BLOCK 3	89	11	77	23	85	15
29	Manufacturing of Pining BLOCK 3	100	0	99	1	99	1
30	Mounting of Piping BLOCK 3	99	1	99	1	99	1
31	Ftd. Steel Remd. Tight ness test BLOCK 3	100	0	98	2	100	0
32	Blasting and painting of BLOCK 3	91	9	43	57	19	81

33	**Fabrication of Independent Units**	95	5	98	2	89	11
34	Manufacturing of Independent Units	100	0	100	0	100	0
35	Assemblage Units of Independent Units	100	0	100	0	100	0
36	Assemblage of Independent Units	100	0	100	0	100	0
37	Ftd. Steel Remed - Independent Units	100	0	100	0	100	0
38	Blasting and Painting of Independent Units	70	30	84	16	0	100
39	**Fabrication of BLOCK 4 (Superstructure)**	95	5	91	9	82	18
40	Manufacturing of hull units BLOCK 4	100	0	100	0	100	0
41	Assemblage of Hull Units BLOCK 4	100	0	100	0	100	0
42	Assembling of BLOCK 4 (Superstructure)	95	5	87	13	84	16
43	Manufacturing of secondary steel works Block 4	99	1	99	1	99	1
44	Mounting of secondary steel works BLOCK 4	88	12	77	23	75	25
45	Manufacturing of Piping Block 4	100	0	98	2	99	1
46	Mounting of Piping BLOCK 4	98	2	73	27	89	11
47	Ftd. Steel Remed - BLOCK 4	100	0	100	0	100	0
48	Blasting and painting of BLOCK 4	76	24	88	12	0	100
49	**Mounting of Hull and Superstructure**	99	1	88	12	13	87
50	BLOCK 2 + BLOCK 1, Mounting of Hull & Superstructure	100	0	95	5	0	100
51	BLOCK 3 + BLOCK 2, Mounting of Hull & Superstructure	100	0	100	0	0	100
52	Mounting Independent Units, Mounting of Hull & Superstructure	99	1	87	13	11	89
53	U (401-404) + U (322 +323+324), Mounting of hull & Superstructure	100	0	100	0	50	50
54	U (501+ 601) + U (403 + 404), Mounting of Hull & Superstructure	100	0	0	100	0	100
55	**Mechanical Works (Propulsion System)**	89	11	49	51	35	65
56	**Alternative Mechanical Works**	63	37	40	60	3	97
57	**Electrical Works**	80	20	97	3	88	12
58	**Final Painting**	18	82	9	91	0	100
59	**Launching**	0	100	0	100	0	100
60	**Delivery**	0	100	0	100	0	100