Project Analysis of Installation of Chilled Water System on Trenching Support Vessel

Ioannis Laskos

Master's thesis
November 2024
Master's Degree in Professional Project Management

jamk | Jyväskylän ammattikorkeakoulu
University of Applied Sciences

jamk

Description

Laskos Ioannis

Project Analysis of Installation of Chilled Water System on Trenching Support Vessel

Jyväskylä: Jamk University of Applied Sciences, November 2024, 101 pages.

Degree Programme in Professional Project Management. Master's thesis.

Permission for open access publication: Yes

Language of publication: English

Abstract

Shipping is one of the most important sectors of the global economy. However, shipping is also strongly correlated with crucial issues of world society like environmental ones. A number of projects in marine sector are completed every year. Those projects include both newbuildings or modification of the existed vessels. Both projects must be driven by existed economical conditions, enviromental requirements and technological capabilities. This thesis is focused on the vessel's modification projects. Because of the special nature of this type of projects, it was considered very important to describe and analyze their special characteristics that differentiate them for the rest of the constructional projects.

For this reason, there was an emphasis on presentation of 3 tools, used for the effective management of this type of projects, as well as a proposal for implementation of machine learning technology for creating a decision support tool in vessel's modification projects.

The implementation of the particular research started with the review of bibliography about subjects like constructions' project management, shipyard manufacturing processes and machine learning technology.

The next stages included the implementation of a qualitative & quantitative methods' mixture for the collection and analysis so as to proceed in the objectives' accomplishment of this research.

The results of this research effort are presented by a mixture of matrices, graphs and text for the presentation of the project evaluation indicators and machine learning programming code respectively. Hopefully, the conclusions of this report will be useful for creating a marine project management mentality to employees of shipping and marine sector and giving an important starting point for researchers, that are interested in subjects of machine learning implementation in project management.

Keywords/tags (subjects)

Marine modification projects, marine sector projects, project management in shipping sector, machine learning in project management, project management tools, prediction applications of machine learning technology.

Miscellaneous (Confidential information)

Not included.

Contents

1 Introduction

Marine vessel's modifications projects are some of the more usual manufacturing/constructional projects. Generally, the marine vessel projects are quite different from other projects, because of the involvement of a number of strict stakeholders, other than the final customer. Particularly, as extra stakeholders that are included directly in the procedure of project management in relation to other projects, are shipyard representatives (where the works of modification take place), class society representative and the respective factors that accompany them, it makes the procedures of project management more complicated.

Nowadays, the shipping sector globally includes about 120000 merchant ships with mean age of 27years. The lowest percentage of it, are less than 4 years old, but the 68% percentage of merchant ships are over 15 years old. Despite the fact that many new vessels are built every year, an essential percentage of the works on shipyards, are focused on modification of a vessel, meaning that one or more mechanical systems of it, are modified. This happen either for reasons like upgrade of a vessel's system with one of modern technology and higher efficiency, because of new regulation of International Maritime Organization, that restricts the operation of the old system and demands the operation of another with different specification(technologically higher or simply different), or because of any change in existing operation plan of the vessel (change of load type transported or the load transport destinations to be covered). Taking this into consideration, it is not needed to mention how crucial is the role of the vessel's modification projects (especially on merchant ships) on the global shipyard/ship manufacturing sector. However, the vessel modification projects include some special factors, that make the optimization of the project a survival prerequisite.

Firstly, the scheduling of the project is very strict because of two main reasons. The first reason is that a repairing placement on a shipyards and especially a drydocking tank (if it is necessary on some projects) are reserved for a specific date range with significantly high cost. Any deviation from the initial scheduling plan of the project, means extra cost for hiring the repairing or dry docking placement more days than budgeted. Even worse there may are cases of conflict between the required days for the completion of the works and the availability of the dry docking placement, as the shipyard has reserved the placement for another ship during the additional non-initially scheduled days required. The second effect of mis-scheduling of such a project, is the extra

loss of profits of the shipping company, which is the final customer, because of the extra out of operation days, that the ship should remain.

A second factor that makes vessel's modification project to need a special handling, is a technical one. Because of the fact that the project is to apply some modifications on the vessels, it is unavoidable to appear some extra restrictions to the project in relation to the new buildings. These extra restrictions examples are for instance the place of other already installed systems of the ships (that are not going to be removed), or limitation of hatches, that restricts the space required for installation and space/path required for transferring the new system to the final installation position. Such a problem is not dealt with in new building projects, as the installation of the various subsystems of the vessel and the existence of required transferring paths is pre-scheduled, increasing the simplicity of the works.

Considering all the above, it is crucial to be created a research work, like the one of this thesis, to cover the need of project analysis of vessel's modification projects, taking into account all the special factors that it includes and can be underestimated, if the project is dealt with the regular project management practices, that are followed in land constructional projects. Additionally, to prevent the problem of low efficient management of such a project and the consequences of that, a project management tool must be created, specialized on the particular type of projects. Finally, as the AI and Machine Learning occupies a very important role in the increase of efficiency of any every day and professional duty, it worths to research the way it can help the accomplishment of projects, like that in an optimum way. Most importantly, cosidering how the special factors of the particular type of project, that are already mentioned (like the fast change of regulations issued by the IMO, the role of the shipyard and the strict reservation schedule of it, the pressure of the final customer to the project team as a result of the significant effect of a potential delay of the project to the economical survival of their shipping company, the strong role of authorities like Class Society surveyors), make the project of modification of marine vessels significantly complicated, in relation to the other projects of land. The particular thesis focuses on analysing project case of a manufacturing company of Air Conditioning and Refrigeration Units in marine sector. However, in most of cases the A/C and refrigeration systems have an auxiliary role on the operation of the vessel.

To make matter worse, there are other systems of ship that have a main role on the operation of the vessel like generator engines, steering gear, safety and firefighting systems, where the accomplishment of a modification project applied on them, becomes even more complicated, as the special factors mentioned previously becomes even more complicated. For all the above, it is obvious that marine systems' modification projects require a special management as case studies different from the regular projects developed on land.

Most importantly, by professionals involved on marine projects, it had been recognized the need for developing a standardized management procedure for projects of this family, so as to avoid deviations in time, cost and quality from the planned values. Taking into account the opinon of the professionals of the marine technology sector, it is intersting to proceed on such a research work, so as to be analyzed a marine modification project (the installation of a new chiller unit), to be developed a methodology for handling this specific type of projects and be designed a management tool for increasing the efficiency of future ship modification projects. At this moment, the scientific work in the subject of management of constructional projects is on a sufficient level. However, even if the principles of project management on the regular constructional projects are on detail analyzed in various research works, none of them matches on the special type of ships' modification projects, and none of these takes into account the special conditions and crucial factors that exist and effect on the success of projects, like the one which the particular thesis research is going to focus on.

Despite the fact that, this thesis is applied on the analysis of a particular case, which is the installation and manufacturing of a water chiller unit on a trenching support vessel, the goal is the conclusion from this analysis to lead in the development of a standardized project management procedure, applicable to any ship's subsystem modification project. Moreover, another product of the case analysis of the 'installation and manufacturing of water chiller unit on a trenching support vessel' subject, is the development of a project management tool, ideal for monitoring and controlling of marine sector's projects. Finally, taking into account the continuously upgraded role of AI and Machine Learning on solving a wide variety of problems, this research will make an effort to describe how the data collected and results extracted from the case analysis of the chiller unit, can be used as training set for creation of a prediction tool of the most important project efficiency indicators, used as decision support and planing tool for future similar projects. This final

goal of this thesis to connect the project management principles with machine learning implementation, is an extra qualification, that differentiates the particular research thesis from the currently existing scientific works.

2 Development objectives and research questions

2.1 Research Problem

The shipping sector is one of the most rapidly changing sectors of the global economy. As it is correlated with the transportation of final goods and raw material around the world, it is strongly bi-directionally connected with the prices of them and the economic efficiency of the respective manufacturing sectors. Except for the essential impact of financial issues, the shipping sector is significantly connected with environmental issues and regulations, that are applied by authorities, so as to deal with any potential environmental problems/issues. Finally, as nowadays we are in a technological evolution period, none of the sectors that are correlated with technical products (like a ship is such one) cannot be non-effected by those fluent conditions.

Considering all the above, the managers of the shipping companies are required to align their fleet to the current global environmental, technological and economic conditions. This can be achieved in 2 ways, either by building new ships or by modifying the ships that they already own. Of course, as it is obvious, the first one can be implemented only in a very small part of the fleet, because of cost and timeline issues.

The second option of modification of a vessel, so as to be aligned with the maritime regulations and technological evolution, is the one that is followed in the shipping sector by the vast majority of the fleet managers. However, the realization of vessel's modification project is a very ambitious procedure because of the special circumstances that exist and so make such a project ordinary and look so different to the other types of constructional and technical projects. Characteristics of this type of projects include:

a) The presence of strict neutral stakeholders, like the surveyor of the class society of the vessel. The surveyor is committed to monitor and confirm, that all the regulations under of which the

manufacturing/modification procedure of the vessel must proceed, are followed and indicate extra modification (which are out of the initial scope, budget, and schedule of the main project) of the vessel, in case that the potential works on the ships effects on another subsystem of the vessel. For example, the initial plan of the project may not be applied because of safety structural issues of the vessel, or because a series of piping, not immediate related with the subsystem, must be modified or transferred for safety reasons, as a result of the new conditions that effect on regulations by the presence of the planned to be modified subsystem.

b) The special technical conditions of the project execution. When a new ship is built the construction and assembly flowchart of the various parts/subsystems can be easily created, so as to fulfill the regular order or the works. Many hatches are open and large enough, so that even the larger subsystem can be easily transferred into the ship and be placed to their final position of installation. Piping and wiring, that can be obstacles for the installation procedure, are ordered for installation on the workplan as a work ''downstream'' of the installation of the system. In contrast with this smooth flowchart of works, that can be applied in new buildings, on modifications projects a series of supplementary tasks must be scheduled, because of the fact that this 'smooth flowchart of works is not available anymore. For example, the ship has to be cut so as new hatches to be created and most importantly those ones must be large enough, so as the old equipment to be removed and the new one to be transported into the installation position. Existing equipment that blocks the free transfer of the new equipment, may should be disassembled and get out of the vessel as well. Most importantly, in case that a series of piping is the obstacle of the internal transportation path into the vessel, all that piping must be drained (the fluid transfer included on the piping network is another possible needed duty) cut and removed. Of course, these works as well as the extra works of reassembly of the piping are extra task that can lead to deviation of the planned schedule and budget of the project.

c) In case of an expanded real schedule (not the planned one) of the project, that leads to conflict with the planned schedule of the shipyard, it may result in disappointing KPIs of the project. The shipyard, following its schedule, reserves the 'service tank' required for the works of vessel's modification for a specific time for each of their customers (the shipping companies). In case that a project is out of any margin given to the planned schedule, the next customer (the ship pending to take place in the 'service tank' of the shipyard) has to deal with an essential delay, that under

some cases means loss of profits, cancellation of project, etc. On this case, an existed penalty or a legal appeal can be applied to the shipyard and a domino of consequences can hit the shipyard management and the next customers (shipping companies) that are influenced by this delay condition.

For all the above reasons, it is not unusual for vessels' modification projects either to fail or to be completed with very low final KPIs. This happens because some project teams and managers (less experienced ones) involved in those projects, try to follow the normal project management practices, underestimating crucial special factors and conditions like those previously mentioned. Especially the less experienced personnel with project management duties is usual to follow project management guidance, procedures and practices given to books that are oriented to normal non tricky land constructional projects.This thesis is going to focus on the problem of poor efficient execution of vessel modification projects and offer valuable help for avoidance of those unwanted project completion results.

2.2 Research Questions

The particular thesis is going to answer 2 research questions:

a) What a marine vessel's modification project differs from other constructional projects, and how their project management can be handled?

For answering this research question a review of bibliography and other sources like journals about the project management theory will be done. Secondly, a research about shipyard operations will be made. So, the first stage of project management theory is to review all crucial issues about project management. For this purpose, the thesis includes a description of project management areas, project management phases, procedures and tasks, that should be followed and completed, so as to conclude to a successful completion of the projects as well as a description of the tools and ways that the progress of a project can be monitored and evaluated. By means of the review of shipyards operations, the specific conditions and characteristics of ships manufacturing processes are going to be identified. The analysis of this review is going to indicate why the fundamental project management principles of usual bibliography cannot be used 100%, as a guide for successful management of vessel's modification projects. To make the conclusions more validated,

a case study of management of ‘installation of chilled water system on a trenching support vessel ’ project will be analyzed.

b) Can be developed a standardization of management procedure of vessel’s modification projects for increasing efficiency of execution?

For answering this question, the case study of management of ‘installation of chilled water system on a trenching supports system’ project will be analyzed. The procedure that was followed for all phases of the project, as well as the tools that were used, will be analyzed. The thesis includes the analysis of all the data that should be taken into account, as well as the way that should be collected, documented and maintained, so as the control, monitoring, and evaluation of the project can be achieved. The data provided by these tools as well as the data provided by the various documents of the project, are going to be integrated in a spreadsheet type project management tool. Considering the important role of machine learning nowadays, this thesis makes a proposal of how machine learning can be implemented in the particular project type, so as a powerful project management tool to be created aiming to increase the efficiency of the project’s completion. For this reason, a review of machine learning technology will be done, and a machine learning model will be designed, using the data collected during project’s execution as features of the proposed model.

2.3 Limitations, Scope and Objectives

The scope of this thesis project is to provide valuable knowledge on marine technology and shipping sector’s professionals (especially the less experienced ones), about the way that vessel’s modification projects should be handled, and about the crucial factors that must be taken into account, so as to avoid the possibility of project failure or poorly efficient execution. Additionally, the scope is exempt for providing knowledge, to provide a complete(integrated) project management tool and create the circumstances for further research trial, focused on the development of a machine learning based, project management decision support tool. The objectives of this thesis are:

a) Review of the current bibliography of project management theory.
b) Identification of the special conditions and factors of vessel’s modifications projects, that must

be taken into account by the project's responsible persons, so as to avoid low efficient execution or failure risk of the project.

c) Project analysis of an 'installation of chilled water system on a trenching support vessel project, so as to validate the knowledge provided by (a) & (b) objectives, as well as to make clear on marine technology sector's professionals, the way that vessel's modification projects are differentiated by regular technical projects.

d) The integration of the various project management tools (time scheduling control, cost management, quality management tool), used during the progressing of 'installation of chilled water system on a trenching support vessel project so as to create a central management tool.

e) Description and analysis of the way that machine learning technology can be used to project management, and proposal of a machine learning model, specialized for marine projects.

Regarding the limitations of the particular thesis, we would like to mention that by means of the review of the bibliography about the project management theory and principles, and review of the shipyards' operations, they are made some conclusions about the special characteristics of marine vessel's modification projects, that main project management theory and guidelines are unable to cover. One of the objectives of this essay is the development of a management procedure for this special type of projects. For the development of such a standard procedure, the conclusions of the theory review as well as the case study of water chiller unit installation on a vessel were used. Because of the fact that the practical example used is only one, it is may expected a modification of the procedure, when extra practical cases are researched. Additionally, as we have already mentioned, an essential factor on these projects, is the operations of the shipyard as well as the scheduling of the shipyard. Because of the privacy reason (as the complete shipyard's schedule includes information of other customers), useful information about shipyard's schedule are not available to for this thesis and so both the standardized procedure, as well as the proposed machine learning model are not going to focus on this factor (shipyard's schedule) or give it a higher weight on it. Finally, as we have already mentioned, the accuracy of the data recorded in the phase of works execution onboard is limited, because of the fact that all those information are recorded, and provided by the technical staff manually to the project engineer (who actually is the author of this essay), and so may some data cannot be double validated, as it could happen with a reliably spontaneous monitoring and data recording system (like Epoptia software installed in production department of Psyctotherm). All these limitations may have an effect on the final result and conclusion of the thesis.

2.4 Company / Research Environment

The content of the thesis is divided in a review part of the bibliography, where a review of research about the project management takes place, and a practical part, where it is focused on the analysis of a real vessel's modification project. During the second part, the phases of the project are described, the stakeholders and the cornerstones of the project are indicated and the execution procedures, as well as the control and evaluation practices are analyzed.

As the project that will be used as an example of marine vessel modification type one, is the 'installation of chilled water system on a trenching support vessel', it is essential to signify the environment and conditions that this project takes place, as it is actually the research environment of the thesis project. Most importantly, we would like to mention that the execution phase of the project, takes place in two different places. The first part of the execution of the project, include the manufacturing of the unit to the production facilities of the chiller unit's manufacturer and the second one is the installation of the unit onto the ship, and the required complimentary works of piping and wiring connections that of course are executed onboard.

So, the first environment, the industrial facilities of Psyctotherm, is a space, conditions of which are easily controllable, and parameters crucial to be monitored, are easily monitored. Tools like Epoptia, which is a time control and production line monitoring tool that Psyctotherm uses, gives the advantage of precise delivery time measurements of the separated manufacturing stages, and the fact that this execution part takes place into a close environment, makes the supply chain control and quality control even easier. Additionally, the ERP software that Psyctotherm is equipped with can be used as a reliable supply chain and material cost control tool. So, the evaluation section that refers to the manufacturing stage of the unit, is obviously very precise and is expected that any KPIs regarding this stage are going to be very reliable. On the other hand, the environment of the second level of project's execution, the space of the trenching support vessel, is quite complicated. Lack of an electronic works monitoring system (like Epoptia) and the fact that supply chain cannot be fully controllable, makes the control of time and cost less manageable. For example, the monitoring or the completion of the different stages of execution, is based on the records of the responsible supervisors of the technical team, and the documentation, (where information about objectives delivery times and quality problems recorded), that is filled in by them, after the

end of each working day. Taking this into account, is expected that any KPI of the chiller unit installation process onboard, will be less reliable. All mentioned above should be taken into account for the final results and the conclusion of thesis regarding the evaluation of the project.

2.5 Information Retrieval and Source Material

As it is already clear that the particular thesis consists of 2 parts. Part 1 is the theoretical part, in which a review of the theory about project management principles, and a review of machine learning technology takes place. Part 2 is the practical component of research, where the analysis of 'installation of chilled water system on a trenching support vessel' project is executed.

So, because of the nature of the first part, the information must be used, is actually research and theories, derived by other researchers on the past. For this reason, the sources that the report is focused on includes: a) Books about the whole project management concept and issues. b) Articles edited on scientific journals about the implementation of project management principles, techniques, methods and tools in the industrial and constructional sector. c) Books and articles about fundamental shipyard works and operational principles. d) Books dedicated to machine learning theories and implementation practices of them. e) Scientific articles about the implementation of machine learning technology in constructional projects and impact of the former to the latter. The precise sources of all information are indicated through all the essay's context by means of APA style citation and the relevant reference list at the end of this essay.

For retrieving such information, they were used University's library web research for books, and Janet web platform for research papers. The methodology of the information retrieval included:

a) Search on the mentioned sources, using keywords relevant to the research subject of the thesis.
b) Finding the potentially useful sources.
c) Study and extraction of essential information from the relevant sources.
d) Analyzing, processing the information and deriving a more condensed, and efficient form of it, for using on this thesis.

Regarding the second part of the thesis, the procedure is actually a creating new information one. As, this part is dedicated to the project execution of 'installation of chilled water system on a

trenching support vessel ', aiming to make conclusions about general ship's modification process, it is unavoidable not to focus on the primary data. So, on this part of the project thesis the evaluation and process and analysis of the data must be on a high level. The data necessary on the practical part of the thesis are those required by a regular project management procedure, like data about human resources, time, cost, quality and risks.

Human resources data: It's about the number of technical staff involved in the project (including subcontractors), as well as information about the capacity of them (qualifications, professional abilities, etc.). This information is extracted from the operational chart of the manufacturing company (Psyctotherm), working days schedule document (Psyctotherm's document about technical staff working and off working days).

Time scheduling data: Includes data about the time (man-hours) required for the execution of the project, according to the project plan, as well as data about the actual time arrangement for completion of the various project tasks(actual delivery time of each task)(Project Management Institute, 2004). The retrieval of the particular information is achieved by project tasks arrangement document (describes the tasks required for the execution of the project and the needed working man-hours of them), project flow chart, project scheduling chart(Gantt chart) , Psyctotherm's production manager weekly reports, Epoptia software, daily reports of technical staff's representative onboard (the leader of the technical group for installing the manufactured chiller unit onto the ship).

Cost data: For cost management of the project, information about the working costs, as well as the material cost of the chiller unit's manufacturing and installation must be taken. For this purpose, a series of documents have to be used, among which, are bill of materials, weekly Psyctotherm's production manager report, salary list of technical staff, invoices of materials' suppliers and subcontractors, daily reports of technical staff representative onboard. All the data included on those documents are evaluated and analyzed, so as the essential information to be retrieved and recorded on the ENTERSOFT ERP software for easy handling and further analysis.

Quality data: Data of this category are needed for the project quality management procedures of the chiller manufacturing and installation project. Quality issues include the conservation of the

quality standards of the manufacturer during the manufacturing process of the refrigeration unit, the confirmation that specification of the final product is aligned with the designed specification and the rules and specifications required by the class society of the ship, the installation process and most importantly the test of the new system during the commissioning procedure, has the necessary and satisfactory results(Project Management Institute, 2004). For this purpose, the group of data necessary for the project quality management are collected: a) By the quality control forms filled in, during the manufacturing process. b) Daily reports of the technical staff's representative onboard, during the installation process. c) By the test reports made to the factory of Psyctotherm and onboard, accompanied with the commissioning of the new chiller system. d) The supervision reports written by the class society surveyor, after any quality control made by him/her (American Bureau of Shipping, 2018). All those data, are also uploaded and handled on the Engineering Manager platform of the class society, where all project stakeholders have access and so receive valuable information about the quality control status of the project.

3 Theoretic-conceptual points of departure for the research question no 1

3.1 Project Management Areas

For the successful execution of a project, a group of processes must be accomplished. The range of the processes covers works from initial planning to delivery of the project. Particularly, according to project management theory, a regular project consists of 44 project management processes. Actually, especially in case of complex projects, the accomplishment of such one, is based on the completion of a group of objectives (Project Management Institute, 2004). So, project management processes coordinate the way that the respective objectives can be achieved. Depending on the phase of the project that they are implemented, processes can be grouped in 5 distinct groups(Project Management Institute, 2004): as shown below:

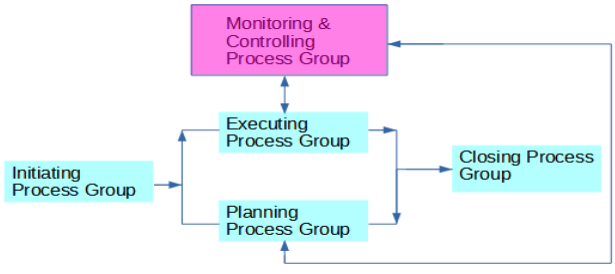

Figure 1. Project management process groups

Additionally, depending on the type and the nature of each process, they can be accumulated and divided in 9 project management knowledge areas as illustrated below (Project Management Institute, 2004).

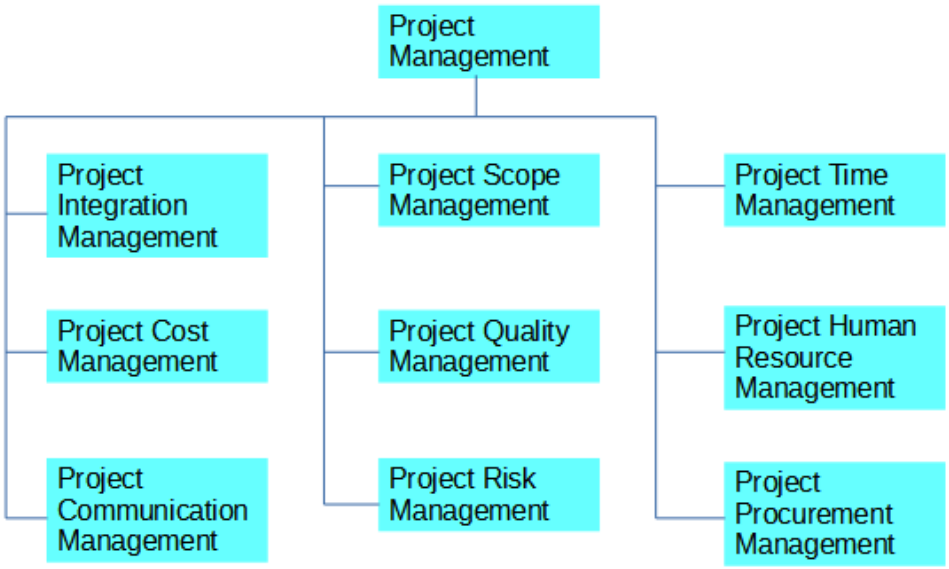

Figure 2. Project management knowledge areas

3.2 Project Management Stakeholders

Stakeholders of a project are defined as the individuals or organizations that are involved to the evolution process of a project (Project Management Institute, 2004). The interest of stakeholders on a project can effect on the result of a project and on the oposite way, the result of a project can effect on the stakeholders' benefits. They have a positive influence on a project, in case that they benefit of a successful completion of a project and a negative one, in case that they desire the fail of a project. So, it is crucial for the final project result, the fact that a project management team is able to identify the stakeholders, rank their importance, and recognise their interests, needs and project objectives that they desire. An inefficient identification of all the above, can result to essential project change requirements, during the project proceeding or total fail of a project (Project Management Institute, 2004). The most common stakeholders in project are:

-Project Manager

-Customer

-Performing Organization

-Project Team Members

-Project Management Team

-Sponsor

-Influencers

-Authorities

3.3 Project Management Processes

For better management of the projects, they are divided in phases. The phases of a project are known as project life cycle. The phases of a project are divided in 3 groups.

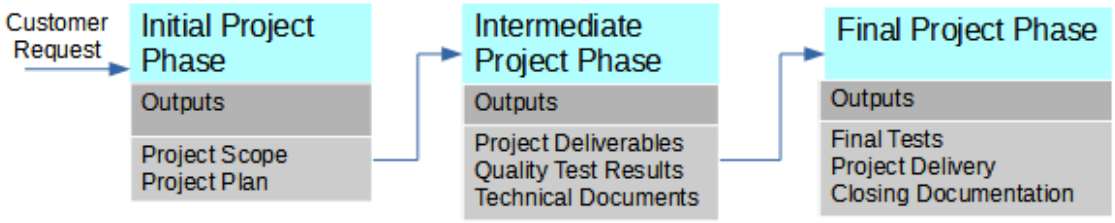

Figure 3. Project phases

The project cycle represents the connection of processes included on each phase, from the start of a project to the end of it (Project Management Institute, 2004). The structure of the life cycle is such one that the objectives and deliverables of one phase are used as inputs on the following phase. In many cases, each phase can be administrated as seperate subproject, as it must include tasks of planning, execution and control/monitoring for the defined objectives/deliverables. The distrubution of resources and the flexibility of changes during the evolution of project phases, is common to all construction projects independently of the type and the industrial sector of it. Particularly, the pattern that cost baseline and human resources needs to follows is such one that, it starts with low level requirements(initial phase), progressively increases during the intermediate phases, where it reaches the top requirement level and dramatical drop to low values passing through the final phase (Project Management Institute, 2004).

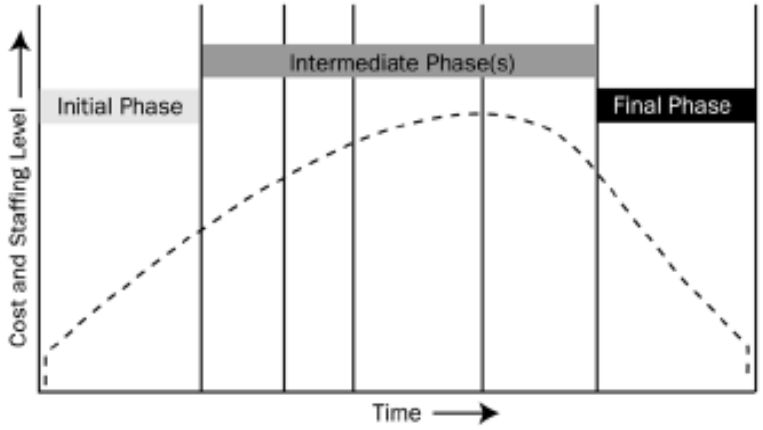

Figure 4.Cost baseline Distribution (adapted from Project Management Institute, 2004)

Regarding, the flexibility of modifying project's requirements, specifications, objectives and scope, is limited without trading off the initial budget. The cost of potetial changes follows a pure increasing trend as the time passes. On the other hand, the various stakeholders of the project are able to influence on the cornerstones of it, like specifications, objectives and deliverables, but such an ability is gradually decreased, as the proceeding time of the project is spent(Project Management Institute, 2004).

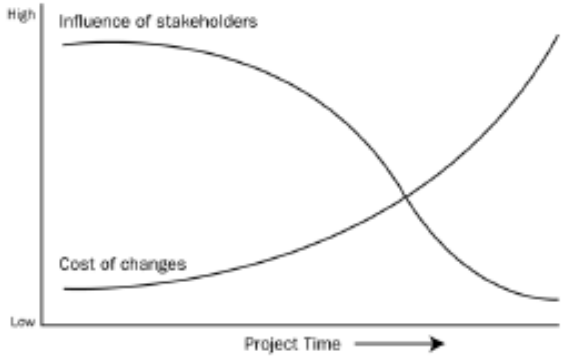

Figure 5. Time line of changes'cost (adapted from Project Management Institute, 2004)

During each phase of a project, a number of processes take place. The various processes are integrated, under the application of project management integration process. In some way, all processes are connected with the upstream and downstream one, so as the inputs of each one are the deliverables of the former and deliverbles of each one are inputs of the latter. Such integration requires that all processes are appropriately contected and aligned each other, so as

the project's cornerstones like planned scope, budget, specification, time schedule and objectives to be idetical with the actual one. However, it usually does not happen, and deviation to some or all these cornerstones does appear.

Despite the fact that, for simplicity reasons a rough image of processes connection is the one of linear form connection between some descrite elements, in reality, the connection is much more complicated with some processes to be overlaping with others and some of them to be iterated many times, during the maturity of the project(Project Management Institute, 2004). As a result of this interconnection, a potential change in a process, has an impact on at least one cornerstone of the project(cost ,time, specification,etc), and so one or more other processes are going to be modified, so as gain to be condinated with the new conditions. For better categorization of the processes, project management principles divide the processes based on the nature, as well as the purpose that they serve on the accomplishment of the project's objectives (Project Management Institute, 2004). The main groups used for this reason are: Initiating Process Group, Planning Process Group, Executing Process Group, Monitoring & Controlling Process Group, Closing Process Group (Project Management Institute, 2004).

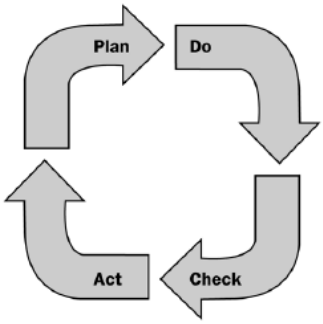

Figure 6. Closed loop project managment (adapted from Project Management Institute, 2004)

The main concept, fundanmental for the successful implemention of a project management theories, is the flowchart Plan-Do-Check-Act, as shown above and actually it depicts the interaction of the project processes. The Planning Process Group is represented by the Plan element of the flowchart. The Executing Process Group is represented by the Do node. The Monitoring & Control Process Group is designed as the Check and Act (taking the corrective actions) nodes respectively (Neeraj, 2015). The Initial and Closing Groups are not part of cycle in a scheme as above, but actualy happen one time during the process life cycle. The Initiating Group

acts at the start of the project, in a position prior to the Plan node of the first iteration cycle, as the first meeting of the stakeholders takes place, the needs of the customer are recorded and the specification of the project that covers that needs are defined. The Closing Process Group on similar way acts onces at the end of the project life cycle, when the check node of the final iteration cycle is finally sucessful, and so the official project delivery procedures to the customer start (like operational manual writing, contract ducumentation closing, etc.).

3.4 Project Management Tools

As mentioned previously, for an optimal implementation of project management disciplines, and so a high project management efficiency to be achieved, the whole procedure should follow a precise structure divided in 9 project management knowledge areas (Project Management Institute, 2004). Each of these areas aims to achieve particular objectives and deliverables, as a means of succeeding integrated project's objectives and scope. Of course, for a successful process, it is required a set of tools to support them, as happens to any standardized process. For this reason, any of the project management knowledge areas includes a specific set of tools (Project Management Institute, 2004).

3.5 Project Management Evaluation

Project's evaluation is an important part of project management and takes place both during the intermediate phases of a project, as well as at the end of the project development procedure. The former type of evaluation has the role of measuring the performance of the project during evolution stages, so as any deviations from the initial plan to be identified. Following of a possible deviation is taking decisions about any corrective actions (Neeraj, 2015). The later type of evaluation is both assessment of the final project result, so as to confirm that objectives' achievement is complete (or partially complete in a level such that closing phase can signified as complete). This type of evaluation is to predict or justify the feedback of the customer, as well as to make crucial conclusions about the project, that can be used as guideline for similar future projects. As part of the evaluation made at the end of the project can be added the self evaluation of the participants of the project. The proceeding stage project's evaluation actually be coordinated in three main perspectives: cost based evaluation, time based evaluation, quality based evaluation.

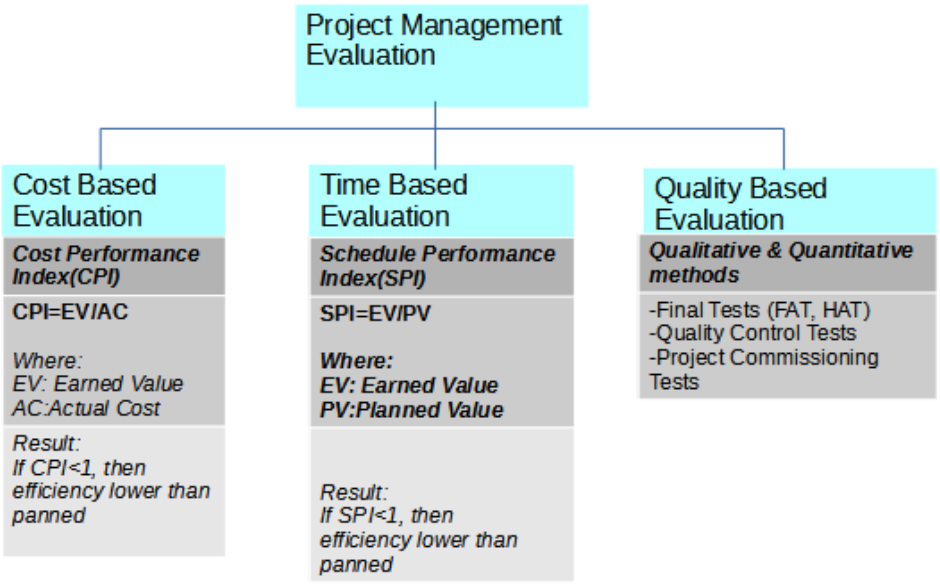

Figure 7. Project evaluation methods

All the method/indicators mentioned above can be used for the final evaluation (in the closing phase) of the project as well, taking into account the values like AC, EV that are used on this case, are those measured at the respective ending stage of the project procedure. Finally, as we mentioned in the start of the chapter, self-evaluation of the participants can take place at the end of the project, either for giving the chance to them to identify what to improve in their behavior and actions in future projects, as well as giving a feedback to the human resources department, so as to implement a training program to the existing staff, or upgrading the staff team with personnel of additional competencies.

4 Theoretic-conceptual points of departure for the research question no 2

4.1 Marine Vessel Modification Procedures

Vessel's modification project is special type of project, because of the special restrictions described in a previous part of this essay. Depending on the type of modification that should be executed, a series of ordinary activities should be followed. However, it is important to give framework of the general implementation procedure, that should be followed. Such a procedure can be decomposed as below:

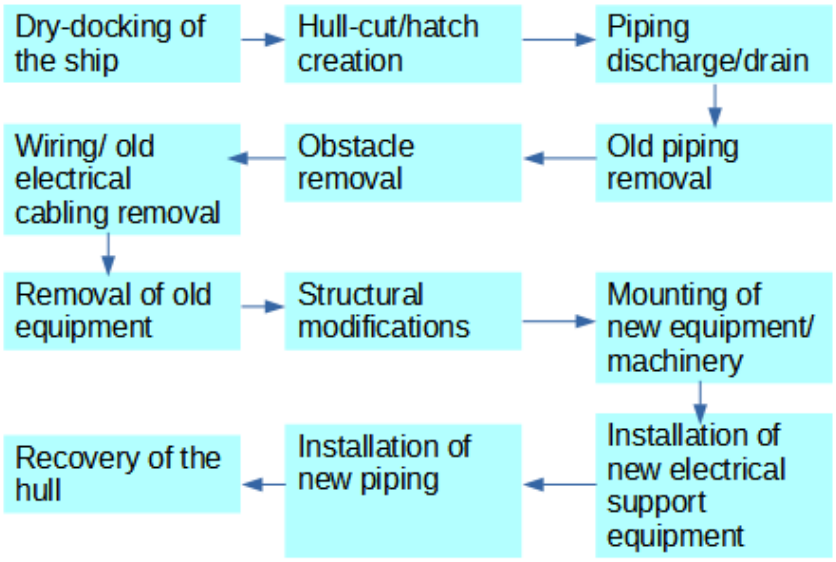

Figure 8. Vessel's modification procedure

4.2 Shipyard Works & Drydocking

The shipyard, where the execution phase of ship modification project takes place, is a factor with definite impact of the scheduling and the cost of completion of such a project, and so it is worth mentioned the structure, as well as the operation framework of the particular stakeholder. Firstly, regarding the operation system of a shipyard can be divided in 6 main sections (Eyres & Bruce, 2012):

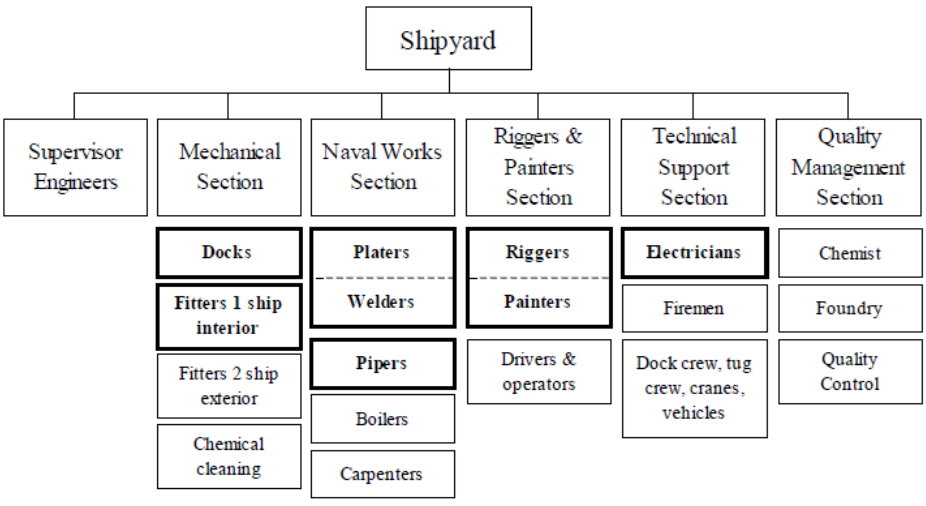

Figure 9. Shipyard workshop structure (adapted from Chryssolouris, 1999)

The operation of the a shipyard is structured in a 4 level hierarchical form (Chryssolouris et al., 1999), as shown below

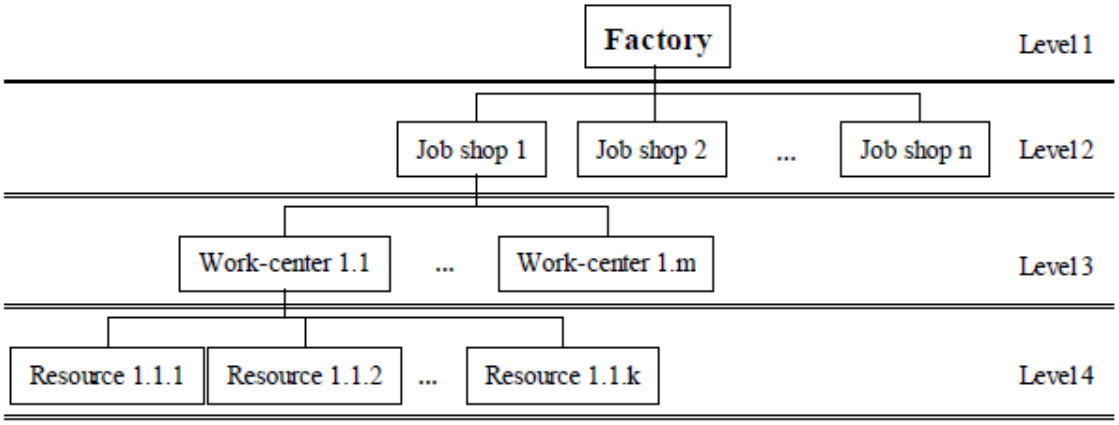

Figure 10. Shipyard operational levels (adapted from Chryssolouris, 1999)

The first level (factory) represents the whole shipyard. The second level describes the various departments of the shipyard, that are responsible for executing a specific family of works. In some way the job shops are the 6 sections of the operatoring system of the shipyard. The capacity of each job shop is divided in a number of sub-units called work centers. Each work center is given to carry out a particular job activity (Eyres & Bruce, 2012). For example two piping technical teams can work in parallel in such a way that one removes old piping and a second one installs the new one. Each work center is on the third level of organization. The last level of the organization is about the allocation of the resources of each work station, so as the job activities of its portfolio to executed. The resources that a shipyard is required to manage are:

Manpower/Human Resources: On this resource group are included the staff of all job shops of the shipyard. The manpower of the shipyard consists of the technical personnel of shipyard's itself, as well as the manpower of the subcontractors the shipyard cooperates with. This resource has the highest flexibility, because in case of poor time performance of a project, the administration of the shipyard can increase the outsourcing percentage of the works (Chryssolouris et al., 1999).

Machinery: This category includes all the machinery used for the accomplishment of the technical works. The level of flexibility is medium, because in case of reservation of some machinery or need for extra machinery capacity, some jobs like sheet metal processing can be outsourced. In other cases like floating drydock reservation, such outsourcing is not available.

Material Resources: This category includes the raw materials and machine components used for the development of the project. The flexibility of this family is also medium, as some common material can be supplied by various suppliers, but some special components that require high level of know how and high delivery time, cannot be substituted by requesting them by many suppliers.

4.3 Ship Classification & Rules

According to IMO regulations, every ship must be aligned with regulations and practices, that assure ship's operation under the optimal conditions for the environment protection, the safety of the crew and the highest profit for the community (American Bureau of Shipping, 2018). For the purpose of monitoring that these regulations and practices are followed by ships that operate legally globally, each nation has created a special authority. Such an authority is known as class society. Any ship must be registered on a class society. Additionally, the registry on class society is for a ship, as a certification and trademark for the shipping company, and takes a role of appealing customers of a shipping company, as the ship's registration on a class society reflects the level of quality of the services that it is able to provide to its customers. As the presence of class society is something that follows a vessel during all its operational life, project development period could not be an exemption. So, class society is a factor in the management of vessel's modification project, that must not be underestimated, and it is one of the most important stakeholders. For making clear the regulations that must conserved by its customers, the class societies have issued a number of regulation editions, depending on the type of the structure to be certified, the part/component of the structure to be certified, and any special group of conditions that is fulfilled to a particular project. In our case of analysis of the project 'installation of chilled water system on a trenching support vessel, the M/V Argo is registered on the American Bureau of Shipping. This authority is one of the main stakeholders in our case of research. The type of the structure is a marine vessel, so the regulations should be conserved are included in the regulations edition named 'Rules for Building and Classing Marine Vessels '. This edition is divided in 6 parts. Each part is focusing on specific vessel's component family, from hull construction and equipment, vessel's systems and machinery, specialized items and system, etc. Each part of the 'Rules for Building and Classing Marine Vessels', is divided in a number of sections. In our case, where the system to be installed is a chiller unit, which is an assistive subsystem of the vessel, the assembly of which includes the construction of water piping and refrigerant piping under pressure, we will focus our

study on the regulations chapters as below(American Bureau of Shipping, 2018):

Part 4- Vessel's systems & Machinery:

a) → Chapter 4-Boilers, Pressure Vessels and Fired Equipment →Section 1- Boilers, Pressure Vessels and Fired Equipment

b) → Chapter 6-Piping Systems→Section 7-Other piping systems

So, all information derived by the text parts above, is a requirement of stakeholder 'Class Society' and will be used as guideline for composing the quality management requirements of the 'installation of chilled water system on a trenching support vessel' project.

4.4 Machine Learning Fundamentals

Machine learning is a science sector that is being developed with tremendous speed, as scientists have identified on this, the ability to solve a variety of problems, that traditionally were difficult to be solved by people, as well as it was found that by means of ML, we are able to exploit the ability of modern information systems to analyze data, so as to classify data or predict various phenomena (Shai & Shai, 2014). The field of ML is about developing a methodology, that can be used to construct new type of self-improving programs, in contrast with the traditional programs, that had to be detailed defined by their programmer in an ' if /case control philosophy'. The concept of ML, known as automated learning (Mitchell,1997), is to develop programs that are able to improve their performance, following an artificial learning process (Mitchell,1997). In any learning process, the experience provided is converted in expertise or knowledge. In a similar way, ML is structured in a way that experience is provided, by means of a set of data, used as input, that results in creation of a program well designed enough to solve a particular problem very effectively. In a generalized form, a computer program is said to learn from experience E, with respect to some class of tasks ***T*** and performance measure P, if its performance at tasks T, as measured by P, improves with experience E (Smola & Vishwavanath, 2008). Key qualifications of machine learning implementation are:

a) Task T: It is the task that is going to be executed by the application of ML.

b) Performance Measure P: It is used to measure the efficiency by which the ML pro gram can execute the task.

c) Experience E: It is the input data used to learn the program to execute a task T with performance P.

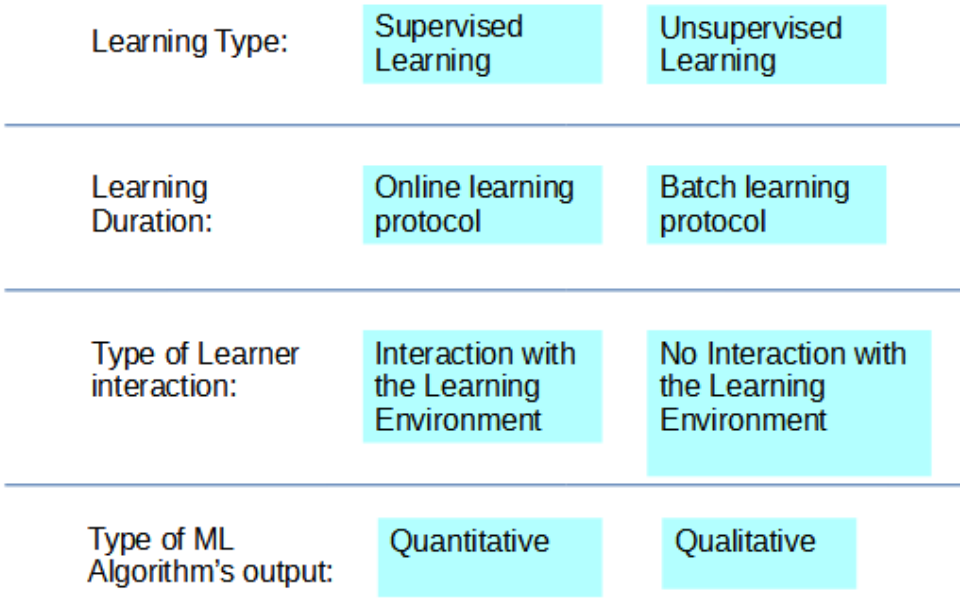

Figure 11. Machine learning algorithms categorization

The supervised learning algorithms are applied to solve classification and regression problems (Mitchell,1997). So, the results of the algorithm can be numerical discrete (transformed in qualitative result) and numerical continuous value respectively) (Smola & Vishwavanath, 2008). Supervised learning is the one that can be used as project management decision support tool and will be analyzed in detail later.

The unsupervised learning algorithms can be used in tasks like clustering, density estimation and dimensional reduction. The first task is used to divide a set of inputs into groups. In contrast with the classification, on the clustering programs, the groups are not known (not pre-defined with labels). The second tasks aims to find the distribution of input data to a space. The third tasks is implemented, in case that the desired result is to map a set of input data, from the original dimension space to a lower-dimension one.

As we have already mentioned the ML technology in project management sector should be implemented using 2 supervised learning forms because a set of information data (collected from various projects completed in the past) will be used as training set. The first purpose is both to find a prediction values about the delivery time and the budget cost at completion. So, for this reason a

regression model should be developed. The second purpose is classify a project, as expected to fail or success, and so a classification model should be developed.

Supervised learning Algorithm

The model development of this type, is achieved by the usage of two predefined datasets the training set and the test set (Shai & Shai, 2014). Each set includes a number of instances. Each instance of the set consists of a number of independent variables, called attributes and one dependent variable which is actually the output (Mitchell,1997). Regarding the training set, the dependent value of each instance is the desired result. The model development starts with the input of training set, with the purpose of finding the suitable parameters, that give the model a sufficient performance (Shai & Shai, 2014). The model's performance is measured by the comparison (calculation of error value) between the output values of the model with the respective dependent values of the test set. In case of poor performance, the model must be reconfigured. One of the most popular prediction supervised learning methods is regression analysis, that is used when the prediction result has continous numerical form. Because of the fact the regression analysis, that is going to be used, is based in more than 4 attibutes, a multiple regression analysis method is used (Muller & Guido, 2017).

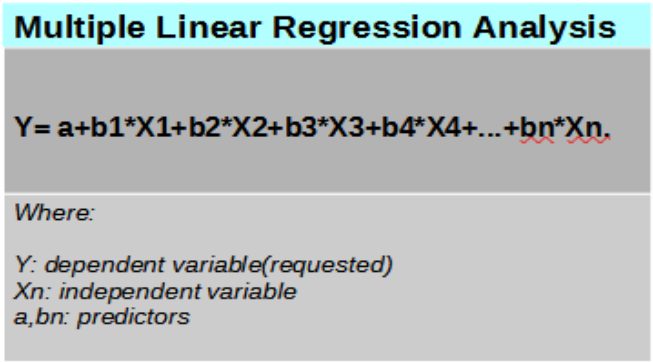

Figure 12. Multiple linear regression algorithm

4.5 Machine Learning Modeling in Project Management

The implementation of Machine Learning in Project Management Area, can have an impact on prediction certainly of cost and schedule of a project. For such a result, ML algorithms can assess and analyses project cost records, project schedule, project change orders and other project information, that can effect on the overall cost(Philip et al., 2023). The ML algorithms, can forecast cost and schedule consequences of a researched project, based on information gathered by similar

projects in the past, and by means of locating patterns and correlations of the investigating project with past ones (Philip et al., 2023).On similar way, the ML can have a contribution on the risk assessment of the project, as events and records on similar past projects, can be used for risk prediction, considering of risk event as well as the probability of occurrence. As we have already mentioned in previous chapter, ML modeling is based on correlation of a requested result values(dependent parameter) with a series of unequally weighted independent values called attributes (Muller & Guido, 2017). So, for the purpose of project management, where 2 result values are searched (cost, delivery time extension) the development of two different ML models is needed.

ML Prediction Models Analysis	
Based on the multiple linear regression formula: **Y= a+b1*X1+b2*X2+b3*X3+b4*X4+...+bn*Xn.** *Where:*	
COST PREDICTION MODEL	***DELIVERY TIME PREDICTION MODEL***
Y: estimated final cost *X1: budget planned cost* *X2: complexity of the project* *X3: age of the ship* *X4: experience ranking of project management team* *X5: type of the subsystem to be modified* *X6: subcontracting works ratio* *X7: competency level of subcontractorst* *a,bn: predictors(derived by the model solution)*	*Y: extension time of delivery* *X1: planned project duration* *X2: complexity of the project* *X3: age of the ship* *X4: experience ranking of project management team* *X5: type of the subsystem to be modified* *X6: subcontracting works ratio* *X7: competency level of subcontractorst* *a,bn: predictors(derived by the model solution)*

Figure 13. ML prediction models

4.6 Machine Learning Development Tools

The main and more usual ML development tool is Python programming language. Python is an object-oriented, high level programming language (Machine Learning Programming Language) (Muller & Guido, 2017). It is very popular, as it combines features from C programming language, like the elegant code of C, and Java, like the classes type of data. Additionally, it is an interpreted language, which means that the source code can be converted in bytecode and executed in a virtual Python machine (Muller & Guido, 2017).

The most important feature of Python, is that it is an open-source language, which means that any user has access to download it and program using it for free. Especially the combination of open

source community's support with the fact that this language is structured in modules, has given Python a huge number of modules, and so a wide variety of programming sectors' implementations. So, by the fact that Python programming language includes data science modules, statistical modules, and function handling modules, have put it in highest place in the most valuable ML programming languages.

The philosophy of the language is to use a combination of modules and specifically the functions included on them, so as to achieve the required programming and calculating result(Muller & Guido, 2017). The modules that should be used during the programming phase, are imported to the virtual Python machine, using the function **import** following by the name of the module to be run. The basic modules that should be should be used for implementation of ML to the management of vessel modifications projects are shown below.

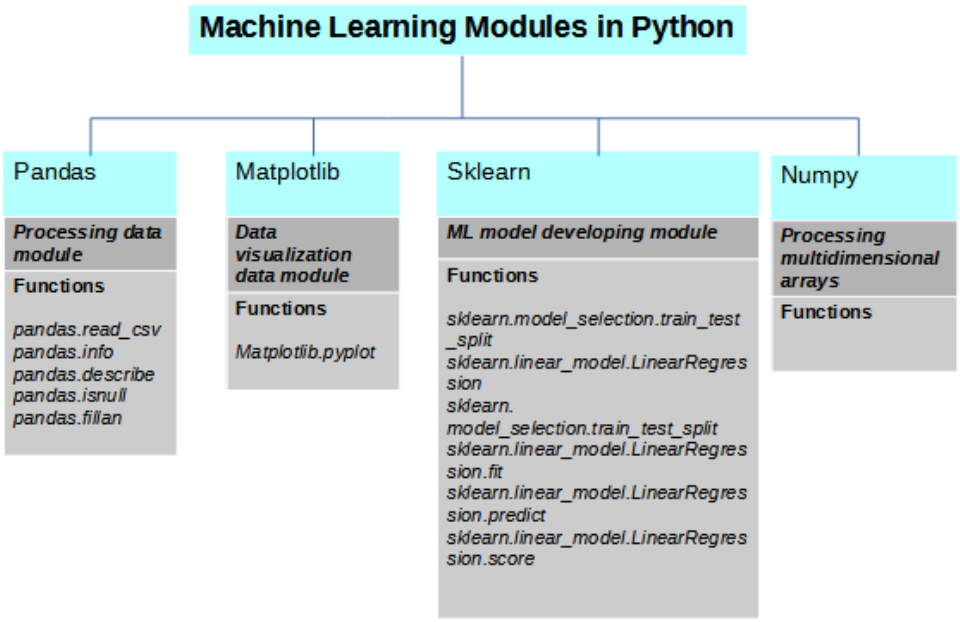

Figure 14. ML implementation functions in Python programming language

5 Implementation

5.1 Method of the development assignment

The methodology that was followed for this essay, can be divided in 4 steps: the study of the subject, the collection of the data, the analysis of the data, the derivation of a group of results and a group of conclusions, based on the results of a data analysis.

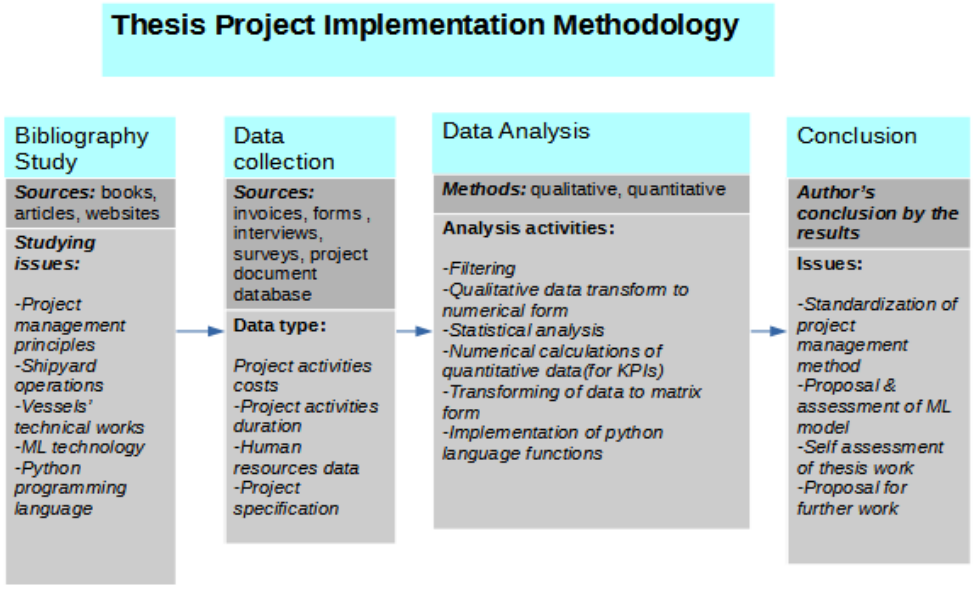

Figure 15. Thesis project methodology framework

5.2 Water Chiller Installation & Manufacturing Project Analysis

As mentioned earlier, this project thesis is based on the ''installation of chilled water system on a trenching support vessel', so as the result of the whole project analysis, to conclude to the general project management procedures must be followed for the vessel's modification projects. So, for better understanding of this essay, we should proceed to the analysis of the real case of the manufacturing and installation of a chiller unit on trenching support vessel.

Scope

The scope of the real technical project, is the installation of a chiller unit on the shipping company's ASSO SUBSEA trenching support vessel, called ARGO, by a well known refrigeration systems manufacturer of Greece, called Psyctotherm. For the scope to be achieved, the final product,which is a refrigeration system to be installed, must be able to cover the special needs of the customer. These needs are covered, if the final product has such dimensions to fit to the available engine

room of the vessel, fulfills the guidelines that all the machinery of its type should comply with according to the ABS class society, and has a specific cooling capacity. Regarding the last one, the subsystems of the vessel require a particular heat load to be rejected, so as to operate safely and effectively according to their manufacturers. The unit to be manufactured, must be able to manage/cover the total sum of these heat loads of the various subsystems, by being able to supply the necessary cooling water to the subsystems of the vessel. By technical angle of view, the specifications that are agreed with the customer, that should be fulfilled, by the product to be delivered, can be summarized as below:

Table 1. Chilled water system specifications

Model	**CU.2.120.SW.D**
Compressor	2 xHANBELL RC2-470B
Power supply	3~690 60Hz
Refrigerant	R134a
Max Cooling Capacity *	2x528.5kW = 1057kW
Absorbed Power at Max Capacity	2x81.9kW = 163.8kW
Min Cooling Capacity (1 compressor at 25% capacity)*	132.2kW
Total heat of Rejection	1220.8kW
Condenser	Sea Water Cooled Shell & Tube
Chiller	Shell & Tube
Control System	Electric Panel with PLC
Dimension	Suitable for Vessel Engine Room

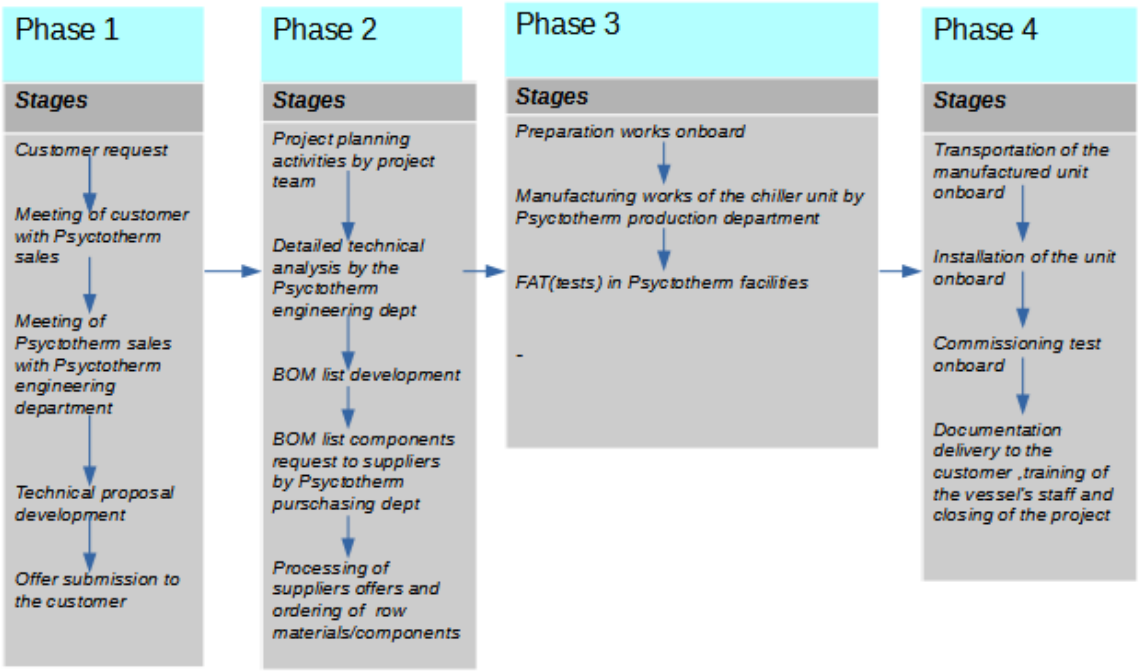

Figure 16. Water chiller installation project phases

Activities of the project

The successful completion of the project, requires a group of activities to be carried out, through the 4 phases of the project. Some of theses activities must be taken over by Psyctotherm, the project administation company, and some others must be outsourced to a number of subcontractors, that Psyctotherm coperates with.

Table 2. Project activities allocation

Activity	Planned Delivery Time(days)	Operator of Activity
Initial Design	4	Psyctotherm
Project Management Planning	6	Psyctotherm
Detailed Design	12	Psyctotherm
Inspection of Vessel by Technical Department	2	Psyctotherm
Derive Specification and BOM list	8	Psyctotherm
Procurement of Compressor by Supplier	63	Psyctotherm
Procurement of Electrical Components	10	Psyctotherm
Development of Electric Panel	12	Subcontractor
Construction of Chiller Unit Frame	10	Subcontractor
Manufacturing of Piping Components	4	Psyctotherm
Assembly of the system components on base and brazing of piping	15	Psyctotherm
Installation of Instrumentation	3	Psyctotherm
Wiring of Electric Panel with Components	5	Subcontractor
Pressure Test of Refrigeration Piping	2	Psyctotherm
Charging of the System with Refrigerant	1	Psyctotherm
Factory Test of Complete Chiller Unit	1	Psyctotherm
Transport of the Chiller Unit	3	Subcontractor
Mounting of the Chiller Unit to Vessel's Foundation	2	Psyctotherm
Water Piping Connection of the Chiller Unit to the Vessel's Water Network	3	Subcontractor
Water Piping Connections Test	1	Subcontractor
Electrical Connections of the Unit to the Vessel's Power Supply	4	Subcontractor
Final Test and Commissioning of the Chiller System	2	Psyctotherm

The necessary project activities are:

Human resource planning of the project: The required human resources capacity is calcualted, taking into account the competency needs of the personnel involved in the projects, as well as the workload needs that are derived by the planned delivery time of the project. Additionally, through this activity the various work activies are allocated between Psyctotherm and its subcontractors.

Time scheduling of the project: As a continue to the logical connection of the technical activities, the workload of each activity and the human resources available to each technical work are used, so as the time schedule of project execution to be created.

Risk assessment process of the project: On this activity, the various risks on the project are

identified, as well as the severity of their consequences and the frequency/possibility of appearance is calculated.

Budget planning of the project: Based on the workload of each technical work of the project, the labor cost of the project are calculated. The material and components cost of the project are added to the labor costs, so as to conclude to the expected total cost of completion.

Risk response planning of the project: The results of the risk assessment process of the project are further analysed, so as to be decided which risks must be eliminated, which must be mittigated and which ones can be neglected. The result of this procedure, is to create a plan of actions againsts the identified risk. This is called, the risk managment plan of the project.

Specification derive and issue of BOM list: After the agreement of the stakeholders regarding the scope and the deiverables of the project, the project administration company derives the specifications of the product to be delivered. Depending of those specs, the bill of material of the product is created.

Components and material requests on suppliers: On this stage the purchasing department of the project administration company makes the requests of materials & components of the product to be manufactured, to a group of suppliers.

Inspection of the vessel by the staff of the technical department: This is the technical inspection is needed, so as all crucial details necessary for smooth installtion of the chiller unit, to be recorded. This inspection includes recording of details like hatches, passages, space availability, main and assistive pipping arrangement, etc.

Detailed design of the chiller unit: On this stage all information collected by specification list and technical inspection are taken into account and the final datailed drawings of the chiller unit are created.

Ordering of materials and components : When the suppliers of the material & components of the refrigeration unit respond to the purchasing departement request, the purchasing department

has to assess the offers, and proceed in the ordering of the equipment.

Construction of chiller unit frame: The manufacturing of the base frame of the chiller unit is the first main component of the unit that should be manufactured.

Mounting of ordered components on the frame of the unit: This is the work activity of assembly of the refrigeration system, where the various components included to the unit must be mounted to their position onto the frame, according to the final drawings.

Cut and processing of piping of unit : This duty is achieved using equipment like cutting and bending machinery, so as the piping components to be created.

Assembly of the system and brazing of the piping refrigerating network: Following the final drawings of the chiller unit, the welders proceed to the brazing of the created, by the last activity, piping components, deforming the refrigerating piping network.

Other refrigeration network jobs like instrumentation installation: This job includes the installations of condition monitoring equipment, like gauges and sensors and wiring works for connection of them to the electric panel.

Pressure tests of the refrigerating piping network: This work takes place, after the completion of the refrigeration network brazing works, and it is a quality control process to detect any leakages to the piping, using nitrogen gas as means of increasing pressure into the piping.

Development of electrical panel and automation system: This is the process of manufacturing the electrical panel of the chiller unit, by means of which power supply as well as control signals, like sensors signals, are connected with the electrical operated components of the unit, like compressor, pumps, etc.

Wiring of the electrical panel with unit components: As a continue of the previous job, the electrical panel is connected with the electrical operated components of the unit, like compressor, pumps, sensors, etc.

Charging of the chiller system with refrigerant: The chiller unit's refrigerant network is filled with the appropriate refrigerant fluid, so as to be ready for operation.

Factory acceptance tests of the completed unit: This category of works includes the series of the tests, that take place in Psyctothem's facilities, to confirm the normal operation of the unit, according to the designed optimal operation.

Mounting of the chiller unit to the foundation of its final position onboard: When the factory tests are successfully completed, the unit is ready to be transported onboard and takes its place onto the final installation position, on the suitable engine room deck.

Water piping connections of the unit with the fresh water network of the vessel: This is actually a welding technical job, where the water piping networks of the vessel are modified, so as to be fitted with the water pipe connections of the installed chiller unit.

Water piping connections' pressure test: This is the quality control procedure, that is followed to detect any leakage on the water piping network. During this, the piping is filled in with water and the pressure internally is increased using vessel's chilled water pump.

Electrical connections of the unit(electrical panel of the unit) with the electrical distrubution system of the vessel: Actually, this activity includes all works so as both electric power to be supplied to the new installed system as well as to the control subsystem of it to be integrated with the central control management platform of the vessel.

Commissioning and test of the chiller unit: This is the final test operation of the chiller unit, taking place in presence of representatives of the customer. By means of this process, the good operation and the conformity of the delivered system with the planned specifications is assured.

Activities connections

The logical connections of the various activities are presented in the arrow diagram shown in appendix 9.9. In red color is presented the critical path of the project (Neeraj, 2015), where any

delay in its activities leads to general project's delivery time delay.

Project Risk Assessment

Crucial part of the project management is the risk management of the project. For this reason, the ordinary risk assessment procedure followed, includes: a) the identification of the risks of the vessel modification project, b) the calculation of probability of each identified risk to be appeared, c) the impact of them, d) the processing of the previous data for calculation of the risk severity. After completion of the risk assessment procedure, the risk response plan should be created by the project management team. The results of the risk assessment and risk response planning are summarized in the matrix below:

Table 3. Risk Analysis Matrix

RISK MANAGEMENT MATRIX								
Risk Description	Risk Probability	Risk Impact	Risk Severity	Risk Group	Indicator	Management	Consequences	Control Action/ Response
Machinery Damage on Production Facility	Moderate	HIGH	HIGH 12	TECH	Visual Observation	Contact Production line manager so as to arrange service of the machine	manufacturing process and heath safety issues	Increasing quality control of machinery services and checks to decrease probability of damage
Fault during transportation procedure	Moderate	HIGH	HIGH 12	TECH	Visual Observation	Contact Project manager in case of damage of the product and hospital in case of injury	manufactured product, injury of employees	Increasing quality of transportation process, find highly qualified transporting suppliers , insurance of the transported items
staff during manufacturing or installation process	Moderate	HIGH	HIGH 12	HEALTH	Visual Observation	Contact Project manager or/and production line manager	Injury of the person, delay on the activity, legal issues	Increasing health and safety measures. Training of staff in health and safety issues
Health problem like virus infection	Likely	MEDIUM	HIGH 12	HEALTH	Person's Symptoms Observation	Contact Project manager or/and production line manager	Delay in manufacturing process	Increasing health and safety measures. Training of staff in health and safety issues, Preparation for reserved human capacity
Fault on main component by supplier	Moderate	SEVERE	VERY HIGH 16	TIME	Visual Observation	Contact Project manager or/and purchasing department	Delay on project	Find supplier of high reliability, sign penalty contract with supplier in case of fault
Delay on Delivery of component	Unlikely	MEDIUM	MEDIUM 6	TIME	Observation	Contact Project manager or/and purchasing department	Delay on project	contract with supplier in case of fault, Readiness to recover lost time with higher human resource capacity
Schedule delay because of own works	Unlikely	MEDIUM	MEDIUM 6	TIME	Observation	Contact Project manager or/and production department to add work shift or outsource part of the manufacturing activity	Delay on project	Readiness to recover lost time with higher human resource capacity . Outsourcing part of works.
Schedule delay because of Subcontractor	Unlikely	MEDIUM	MEDIUM 6	TIME	Observation	Contact Project manage to find alternative subcontractor (or one more)	Delay on project	Find supplier of high reliability, sign penalty contract with supplier in case of delay
Light fault on manufacturing process	Moderate	MEDIUM	MEDIUM 9	HUMAN/ TECH	Observation by Quality control Engineer	Contact Project manager	Delay on project	Increasing quality control of manufacturing process
Serious fault on manufacturing process	Unlikely	HIGH	MEDIUM 8	HUMAN/ TECH	Observation by Quality control Engineer	Contact Project manager	Delay on project, Budget expenditure	Increasing quality control of manufacturing process,Outsourcing part of works if possible
Underpricing of manufacturing activity	Unlikely	MEDIUM	MEDIUM 6	FINANCE	Control of Budget	Contact Project manager	Delay on project, Budget expenditure	Standardization of the pricing process using IT solutions
Failure of assistive subsystem on the vessel	Likely	MEDIUM	HIGH 12	TECH	Observation	Contact Project manager	Delay on project, Budget expenditure	Extended checks of the assistive equipment before dismantling. Focusing on technical staff caution especially on old aged subsystems
Fault on works executed by the vessels crew	Likely	MINOR	MEDIUM 8	TIME	Observation	Contact Project manager so as to inform the shipping company	Delay on project but cause of customer's responsibility	Increasing human resource capacity with shifts if possible to cover the lost time

Project Scheduling

Considering the activities connection diagram(arrow diagram), as well as the workload of each activity(manhours required), the Gantt chart of the project is created.

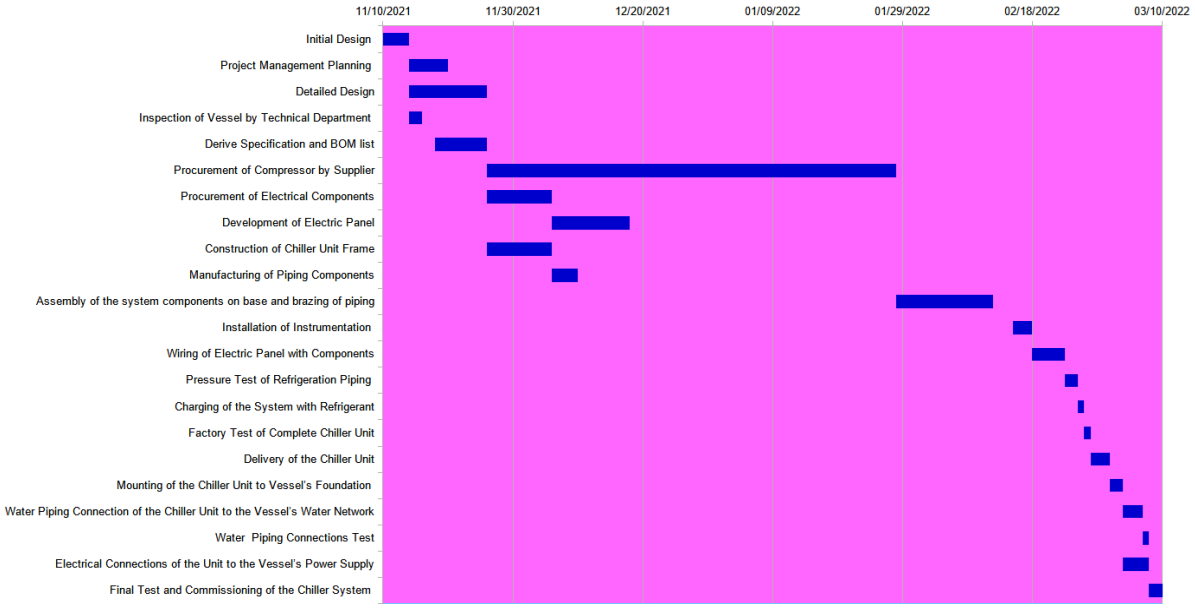

Figure 17. Project Gantt chart

Project Cost Analysis

The cost of any project, consists of the materials costs and the labor costs required for completion. The labor costs are calculated by the work load required for each activity, in combination with the cost of manhour of each activity. So, the labor costs, during the whole project development, are distributed depending on the position of each activity into the project schedule. In the same way, the various materials and components should be available for usage of the specific time of execution of respective work activity. So, the sum of the material and labor costs in coordination with the project life time, are the guideline to plan the budget allocation of the project through time. The actual and the planned cost baselines are created by the actual and the planned cost of the project respectively.

Figure 18. Actual and planned cost allocation

5.3 Psyctotherm Company Structure

The organization which this project thesis is written about is called Psyctotherm and actually it is the project administration company of the analyzed case. Psyctotherm is a company of refrigeration and air conditioning sector. Particularly, it studies, designs, manufactures, supplies and installs a wide variety of refrigeration and a/c systems, focusing on customers of marine sector, like shipping companies and shipyards. The portfolio of the company includes products like aircoolers, crossed fin heat exchangers, provision refrigeration units, central air conditioning units, packaged air conditioning units, air handling units, water chiller units. Water chiller units and central a/c units are the most complicated products, which require customized design and construction, according to the special specification of each ship, as well as installation procedure by specialized technicians. So, these two products are considered as projects and an order of such a construction is proceeding as project development for a particular vessel/customer. The rest of products of the portfolio are certainly supplied as standard products. For the purpose of this essay, the development of water chiller unit project is described and analyzed. Psyctotherm consists of 5 departments (accounting, purchasing , sales, engineering/manufacturing , technical), each of which has its unique special role in the materialization of a project. The roles of each department can be described as below:

Accounting Dept: Handling of financial issues of the company, handling of the receivable payments by the customers of the company, handling of payments of material and components' suppliers .

Purchasing Dept: Communication with material and component's suppliers, for procurement of the components, that the final manufactured products consist of.

Engineering/Manufacturing Dept: Takes over activities of processing the request of the customer, from the technical angle of view, on the stage of the offer request, and activities of design and manufacturing of the final products, in case of confirmed orders.

Sale Dept: Handling of customers requests, communicating with customers, recording the target of a requested product/project, which actually is the main reason of the customer request,

cooperation with Engineering/Manufacturing Dept regarding the needs and the request of the customers, cooperation with Accounting Dept for the payment terms of the orders.

Technical Dept: Taking over activities of inspection of the area/space, that the new customized chiller unit of a project is to be installed, taking over activities of installation of the new chiller system on board.

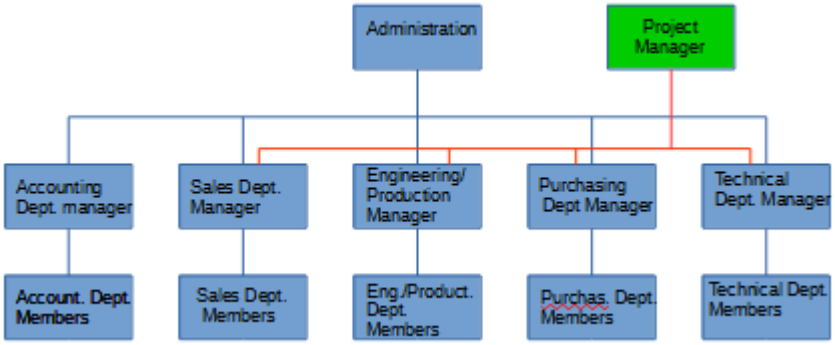

Figure 19. Project administration company's structure

5.4 Documentation of Water Chiller Project

For the management of the project and the effective accomplishment of it, a series of documents are used and distributed, either among the various departments of Psyctotherm or between the company and the stakeholders. The documents used, archived and distributed are the following:

Customer's Offer Request Sheet: This document can be considered the starting point of a project case. This file is sent by a customer, to ask a technical solution for a problem, that should be dealt with by installation of a refrigeration system. The document actually introduces, the scope of the project and briefly mentions the specifications of system to be supplied.

Psyctotherm's Technical Proposal: This document is sent to the customer, in the stage of offer submission. This is the reply of the Sales Department to the Customer's Offer Request Sheet, and summarizes information of the proposed technical solution. It includes the specification sheet as well as a general drawing of the system.

Psyctoherm's Cost Offer: This document includes economical information of the offered project solution like cost, payment terms and delivery time. It is sent to the shipping company, accompanied with the Technical Proposal document .

Customer's Official Offer Acceptance: By means of this document, the customer accepts the offer of the manufacturer, and so the project passes the stage of offer and enters the stage of offer. There is no standard form of this document, but is up to the customer which is the writer of it.

Psyctotherm's Order Confirmation: Order confirmation is a standardized document, sent as a reply of Psyctotherm to Official Offer Acceptance of the customer. Its sealed and signed by the Sales Department's representative, assuring the customers about the successful receiving of their official offer and confirming the fundamental terms of the project (offer's ID number, cost, delivery time, payment terms,etc.)

Psyctoherms' Proforma Invoice: This is sent to the customer by Psyctoherm's Accounting Department, providing all the necessary information about payment of the project, amount, payment terms, bank accounts, etc.

Various Drawings and Technical Documents: This is a group of technical documents, created by the Engineering section of Engineering/Manufacturing Department, with receiver the technical staff of the various workstations of the manufacturer. The archive includes documents like 3D drawings, P&I diagram, detailed specifications sheet and it is to provide all information required to proceed in the manufacturing of the ordered refrigeration system.

Bill of Materials: This is a list of all the components which the final manufactured system will be composed of. It is written by the Engineering/Manufacturing Department of Psyctotherm. This is useful both for assembly procedures executed by its technical staff, as well as for the Purchasing Department and so it is issued as guideline for the department, so as to proceed in components request on various suppliers.

Psyctoherm's Material Request Form: This is a form that records the detailed specifications of a requested materials, based on the guideline of bill of materials, and it is sent by Purchasing Department to various suppliers', during components request stage(planning phase of the project).

Supplier's Material Specification Sheet: This is the datasheet, that accompanies the reply of the suppliers (cost offer) to the material request of Psyctotherm. It includes all technical information of the component, so as Psyctotherm to be assured, that the offered component is under agreement with the planned specifications of the project.

Supplier's Material Offer: This document includes economical information of the offered item, like cost, payment terms and delivery time. It is sent to Psyctotherm, accompanied with the Material Specification Sheet .

Psyctotherm's Official Offer Acceptance:By means of this document, the Psyctotherm's Purchasing Department accepts the offer of a supplier, and so the latter proceeds in the delivery of the ordered component .

Supplier's Proforma Invoice:This document is sent to Psyctoherm's Accounting Department by the suppliers, providing all necessary information about payment of the project, like amount, payment terms, bank accounts, etc.

Manufacturing Department's Weekly Reports: These documents are used to record difficulties ,bottlenecks , deviations from the initial plan that the Engineering /Manufacturing Department dealt with the last week of the project's execution stage . This document both helps Engineering /Manufacturing Department to develop ability and enhance experience to deal with similar problems successfully in future projects, as well as it helps project management team to make revision and changes to the current project plan documentation.

Manufacturing Department's Quality Control Report: This is a standardized report used by the Engineering /Manufacturing Department, to assess the manufactured product, manufacturing process, and gives a feedback for the continuous improvement of processes, and correction of faulty principles in production line.It is part of ISO 9001 quality standards that Psyctotherm conserves.

Manufacturing Department's FAT Report: This report is used for recording the results of final tests of the manufactured system(when the construction is completed) , that are made in the manufacturer's facilities(this is why it is called Factory Acceptance Test).

Technical Department's Inspection Report: This report is filled in, by the Technical Department of the company. In some projects it is considered necessary, the area of the installation of the new system to be visited and inspected, before planning of the project and design of the final structure. This period is scheduled after the confirmation of the project's order. So a group of members of the Technical Department of Psyctotherm visit the vessel and make notes regarding special factors that should be taken into account, during the design, like geometry of the area, arrangement of the space, restrictions and obstacles of the installation space, etc. All these comments and notations are written to the Technical Department's Inspection Report and this document is submitted to the Engineering Department of Psysctotherm.

Technical Department's Weekly Report: This report is written by the chief of the technicians group, in weekly base, at the end of each week. On this document are recorded significant points about the installations of the ordered chilled water system, and the progress of the necessary technical activities onboard. This report may includes problems that may be dealt with during installation procedure, improvements that are implied to resolve those problems, summary of the working activities that took place the particular week, as well as proposal for changes of the plan. This document is used as an assessment tool of measuring the efficiency of the project's progressing, and possible deviations of the actual installation phase from the plan.

Technical Department's Commissioning Report: Actually, a series of tests (HAT – Harbor Acceptance Test and SEA-Sea Acceptance Test) are made on board, after the installation of the chiller unit, before the issuing of Official Delivery Document of the project to the customer. The first start of the unit/commissioning, takes place at the presence of customer's representatives. This document is issued by the Technical Department of our company, and contains results and comments, regarding the final test and commissioning of the unit, as well as the measurements are taken during the commissioning procedure .

Operating and Service Manual of System: Actually, this is an archive that contains all the information necessary for operation and periodical service of the delivered system. The creation of this archive is a duty of Psyctotherms' Engineering Department. It collects all the datasheets and manuals of the components of the chilled water unit, as well as the electrical drawings of the unit in a archive and writes the official Operating and Service Manual, that the manufacturer delivers to the customer after the successful commissioning of the unit.

Spare Parts List of System: This is a list that contains all the spare parts of the chilled water system, accompanied by an explode version of the unit's 3D drawing. It is delivered to the customer in combination with the Operating and Service Manual of System archive. This list is used by the customer, as guidance for asking the necessary spare parts in the future and it has an important role on the after sale services of the product.

Psyctotherm's Official Delivery Confirmation: This is the final document that it is issued, when all requirements of the official delivery are fulfilled, like successful commissioning procedure by Psyctotherm, and payment of the project's cost by the customer's accounting department. It is a contract type document, that is issued by Psyctotherm and and it is signed by both manufacturer and customer of the project.

5.5 Engineering Manager Platform as Quality Control Tool

For the quality management and change management of the chiller unit installation project, the Engineering Manager Platform of the ABS class society can be used as reliable tool. For the usage of this platform, all stakeholders of the project should create an account to the portal. The owner of the project, which is the shipping company that owns the vessel, in cooperation with the ABS class society, creates an online archive of the project. Afterwords, the ship owning company gives specific access rights to each stakeholder(for reading, writing files or both). Psyctotherm, as administration company of the chiller unit installation project on the M/V Argo, has full access on reading, modifying or adding files. The entering screen of Psyctothem account for the particular project is the one below, where the ID number of the project as given by the class society and name of the vessel shown:

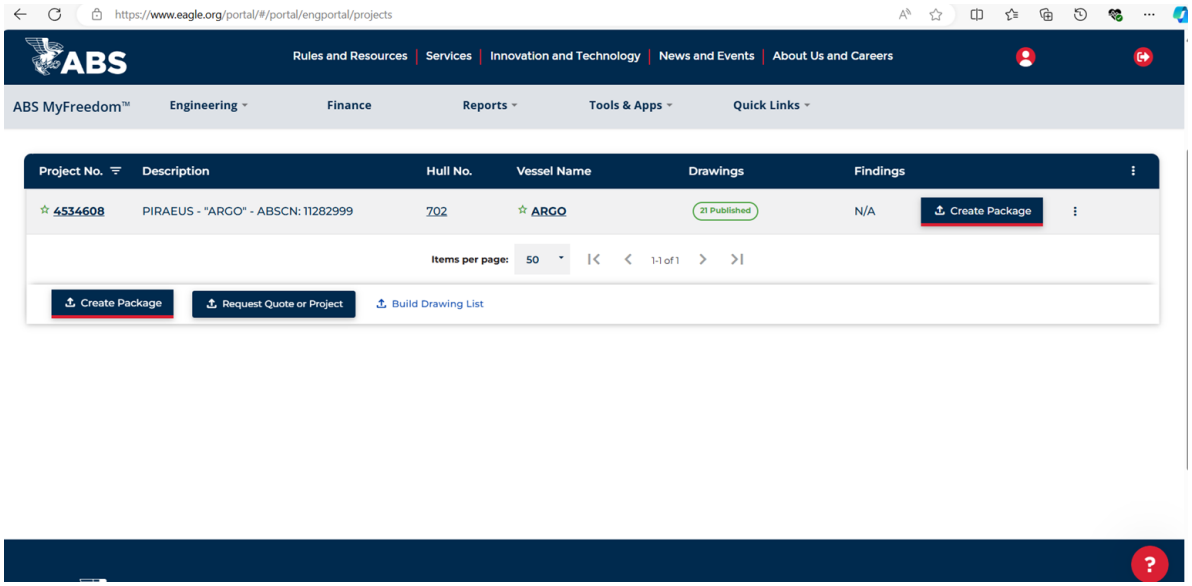

Figure 20. ABS Engineering Manager platform illustration 1

Clicking on the project No, the administrator of the project, can surf to the various details of the project, using the tab list on the left.

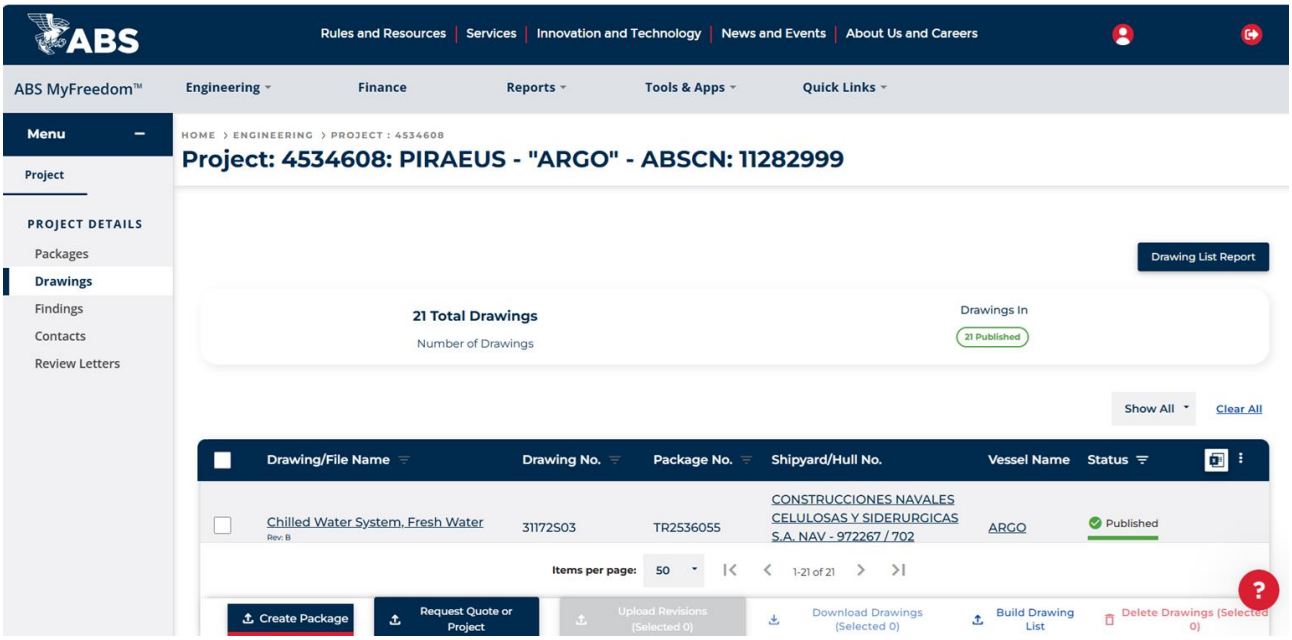

Figure 21. ABS Engineering Manager platform illustration 2

By means of it, all the technical based information of the project can be accessed. Information includes sections: packages, drawings, findings, contacts, review letters.

Drawings: This section include all drawings, as well as additional technical documents requested by the class society (like BOM of the chiller unit, certifications of the various equipment components, etc.)

Findings: This chapter includes all the test results, made by the project administration company, as well as findings notes of the class society's surveyor, during the periodical inspections onboard, as the project is proceeding.

Contacts: It includes the contact list of the representatives to solve any issue, or giving clarifications related with a particular issue, among stakeholders.

Review letters: It includes the review letters of the ABS, when a modification on the project or a surveyor's inspection of the project takes place.

So, by means of this platform, Psyctotherm can upload and make accessible, all information about technical details, specifications and quality control tests about the project, to all stakeholders given permission by the shipping company. The ABS or customer company is able to review the data provided, make comments, identify potential quality non conformity, request modifications from the current technical specs, etc. The ABS class society issues a review letter to confirm or not, that the corrections/modifications requested to the project administration company are completed successfully.

5.6 Epotia Platform as Scheduling Control Tool

Epoptia is a software platform that can be used as a scheduling tool, but actually it is a production management and monitoring tool. So, it was used as a time management tool in the phase of manufacturing the chiller unit in Psyctotherm's facilities. This platform has 2 parts, the administration part and the workstation operator part. The first one is the framework, by means of which the status of the production line is monitored, modified and recorded. The framework of the administrative part is the one shown below:

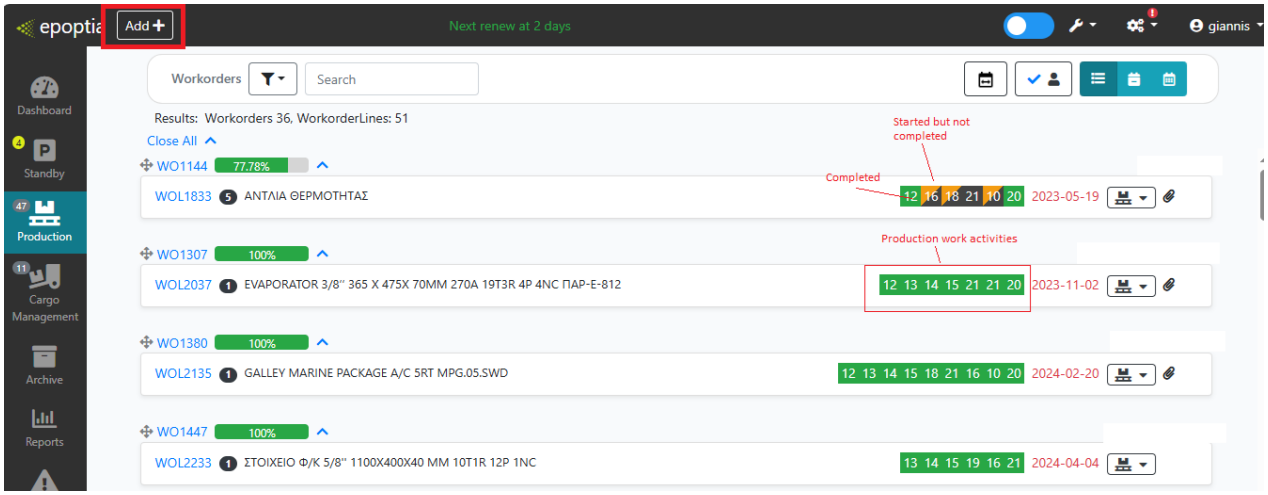

Figure 22. Epoptia production monitoring menu

In the left side of the framework, there are selection options for the administrator of the manufacturing line, including standby (paused work orders), production (proceeding workorders), archive(archived/past workorders), cargo management(completed workorders ready for packing), reports (statistic analysis of completed workorders), alarms (alarms and warnings appeared cause of various problems that one or more workstations dealt with).

Choosing the tab production, the administrator can monitor the existing workorders of the production line, where workorder is actually a product under manufacturing process. The completed work activities of each product manufacturing are shown with green color and the started but not completed work activities are presented with orange color. When the manufacturing of a new product/project should be entered in the production line, the administrator pushes **Add** work order button. After that, administrator should filled in a series of fields of information, which are accessible to the operators of the respective workstations (the technicians of the workstations, where the needed work activities are going to be executed). These fields include the flowchart of the manufacturing work activities, uploading field for files (like drawings, material lists, additional guidelines for the manufacturing), client information and comments, etc.

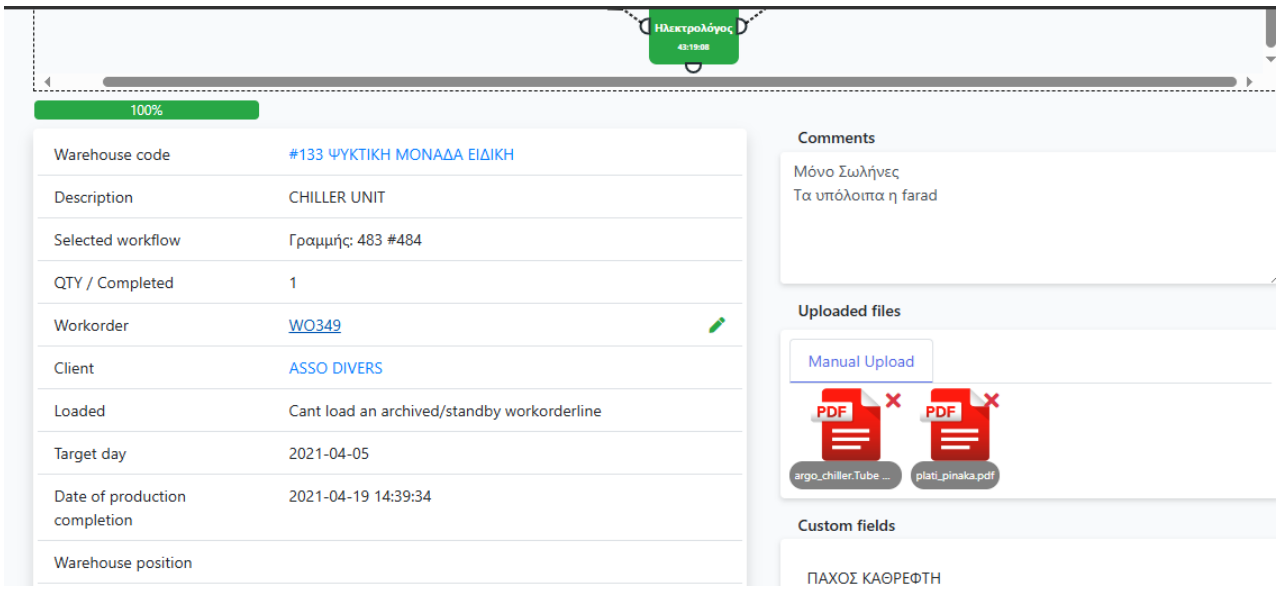

Figure 23. Epoptia parameter fields 1

A second series of settings that the administrator can set, are the fields that are requested to be filled in, by the operators of the workstations including, notes, proposals for correcting the product, measurements taken as part of quality control etc. As indication for the nature of those data, we can use the production of the chiller unit, where fields that workstation operators should fill in are:

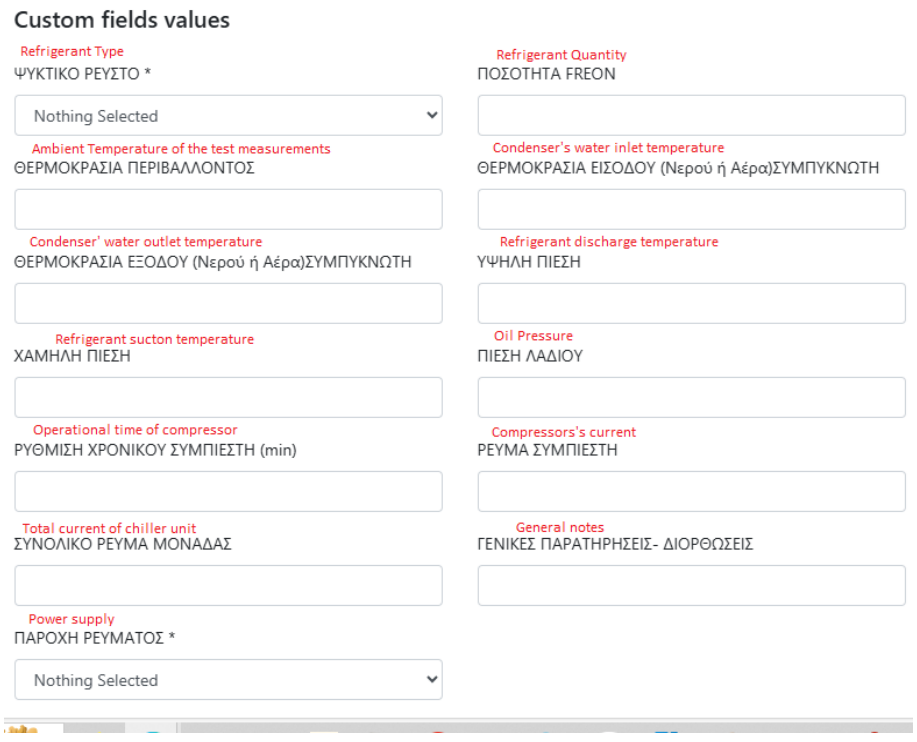

Figure 24. Epoptia parameter fields 2

Regarding the flow chart of the work activities of any project that should be executed, these must be specifically defined by the administrator of the production line, depending on the processes required for each particular product. In case of the chiller unit, the flowchart is the one below, where the work completion time of each stage, is indicated and can be used for schedule monitoring and control, as well as the calculations of time schedule efficiency indexes.

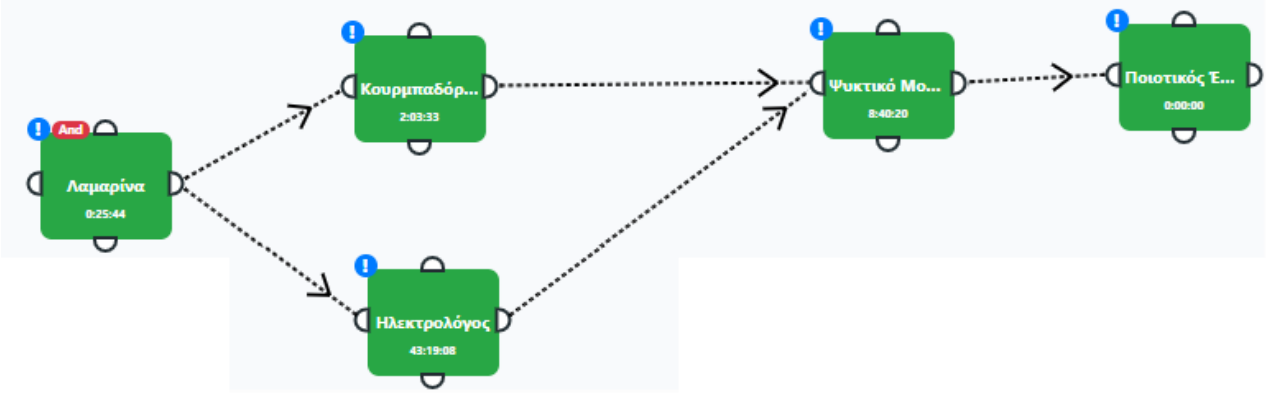

Figure 25. Chilled water manufacturing activities diagram

Finally, using Epoptia software platform, technical staff of the workstations, can trigger an alarm, pausing the manufacturing process, any time that they deal with a technical problem with the machinery that they operate, or most importantly if they identify a quality type or other non conformity of the product under manufacturing, in relation with the planned specifications of it.

5.7 Entersoft ERP as Cost Control Tool

Entersoft is a ERP software, and so it is able to manage all the data of Psyctotherm about customers, suppliers, invoices, order of customers and orders to suppliers. As a software with such capabilities, it can integrate a project as a customers order with orders to suppliers for the various components of the project, so as to monitor and control the cost of the projects.

The software is divided in divisions like: sales, marketing, contacts, customer service, logistics, purchasing & supplies, production, accounting, etc. For exploiting the project cost control capabilities of the software, the usage of it will focus on the sales, logistics, purchasing & supplies, accounting software divisions.

The first step is to register the customer of the project (registering all the details of them), using

the subdivision *customer* to the *sales* division. This duty is done by the sales department since the moment of submitting the offer request about the project.

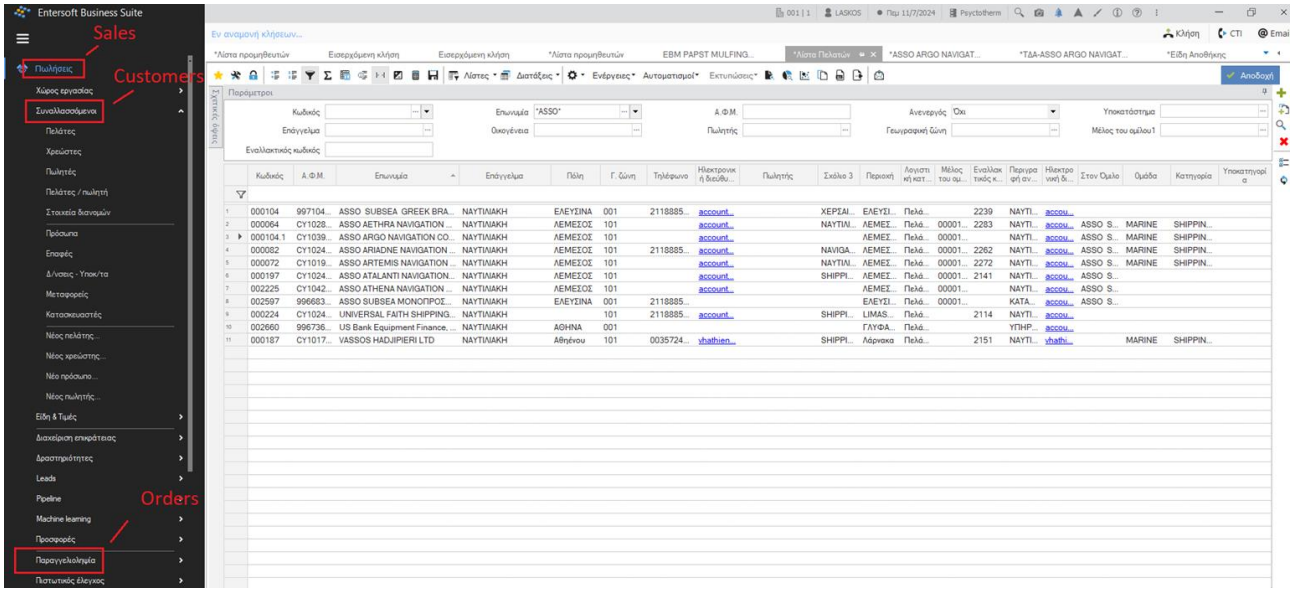

Figure 26. Entersoft ERP customer-order search menu

The second step is to create the item of the order, which actually is the project to be delivered. The process is achieved by creating a new item using the subdivision *item to the logistics* division of the ERP. For creating a new item record, details like budget price, weight, supplier, and other comments can be inserted. To our case the supplier of the water chiller system is Psyctotherm, as it is the project administration company, and the budget cost is the cost that is derived to the project planing phase.

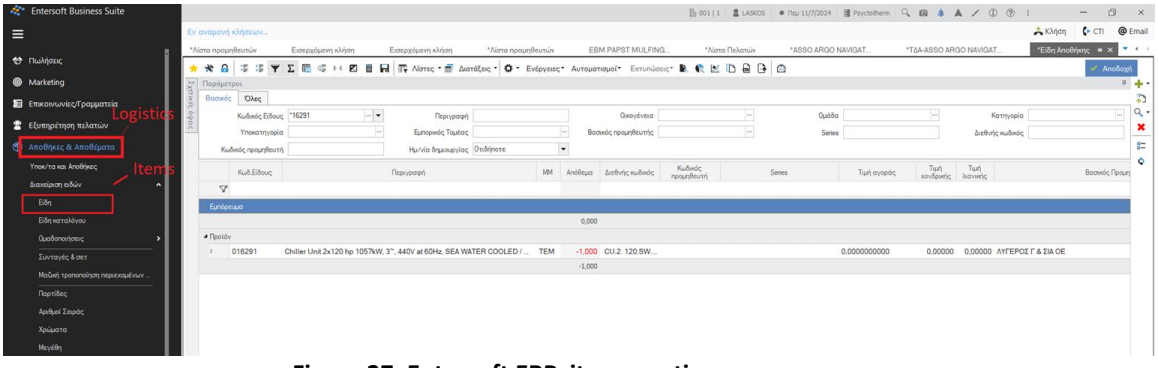

Figure 27. Entersoft ERP item creation menu

The order of the project is registered using the orders subdivision of the sales division of the ERP, by selecting the shipping company ASSO ARGO NAVIGATION COMPANY, as the customer of the order, and inserting the previously created item, as the item included to the order. The suppliers

that are involved to the project should be registered using the subdivision *suppliers* to the *purchasing and supplies* division of the Entersoft. As suppliers should be inserted, both the suppliers of the various components of the project as well as the subcontractors of the project, that actually offer technical works.

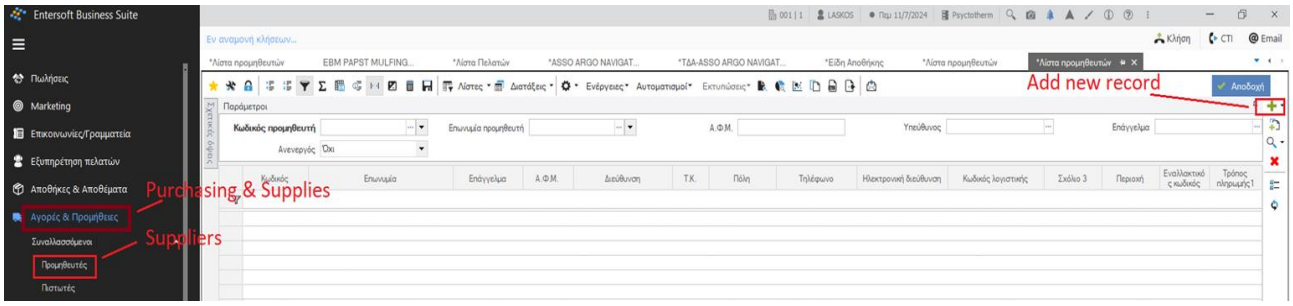

Figure 28. Entersoft ERP suppliers record menu

Following the process used in second step, the items that are going to be provided by the suppliers are created. The field of *cost* of each new record is filled with the planned cost of the particular item, according to the supplier's offer. For each item recorded, a bill of materials can be created. And so with the item of the chiller unit, that is the final deliverable of the project (that is recorded as item of the supplier Psyctotherm) the same procedure should be followed. The bill of materials is created, by entering the item supplied by Psyctotherm (project's item), selecting lists and inserting the items of the various suppliers, that have already created and are going to be included to the delivered water chiller system.

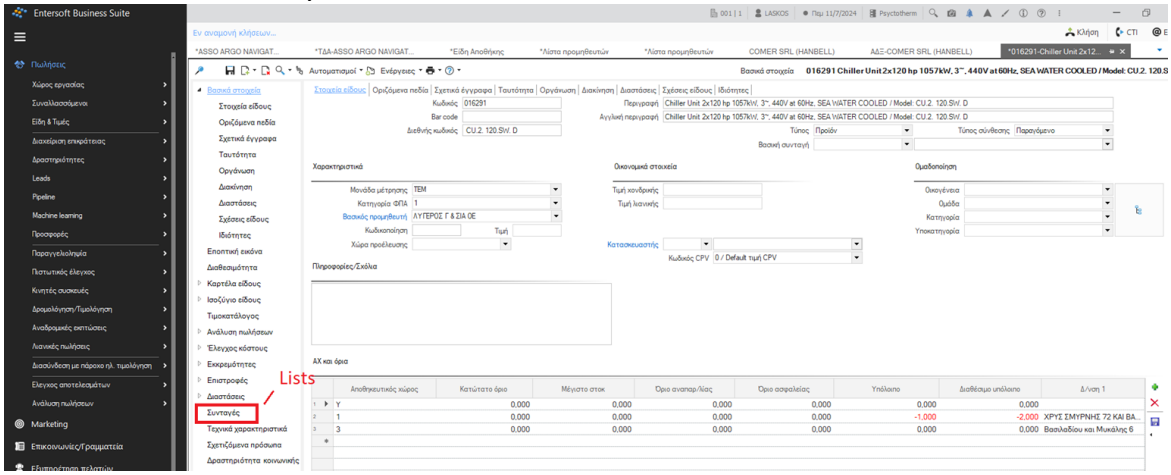

Figure 29. Entersoft ERP item bill of materials menu

When the full list is created, the software is able to record, calculate the total expected cost of the project, and delivery days of each item included to the list of main project's items. By means of this tool, the Entersoft is able to monitor the cost and the budget allocation of the project (which is additionally a time scheduling type of information). Every time an ordered item is arrived to

Psyctotherm facilities, an invoice is issued. The cost of invoice is the actual cost of the item. So, when the invoice is registered by the accounting department of Psyctotherm, the actual total cost of the project is updated. Additionally, the Entersoft is able to trigger an alarm, when a deviation in delivery time (by means of cost allocation) or in total cost is identified (by comparing the summing costs of the list of the project items, with the budget cost that was inserted as value, when the project item was created). So, this provides a warning to the project team, to proceed in corrective actions if it is necessary.

6 Results/Analysis

6.1 Integration of Project Management Tools

The combination of the 3 previously described tools (Entersoft, Epoptia, and Engineering Manager portal), can lead to a powerful project management tool. The integration of them, can be based on either in Microsoft Access data form or in a spreadsheet form. The simplest and more user friendly form, is the spreadsheet form (excel file). Structuring the spreadsheet form of the integrated tool, we should firstly create 3 different tabs on the spreadsheet, each one specified to the management of a particular project management area: a) quality and change management, b) time management, c) cost management.

Quality and Change Management tab

This tab supplies data access and information registered on the Engineering Manager access. The cells of this tab are manually filled in, by the project manager. The columns that the data are structured, are the planned specification description, project modification/change, cause of modification need, issuers of change approval, date of change approval, change completion date, read document, quality test of the executed change, date of quality test of executed change.

Planned specification description: This column includes information for the initial specification of the project, as they were confirmed during the planning phase of the project.

Project modification/change description: It includes information about the project changes to be executed.

Cause of modification need: On this cell of the spreadsheet, it is recorded the reason why the modification of the project is needed.

Issuers of change approval & date of change approval & change completion date: It records the people involved in the project, that have agreed to the project change, the date that this change was agreed, and the date that the change was executed respectively.

Read document: this column includes links of the IT server of Psyctotherm, where all documentation are archived.

Quality test of the executed change & date of quality test of executed change: the particular field records the type of test, by means of which the modification's success is confirmed, as well as the date that the test was made.

Time Management tab

This tab of the spreadsheet type project management tool, accumulates all information collected and recorded by Epoptia production monitoring platform. So, the data are structured on columns like: a) work activities, b) planned time of activity completion, c) starting date & time of activity, d) finish date & time of activity, d) actual duration of activity, e) activity executor, f) number of people on duty of work activity, g) SPI value of activity, h) deviation from planned completion time, i) estimated time to project completion

Work activities: It includes the name of the work activities needed, for project completion, according to the WBS of the project.

Planned time of activity completion: The duration of each work activity, according to the initial planning management of the project.

Starting date & time of activity, finish date & time of activity: It specifies the actual moment (date and time) that a particular activity starts and finishes.

Actual duration of activity: This value derives from subtracting the values of the starting and finishing moments of each activity, to calculate the actual duration for completion.

Activity executor: it includes information about who executed the particular activity (Psyctotherm or subcontractor).

SPI value of activity, deviation from planned completion time, Estimated time to project completion: They are columns used for calculating time management efficiency factors, as they are described in the chapter of project evaluation of this thesis.
Number of people on duty of work activity: this column records the number of people involved on the task, so as the manhour value (and so the workload of it), to be calculated, project's earned value timeline and project's time deviation graphs, etc. This tab is also used for feeding information, required for the calculation of labor costs, as they are calculated in the cost management tab.

Finally, the time management tab includes all the project time monitoring graphs like Gantt chart.

Cost Management tab

This tab accumulates all the data required for the cost analysis of the project. Those data are collected by the tab time management (as regard to the labor cost) and Entersoft ERP (as regard to the material costs). For the latter, the data can be read from special csv files, that can be periodically extracted by Entersoft, using program routines of it. So, a csv file with the required data, can periodically updated, and every time we use this spreadsheet type project management tool, the updated data will be loaded to the columns of the cost management tab. The column group of this tab includes: a) work activities, b) planned total cost of activity, c) actual labor cost of activity, d) material cost of activity, d) actual total activity cost, e) CPI value of activity, f) deviation from planned activity cost, g) estimated cost to project completion

Work activity: It's similar to the respective columns of the time management tab
Planned total cost of activity: This columns informs the user about the budgeted cost of the activity, as it was derived during the project planning phase.
Actual labor cost of activity & material cost of activity: It includes information about the cost of the human resources used, and the material used on the particular activity respectively.
Actual total activity cost: it is derived from the summing of the previously mentioned costs (columns' values).
CPI value of activity, Deviation from planned activity cost, Estimated cost to project

completion: These columns are used for calculating cost management efficiency factors, as they are described in the chapter of project evaluation of this thesis.

Additionally, this tab includes a series of graphs for monitoring and control project's costs, assisting the project team, to takes promptly the necessary corrective actions. The groups of graphs include the planned cost allocation timeline of the project and the actual cost allocation of the project, using the earned value methods, as they mentioned in the project evaluation chapter of this thesis.

6.2 Water Chiller Project Evaluation

In general view, the whole project of the water chiller unit's installation is successful. The main scope of it, which is to supply the trenching support vessel with a new machinery of defined specification was achieved. During the commissioning tests, the cooling capacity measurements taken were very satisfactory. The suitability of the system to fulfill the prerequisites of the customer request, as they were officially agreed between the shipping company and the project administration company, by contract signing in the order stage, was also confirmed by class society, issuing the respective approval for the new system. The system since its installation operates normally without any problems, and all technical operations that were needed on it, were only the periodical, regular maintenance works, according to the maintenance scheduling plan. The satisfaction of the customer, by the completion and the results of the project, that was given as feedback to Psyctotherm, is also a sign of the success of the project. This success of the project is in some way certified, by the fact that the shipping company made a new request to Psyctotherm for a project of similar specifications, for another vessel it owns, which has similar characteristics with M/V Argo. Regarding the quantitative evaluation of the project according to the project management theory, it's worth to mention that:

As for the time scheduling evaluation, it was observed that completion delays happened on activities of project management planning, detailed design, procurement of compressor & heat exchangers by supplier, procurement of electrical components, development of electric panel, construction of chiller unit frame, assembly of system components, mounting of the chiller unit to vessels foundation, water piping connection. So, the respective SPIs on those stages were <1 that indicates a project efficiency lower than planned, on those project life points.

However, Psyctotherm recovered the lost time on each critical path of the project, increasing the human resource capacity, by means of extra shifts of its own personnel or requesting extra human backup by its subcontractors, where was possible. So, finally there was no deviation of the actual delivery time in comparison with the planned one. On the other hand, as a result of this unexpected need for labor capacity increase, the final completion cost of the project was higher than the initially budgeted one. Particularly, the evolution of this cost deviation was presented on the figure No8, but also using the CPI index at the completion of the project, we conclude that

CPI= EV/AC=91715Euro/95005E=0.965

and so it's observed an almost 3.5% negative deviation of the actual cost of the project, in relation with the project planning. The delays recorded are generally in reasonable levels, but can even more be improved, by means of better estimations, that can be achieved on future vessel's modifications projects, as a result of improved experience of the participants on the similar project or by implementation of machine learning technology as prediction tool.

Regarding, the risk management of the project, it can be considered satisfied, as many risks were lowered by providing extra training and giving instructions to the people involved. When risks could potentially explode the cost of the project and lead to failure, Psyctotherm had taken measures like signing insurance contracts and special contracts, that included financial penalties for subcontracting companies and equipment suppliers, in case of faulty components and serious delivery delays by them.

6.3 Machine Learning Modeling of Water Chiller Project

The project of installation and manufacturing of a water chiller unit, is of course a marine constructional project, and as for the machine learning modeling of any marine project, the procedure that was described in chapter 4.5, can be followed.
To specify the proposed model, so as to fit on water chiller system's manufacturing and installation project, the attribute X2, which represents the complexity of the project, should be substituted by the value X2= 0.1*HT+0.25, according to the mathematical function that is presented in the chapter 6.4. The rest of the attribute values of the model as described in the chapter 4.5, cannot be generalized as common for all water chiller installation projects, but are ordinary for each

project and are dependent on factors like the subcontracting work ratio, competency level of sub-contractors, age of ship, etc.

6.4 Data Collection of Vessels Modification Projects

For the implementation of the ML model, records of data from past project has to be able to re-trieved. Actually, the form of the data to be used, as input to the ML application programmer, has to have a matrix form, so as to be easily accessed, processed and analyzed. The most usual type of such a form is a Microsoft Excel file. Every time a project is completed, a set of values are rec-orded. These values are nothing else than the attributes of the ML model to be developed, as de-rived from the measurements taken and the evaluation of the project. The set of the values col-lected by a separate project, can be represented as a row in the matrix of the spreadsheet file, in which every attribute is represented as a separated column in the file. During the execution and completion of more and more vessel's modification projects, additional similar sets of values are collected. Every new set of values collected, is a new record and so it fills a new row in the data spreadsheet type file. Summarizing the data to be collected, so as the ML implementation to be facilitated, they can be listed as below:

- Budget Planned Cost
- Age of the Ship
-Complexity of the project
-Competency level of subcontractors
- Subcontracting Work Ratio
- Planned Duration of the Project
- Experience Ranking of the Project Management Team
-Type of the Subsystem to be Modified

6.5 Training & Test Set in Vessels Modification Projects

As we have already mentioned, the completion of a machine learning algorithm includes 2 phases. The training phase and the evaluation phase. The first one is executed by using a group of data col-lected, so as to implement the selected ML algorithm, which in our case is the linear regression method. The result of this phase is to find the multipliers/factors of the ML algorithm, that fit bet-ter, so as the derived prediction model to conclude to the optimum prediction results for any set of independent variable. The assessment of the ML model takes place in the evaluation phase. For

this phase a separate group of data is used. The sets used on each phase are called training and test set, for the training and evaluation phase respectively. Both data has the same form, which means as they consisted of the same attribute families, that mentioned on previous section of this essay. However the content of the training set cannot be based on same the records used for the test set. To assure this, the implementer of ML should take the data file, that was created by the information of the past modification projects, and split it in two parts. The first one is the training set and the second is the test data group. The efficient implementation of ML algorithm is to use as much as records to train the model, so as to assure that the 'experience' of the model is enough, so as the expected reliability of its results to be high. However, to confirm that the model is able to cover effectively a high percentage of future input variable cases, similarly the model should not be tested with poor amount of input cases. As actually the collection for training and test set uses the same database, but the two groups cannot have common part of the database, the compensation that ML programmers use, is to assign the 75% to 85% of the database to the former set and the rest of records to the latter one (Muller & Guido, 2017). So if we consider the database as a two dimension matrix, the 75% to 85% of its rows is assigned to the training set and the rest matrix rows to the test set.

6.6 Implementation of Model in Python Programming Language

The data to be used for implementation of ML models, both for cost and delivery time estimation of project, has to be in 2 dimension array form, recorded in a CSV file. The content of those files should be as below:

Table 3. Cost prediction attributes' matrix

Project ID Number	Budget Planned Cost	Complexity of the Project	Age of the Ship	Experience Ranking of Project Management Team	Type of the Subsystem To Be Modified	Subcontracting Works Ratio	Competency Level of Subcontractors
1							
2							
3							
4							
.							
.							
n							

Table 4. Time prediction attributes' matrix

Project ID Number	Planned Project Duration	Complexity of the Project	Age of the Ship	Experience Ranking of Project Management Team	Type of the Subsystem To Be Modified	Subcontracting Works Ratio	Competency Level of Subcontractors
1							
2							
3							
4							
.							
.							
n							

Prior the implementation of the ML algorithm, first of all, it should be confirmed that the Python language modules: pandas, sklearn, Matplotlib, numpy are installed to the virtual Python machine. If there are not installed, it should be proceeded by the programmer running to the Python virtual machine the function **pip install** *module*, where *module* must be replaced by the name of the module to be installed. When installations of all modules are completed the steps illustrated below should be followed.

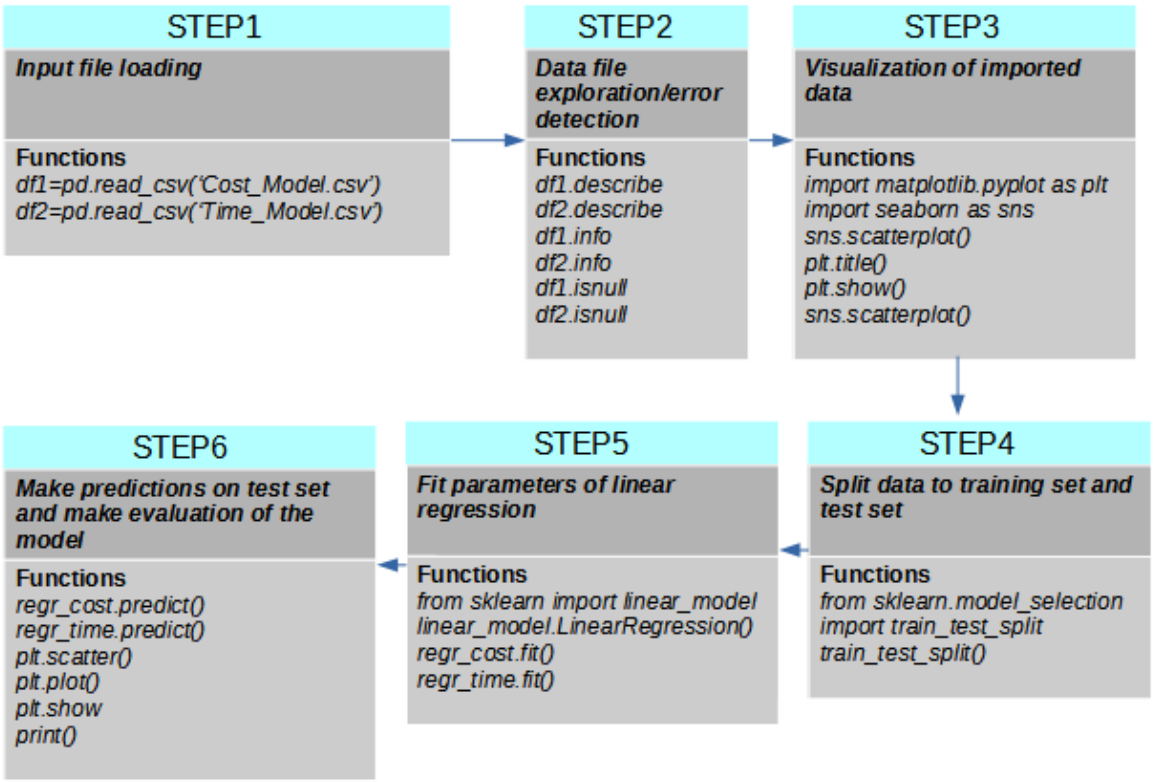

Figure 30. ML prediction model flowchart

6.7 Reliability

Regarding the reliability of information used on this thesis, it can be divided into 2 main categories. The first one is the theory and the fundamental knowledge about project management principles, and the second one is the data about the implementation of project management in the analyzed water chiller system, that was installed on a trenching support vessel.

As for the former category, all the information used are collected by the global bibliography, focused on issues of project management, machine learning technology and python programming language. The reliability of the particular sources, is confirmed by the APA style citation method that is followed throughout the writing of the particular essay.

As for the latter, the category of data used, the reliability of them is confirmed by multiple ways. The first one is the fact that the author of this essay was immediately involved in the project of the installation of water chiller system on the vessel Argo, as project manager, so all the official data were accessible to be collected, by means of the real project documentation recorded that period. Particularly, for cost analysis part, the real costs were collected by means of the official proforma invoices that were issued for the purchased components, that were installed on the chiller unit, and the subcontractors that took over elements of the work activities.

Additionally, the actual delivery times of the various objectives of the project, during the manufacturing phase on Psyctotherm's facilities, were collected by the data logs of Epoptia manufacturing line monitoring platform. By means of this IT system, any faults on data about actual completion times of work activities, that could be a result of human error, were prevented. Moreover, information collected by technical staff reports, were double checked by the author of this thesis personally, as it was included in project management procedures, a meeting/unofficial interview to take place between the project manager (author of this thesis) and the person that signed and submitted the report.

Finally, as it is already mentioned, an important part of data about the project, was uploaded to the ''Engineering Manager Platform'' of ABS class society, and was reviewed by one or more stakeholders of the project. So any information that was collected from there, to be used on this thesis,

was the real objective side of information, and not the subjective opinion of the author of this thesis.

6.8 Ethics

The research project's scope, is to provide a research about project management on marine vessels modification projects. So, the research and conclusions recorded on this essay, are pointed to provide honest and unselfish help on the professionals of marine technology sector, and especially on those, that are employed in project management roles, so as to increase their efficiency on similar projects. All conclusions that are noted on the respective chapter, are honest result of the experience of the author and are pointed to help employees of similar work position with him. All data used on this essay by the author, are under the agreement with Psyctotherm, which is the project administration company of the 'water chillller manufacturing and installation project'. No, personal details of project management team members are mentioned on this particular project. Additionally, brand names of suppliers, that are responsible for delay on the project completion, are omitted, so as not to harm their reputation. Additionally, sensitive technical information about the vessel's characteristics, that could be used by competitors of the shipping company are omitted, and any technical data used, are only those related with the chiller system manufactured by Psyctotherm, with which there is an agreement for free usage of all data included on this essay, or those data, that are freely accessible by any web user on the shipping company's web site. The structure of the essay is such one, that can be used by other students or researchers, for further research in the future and data or information are not distorted, so as further research by future researchers, that is based on some conclusions of the particular thesis, to be reliable, and any result or conclusion of it will be really helpful to the academic and professional community. For all theory used on this thesis, there is efficient citation according to academic regulations.

7 Discussion

7.1 Discussion of the main results

Regarding the conclusions that can be made by the results of the particular thesis project, the whole discussion can be divided in 3 sections:

a) Conclusion about the completion results of the installation and manufacturing of chilled water system on a trenching support vessel: As for this section, it's worth to mention that the management of the project was successful. To be more specific, according to the quality metrics of delivered product, there was not indicated any deviation of the final product from the initial quality management plan. What makes this conclusion clear, it is both the fact that the test operation results of the installed chilled water unit were very satisfactory, as well as the fact that the feedback of the customer about the regular operation of the unit after a long period is similarly satisfactory. However, in the time scheduling part of the project, as mentioned in the evaluation section of this thesis, there was indicated a lower efficiency in some activities (SPI<1 in some points of the project life-cycle). The project management team, considering that any lag in the delivery time of the final product must be prevented, because it would harm the reputation of the project administration company, decided to cover the time scheduling deviation, by proceeding in increasing the number of the shifts in some work activities and hiring extra subcontractors, so as to increase the labor capacity involved in the project. As a result of that situation, cost efficiency of the chilled water system (CPI) at completion was lower than 1, and particularly there was indicated an about 3.5% deviation from the ideal progress in the 'cost side' perception of the project. At any case, all problems that dealt with during that project, were recorded and the experience acquired is valuable for improving the management efficiency of similar future projects.

b) Conclusion about the usage of ERP, Epoptia and ABS Engineering Manager, as well as the integration of them as a complete project management tool: As for this section, it should be mentioned that the role of three software/platforms is very important and helpful for the management of a marine vessel's modification projects. Particularly, the ABS Engineering Manager platform, deforms a 'quality baseline' for the project, as any deviation from the planned quality specifications is identified either by the project administration company or by class society. Additionally, this platform is a useful communication tool of the various stakeholders, and an approval tool of the corrective actions needed, in case that quality deviation from the initial project plan, requires approval from the stakeholders that have access on the ABS Engineering Manager platform. The ERP software is proved to be a good tool for official records of the cost analysis data of the project, as well as a supply chain management tool. As it was mentioned in previous sections, the orders of the components necessary for the manufacturing of a product, can be handled and the delivery time and cash flow required for them can be easily monitored. All the data recorded on

this software can be extracted in a spreadsheet type form, for further usage. The Epotia production line monitoring platform, can help significantly for the monitoring and control of the technical activities of a marine modification project, by means of recording precisely the actual completion time required, supporting the decisions about corrective actions needed and supporting the precise calculation of the actual labor costs. Regarding the integration of these mentioned tools, even the simplest form of integration in an excel file, offers the project management operators a powerful complete project management tool. However, the need for manual adjustment of it (like manual update of the data/cells and modification of the mathematical functions used) by the operator makes the usage of it, little tricky. For this reason, the form of the integrated tool can be upgraded, as it is going to be described in the next chapter of this essay.

c) Conclusions about the implication of ML technology for creating a prediction and decision support tool focused on marine vessel's modification projects: The ML implementation in project management sector, can have a crucial role in improving the efficiency of marine vessel's modification projects. This role can be taken, because of the prediction capabilities that can be given to the project management team, warning them about low time scheduling and cost efficiency of potential projects. The proposed ML model on the particular thesis, is driven by identifying the various factors that can effect on the success of a project. So, identification of those factors leaded in defining them as attributes of the ML model. The importance of each factor, and so attribute, by means of which is represented on the model, on the final result leaded to the defining a particular weight of each attribute to the ML model. This model can be very helpful as a decision support tool for project management operators. However, because of the fact the efficiency of a ML model, is correlated with the size of the data used for the training and testing of it, it is required a detailed research to made in the future, so as the model to be optimized, either by the modification of the attributes used, or by the configuration/adjustment of the weight values of each attribute included.

7.2 Conclusions and development proposals

Regarding the development proposals of the particular project thesis, it's estimated that there is essential potential of improving the project management tool of vessel's modification projects, expanding the existed research in 4 different sections:

a) Increase of data collection reliability: The analysis of the vessel's modification project and so the conclusion that were made about this, as a special type of constructional projects, is based on a series of data collected for the project 'installation and manufacturing of chilled water system on a trenching support vessel'. Particularly, the data used for the analysis made on this thesis, are collected by sources like official project documents (project components invoices, drawings, etc.), project manager's & project team member's periodical reports, interviews of technical staff, technical activities feedback forms filled in by the technicians, data records of team leaders on board during the installation of the chiller unit on the vessel, IT automated collected data (like Epoptia production line's monitoring platform). The reliability of some data, like those collected by official documents and by means of Epoptia are on very high level, but the reliability of the other data can be further improved. For the data collected as feedback of technical staff involved in manufacturing activities in Psyctotherm's facilities, and the respective installation activities onboard, it can be created a special feedback form, so as the answers given by the people that filled in them, to be really helpful for the prevention of problems dealt with during last projects and improving efficiency of technical activities executed by them in respective future projects. Most importantly, it was already mentioned that the data collected about the chilled water system's installation activities onboard, are manually collected by the reports and additional records, made by the leader of the technical staff onboard. The usage of an IT based monitoring platform, like Epoptia in the stage of installation of the unit onboard, could increase significantly the reliability of those data, as the completion time records of each technical activity can be precisely recorded and important notes about the evolution of the works can be recorded on time, personally by the executors of the activities.

b) Increase of the data size of the vessel's modification projects: The analysis of the vessel's modification project and so the conclusion, that were made about this, as a special type of constructional projects, are based on the project 'installation and manufacturing of chilled water system on a trenching support vessel'. To make the proposed project management procedure of this thesis representative in a more generalized form, it is necessary to add extra data for our analysis. This means that it is required by future researchers, to proceed in the analysis of additional vessel's modifications projects. As it is obvious, the results of the particular project analysis and the conclusions derived by them, are dependent on factors like the type of the ship that the new system is going to be installed, the age of the ship as well as the type of it. So, ideally the extra data that

must be collected by other vessel's modification projects, have to be a combination of projects partly or totally different in relation with the various factors mentioned above.

c) Improvement of the proposed integrated project management tool: As it has already mentioned, the proposed integrated project management tool has a very simple form of spreadsheet type file, combining information about project's time, cost and quality, as collected by Epoptia, Entersoft, and ABS Engineering Manager. By means of this integrated tool, the necessary data are manually recorded, represented in arrays and processed using functions and further capabilities of the Microsoft Excel software. The results of the data process are filling in spreadsheet cells, that represent project's performance indicators, summarizing project evaluation data, like actual total costs, as well as they are used for creation of a series of graphical representations about the whole evolution of the project lifecycle. Of course, despite the usefulness of this tool, the simplicity of it demands the effort of the operator for manual update of the data, and in some cases the modification of the mathematical functions' various parameters. Additionally, the illustration of the created graphs is limited by the capabilities of the Microsoft Excel. For upgrading such a tool, it is proposed the modification/upgrade of the tool in an application form, instead of a simple spreadsheet type file, using a programming language like C or Python. In the meanwhile, in cooperation with the developers of Epotia platform and ERP software, it is possible the data of them, to be autonomously extracted periodically, to file type readable by the upgraded application form of the integrated project management tool. As an option for this, it could be the usage of Microsoft Access capabilities as well. Moreover the upgraded form of the tool will be able to cooperate with a graph creating software for creating graphical representations of the project monitoring data and evaluation results, in a quality much higher than the one that is offered by the Microsoft Excel. Finally, the developing of project management tool in application form of a well known programming language, can make a tremendous advance in the GUI, making the interaction of the tool with the operator very easy and so the decision support on the project management by it, even more effective.

d) Improvement of the proposed machine learning algorithm: The proposed ML model, is based on the reasonable impact of the various factors, (like age of the ship, type of the ship's subsystem to be modified and others), on the completion results of a vessel's modification project and so on the prediction of the particular results. As extra case data from additional projects are added for

the training and testing of existed model, it is may shown, that the proposed model (the existed attributes and the weight values of them), needs modification, either by removal of some attributes, addition of some others and changing of the respective weight values of the existed attributes. So, considering the importance of a number of factors on completion results of a project, and the limited number of case projects in which there was access, proceeded to a particular ML model. However, as new data from more case projects are added by other researchers that would like to continue this thesis, it is may proved, that the prediction capability of the existed ML model of this thesis is poor, and a substantial modification of the proposed ML prediction model must carried out by future researchers of similar thesis subjects.

References

American Bureau of Shipping(2018). *Rules for Building and Classing Marine Vessels* (1rts ed.).

Chryssolouris, G., Mourtzis, D., Makris, S., Papakostas, N. (1999). A Planning and Control Method for Shipyard Processes*,* 10th International Conference on Computer Applications in Shipbuilding , Massachuasetts, USA

Eyres, D., J., Bruce, G., J.(2012). *Ship Construction* (7nd ed.). Elsevier Ltd.

Mitchell,T.(1997). *Machine Learning* (1rts ed.). McGraw-Hill Press.

Muller, A., Guido, S.(2017). *Introduction to Machine Learning with Python* (2nd ed.). O'Reilly media.

Neeraj, K.(2015). *Construction Project Management: Theory and Practices* (2nd ed.). Pearson Education.

Philip, A., Francis, N., Guido, S.(2023). *Automated Project Management System,* National Conference on Emerging Computer Applications

Project Management Institute.(2004). *A Guide to the Project Management Body of Knowledge* (3rd ed.). Project Management Institute

Shai,S.,S.,S., Shai, B.,D.(2014). *Understanding Machine Learning: From Theory To Algorithms* (1rts ed.). Cambridge University Press. http:// 10.1093/oso/9780198828044.001.0001

Smola,A., Vishwavanath, S.V.N(2008). *Introduction to Machine Learning* (1rts ed.). Cambridge University Press

Appendices

Appendix 1. Project management knowledge areas

Project Integration Management: This area has the role of identification of links and relations between activities of the various project management groups, and includes all the activities and processes required, so as the results of the various activities of each group to interact and be combined in such a way, so as the objectives of the project to be achieved, the specifications of the final developed project to fulfill the initially planned specifications of it, and concluding the project to be able to cover the needs of the costumer. This role is crucial because in real projects usually the activities of a group are not distinct by the ones' of other groups, but all together are carried out on an integrated way, making an impact on the results of other (Project Management Institute, 2004). For example, a cost estimate for a whole or a part of a project in the planning stage (and so a planning process), is dependent not only on factors and processes included in the cost management area, but also to those that are in content of time management area, risk management area, human resource management area. Most importantly, in case of competing project objectives, integration management supplies the tools to make the optimum trade offs between these objectives and processes needed for possible revisions on the initial objectives. Processes of this management knowledge area are: Develop Project Charter, Develop Preliminary Project Scope Statement, Develop Project Management Plan, Direct & Manage Project Execution, Monitor & Control Project Work, Integrated Change Control, Close Project (Neeraj, 2015).

Project Scope Management: This area includes the processes required, so as to secure that all works, tasks and objectives are included to the project, so as the project to be successfully completed, according to its scope (Project Management Institute, 2004). In the same way, implementation of scope management's processes, acts as guideline, for suspending any useless activities and objectives that are meaningless to the final scope and decrease the efficiency indicators of project. Processes included in this area are: a) Scope Planning, b) Scope Definition, c) Create WBS (work breakdown structure), d) Scope verification, e) Scope Control (Project Management Institute, 2004).

Project Time Management: It is one of the most important knowledge areas of the project, as it includes all processes required for prediction, monitoring and control of delivery times (times of

completion) of all tasks required for the successful execution of the project (Project Management Institute, 2004). So, it includes cornerstone activities like:

a) Activity Definition: It includes the identification of the required tasks to be scheduled, so as the objectives of the project plan to be achieved.

b) Activity Sequencing: It's about identifying the connections and relations (dependencies among them) of the required scheduled activities/task and creating a presentation of those connections. The result of the Activity Sequencing process is an arrow diagram of scheduled activities.

c) Activity Resource Estimating: This activity's role is to estimate the qualities and quantities of resources required on each project task. Actually, estimation includes training background of human resources, the size of the team, the specifications of machinery and tools, as well as the necessary number of them (Project Management Institute, 2004).

d) Activity Duration Estimating: This activity is about the estimation of the time needed for completion of each scheduled project task. This activity is based on the experience of the project management team to define the time requirement of each activity, identifying the special difficulty factors of the project in correlation with the specification of human resources involved and any constrain, that exist to the project (Project Management Institute, 2004).

e) Schedule Development: It's the activity of analyzing tasks flow chart (arrow diagram), duration of tasks, resource requirements and schedule constrains, so as to create the project schedule. In most of the cases, the result of this activity is a Gantt chart, that depicts the project's time plan (Project Management Institute, 2004).

g) Schedule Control: This is to control any potential change to the project schedule.

Project Cost Management: The processes of this area have a tremendous impact on the successful completion of the project, as cost efficiency is the most important index that project's customer usually focus on. The processes of this area aim to the planning, estimating, budgeting and controlling cost, so as the actual final cost does not exceed the initial budget. The processes of this category are strongly related to processes of other knowledge areas, like time management and human resources management (Project Management Institute, 2004). Processes included are:

a) Cost Estimating: It's role is the estimation of the expected cost of resources (both material and human), necessary for completion of scheduled tasks.

b) Cost Budgeting: It's the process of aggregation of the separated tasks' estimating cost, to conclude to a total project budget cost. This budget cost is used as baseline for Cost Control process.

c) Cost Control: It's the process of controlling the actual project costs, within the budget baseline. This is achieved by monitoring the cost and taking corrective actions, whenever cost variations are identified (Project Management Institute, 2004).

Project Quality Management: It includes all the processes implemented by the manufacturing company, to develop quality policy and define quality objectives and responsibilities. By means of the combination of this category's processes, the company implements a quality management system, necessary for assuring that specifications of the final project/product will be aligned with the planned specifications, that fulfill customer's satisfaction (Neeraj, 2015). Processes are:

a) Quality Planning: This process aims to the identification of quality standards that must be used, so as the specifications of delivered project to be as planned, as well as the way, that those standards can be implemented (Project Management Institute, 2004).

b) Perform Quality Assurance: They perform the selected ways of implementation of the necessary standards (those identified above), so as the quality level and desired specification of the final project to be assured (Project Management Institute, 2004).

c) Perform Quality Control: It facilitates the procedure of quality monitoring of the project, during the various execution stages, as well as the ways that corrective actions will be taken, in case that variations from the planned quality requirements are identified (Project Management Institute, 2004).

Project Human Resource Management: Those processes' purpose is to organize and manage the project team. They are involved in issues of identification of human resource requirements of the project (the size of the human resources capacity as well as the characteristics of it), the qualifications of the individuals, the training needs of the staff, so as to keep up with the project tasks' needs, allocation of roles to the team members and respective roles to the subcontractors (Neeraj, 2015). Processes are:

a) Human Resource Planning: Identifying project roles and responsibilities, as well as the relations between the people by whom the roles are taken over (Project Management Institute, 2004).

b) Acquiring Project Team: Creating the team by giving a role to the existing staff, hiring new employees or making an agreement with a subcontractor (Project Management Institute, 2004).

c) Develop Project Team: This process aims at improving the performance of the team, either by upgrading the competences, by means of training, or by enhancing the interaction efficiency of the team members (Project Management Institute, 2004).

d) Manage Project Team: It's about monitoring performance of the team, dealing with team's issues harmful for the project and taking corrective actions to improve the project efficiency (Project Management Institute, 2004).

Project Communication Management: This area employs all activities relevant to the collection, storage, retrieval and distribution of information, so as to be easily accessible to all stakeholders.

By means of this area, the effective information management is achieved and the optimal decision making is performed (Neeraj, 2015). The components of this area are the following:

a) Communication Planning: Defines the information must be collected, stored and distributed among stakeholders, during the project development (Project Management Institute, 2004).

b) Information Distribution: Defines the ways that necessary information can be distributed among stakeholders (Project Management Institute, 2004).

c) Performance Reporting: It includes documentation relevant to the performance of the project, as well as it defines the methods of collection, distribution of the particular information (Project Management Institute, 2004).

d) Manage Stakeholders: Managing communications issues, with regard to the interaction of information among stakeholders (Project Management Institute, 2004).

Project Risk Management: This group includes processes relative to the identification, mitigation, monitoring and control of potential risks on a project. So, the target of the project risk management is to prevent an unexpected event, lower the possibility of such an event to happen or lower the negative impact, in case that it finally was not prevented (Neeraj, 2015). So, this knowledge is considered as one of the most important, to assure the smooth completion of a project and the safety of the people involved. This category's range consist of the following processes:

a) Risk Management Planning: It creates a framework of risk management activities, covering the stages of plan to execution (Project Management Institute, 2004).

b) Risk Identification: It filters the risks, so as to find those that have impact on the success of the project and record their characteristics (Project Management Institute, 2004).

c) Qualitative Risk Analysis: This process is to rank the potential risks, by analyzing the probability of occurrence and the impact of such one (Project Management Institute, 2004).

d) Quantitative Risk Analysis: Concludes to the effect of a risk on the objectives of a project based in a numerical form, for better prioritizing (Project Management Institute, 2004).

e) Risk Response Planning: It's about the development of a plan that should be followed, as guideline for taking preventive and corrective actions of the identified risks (Project Management Institute, 2004).

f) Risk Monitoring and Control: It's the process of monitoring risks, executing correction actions, according to the response plan, observe the results of correcting actions and reassess the existing risk response plan (Project Management Institute, 2004).

Project Procurement Management: This final knowledge area includes the processes of purchasing and acquiring resources, externally of the teams environment. Particularly, the goods are going to be acquired are raw materials, components as well as contract agreements for works using human resources of subcontractors (Neeraj, 2015). Main processes are:

a) Plan Purchasing & Acquisition: It makes a scheduling of the required purchases of a project (Project Management Institute, 2004).

b) Plan Contracting: It's about documenting the requirements of products and services, with the aim of making a research of the potential sellers (Project Management Institute, 2004).

c) Request Seller Responses: It includes collection of potential suppliers proposals (documents about costs and technical specification of offered materials) (Project Management Institute, 2004).

d) Select Sellers: It ranks the sellers and derive the optimal selections among them (Project Management Institute, 2004).

e) Contract Administration: It's about managing the agreement between the sellers and the buyers. By means of this process all details about delivery times, payment terms, and corrective actions of suppliers (in case of defective product) are clearly written.

f) Contract Closure: it involves the procedures needed for smooth completion of contract (Project Management Institute, 2004).

Appendix 2. Project stakeholders

Project Mananger: This person is the one on the top of the pyramid, as he/she is responsible for the project and the one that acts as the central connection link between all other stakeholders. Usually, in marine vessel modification projects, this role is given to a person employed by the installation company of the new installed/modified system. So, actually project manager is an employee of the project administrative organazation (Project Management Institute, 2004).

Customer: He/she is the person that is going to use the results of the project's accomplishment and expected to receive the highest benefits from the success of it. So, usually it is the one with the highest interest and motivation, through the project development procedure. In the case of marine projects the role of customer is taken be the shipping company, into the ship of which the modification project is implemented (Project Management Institute, 2004).

Performing Organization: It is the company the employees of which are involved in the highest level to the execution on the project. Actually, the stakeholder customer is actually the customer of the perfoming organization and it is immtiately connected with it. One of the employees of preforming organization is the project manager too (Project Management Institute, 2004).

Project Team Members: Project team members include all the people that take part to make the project happen. In a case of a marine project, it inlcudes all the technical staff and non-technical

staff of the companies that are involed to the execution of the project. On a vessel's modification project such a stakeholder type includes the main installer/manufacturing company, material & equipment suppliers, subcontractors & techical service companies, shipyard (Project Management Institute, 2004).

Project Management Team: The members of the project team, that are responsible for the accomplishment of the project managment activites. This team is directed by the project manager.(Project Management Institute, 2004)

Sponsor: If a project includes a sponsor, it is the organization or person that supplies financial resources necessary for the execution of the project. In marine modification projects, banks that provide a loan to the customer (shipping company), may have such a role. On different cases, the customer is the one and only individual that financially supports the project (Project Management Institute, 2004).

Influencers: This category's base is teams and organizations that act as lobby or against the successful competion of the project, as they have intermediate interests on it. Enviromental lobbies can be mentioned as common stakeholders of this type, as they are able to make pressure on the development marine vessel modification project. Customers' of the shipping company can be another influencer stakeholder in some cases (Project Management Institute, 2004).

Authorities: This type of stakeholders, is one of the strongest, that can effect on the scope and objectives of the project, influencing the project procedure, by forcing the project management team to make changes to the initial plan or take corrective actions, as the project is proceeding. In authorities stakeholders of a marine project are included, flag state of the ship, the IMO. The first one is the country, on ships list of which it is registered the ship to be modified . Both first one and third one implement the rules that the vessel should follow during its opearation, and the second defines speficiations that ships should fulfill, so as to give their assurance about ships capability to operate, according the rules of flag state and IMO.

Appendix 3. Project phases

Initial Phases: Certainly, the outputs of it, are such as scope definition and the project objectives definition and so includes the processes that lead to those deliverables.

Intermediate Phases: consists of deliverables from documentation type, like planned and actual cost analysis reports and technical drawings to execution results, like the manufacturing of a part or whole of project, and so includes the processes and tasks related to those outputs.

Final Phase: It includes final test, delivery and conclusion documentation.

Appendix 4. Project management process groups

Initiating Process Group: It includes all processes must be done, to authorize the project management team and manager to start the new project (Project Management Institute, 2004). By means of these processes, the project description, scope, requirements, objectives, expected delivery time and resources are defined and clearly documented, after the completion of a series of meetings between the crucial stakeholders.

Planning Process Group: It includes the collection of all information created by the Initiating Process Group and those derived by the experience of the project management team acquired dealing with similar projects in the past, and analysis of the specific data, so as to develop the group of plans, necessary for the exection phase of the project (Project Management Institute, 2004). The results of this group, are the develpment of the project management plan, as well as the documentation of the official project scope, deliverables, techical datasheet & drawings, cost budget plan, planned schedule, planned resources requirements, all justified by proof based calculations.

Excecution Process Group: It cordinates people and resources, following the information documented into the project management plan and other documentation, in which the processes of the previous group concluded (Project Management Institute, 2004).

Monitoring & Controlling Process Group: It includes the processes of Check & Act, that are followed on each process of the execution group (Project Management Institute, 2004). The current conditions of the project in the frame of time cost, resources, objectives and quality are compared with the identical ones, as documented on the respective planning records. In case of deviation identification in actual conditions in relation to the plan, the process of this group provides also either change proposal or takes actions required and any objectives' trade offs needed, so as to align the current condition with acceptable project requirements (Project Management Institute, 2004).

Closing Process Group: The processes executed, have the aim of officially signify the termination of the project with a successful or not result (Project Management Institute, 2004). All documention must be given to the customer, is collected and all supplementary task (like accounting and contract tasks) are accomplished following processes of this group.

Appendix 5. Project Management tools

Project Integration Management:

a) Project Management Information System: It supplies the project management team with a software type tools, by means of which they can control all changes that must be done to the project, identify all the components of the project that are affected by these changes (for example which documents of cost management area have to be modified), apply revision of any affected part of the project (for example budget baseline), automatically ask for revised documents to be approved and auto-substitute the documents to be modified with the respective revision on a common project document data base.

Project Scope Management:

a) Stakeholders Meetings: it's the most interactive way of communication between the stakeholders. This takes place firstly, when the specifications of the product, and so the scope of the project should be initially defined. It is repeated again, when there is a need of change on the project, that result in a revision of the scope. So, the modified scope is communicated, any trade offs are assessed, and the modified scope is approved.

b) Scope Statement Documents: It includes the official, clearly written recording of the scope of the project, as it is discussed and approved during the stakeholders meeting.

c) Work Breakdown Structure Document: This is a cornerstone document of a project, as it is a representation of all activities must be executed by the project management team, so as all the objectives to be accomplished and the deliverables to be created. The WBS has hierarchy based decomposition form of project, so as the lowest size components, known as work packages can be scheduled, cost estimated, monitored and controlled(Project Management Institute, 2004).

d) Scope Planning Document: It is the document, where the specifications of the project are listed, as well as the analysis of them, in combination with the competency of project management organization and the result of this analysis (which is the planned scope of the project), are officially recorded.

Project Time Management:

a) Project Team Meetings: These meetings take place periodically, in pre-defined time as a way to revise monitoring of the projects proceeding conditions and discussing any proposals for required correcting actions, before ask contribution of rest stakeholders(if the situation demands such one).

b) Work Breakdown Structure Document: As described earlier.

c)Scheduling Planning Document: The role and the structure of it, is as described in project scope management tools' section.

d) Gantt Chart: this is the most usual schedule monitoring tool used on project management. It can be created either by using a spreadsheet based software or other specialized software application. This scheme represents the various project activities to be carried out, in the form of horizontal bars. The horizontal axis of this chart represents the process time of the project(Project Management Institute, 2004). The start (left end) of each bar is set to the start time of the particular activity, whereas the end(right one) is set on the ending time of the activity. The length of the bar is proportional to the duration of the specific activity. All the bars are arranged in a top down form, with the earlier tasks to be positioned on the top. The scheduling of the project with this chart is very convenient, as any overlapping of 2 bars in relation to the time axis, represents ability of these tasks to be proceeding

concurrently, whereas any constrain that requires one task to be finished before a second starts, is shown with 2 non-overlapping bars(the start of the downstream is fixed to the end of the upstream)

e) Activities Arrow Diagram: It is network logic diagram, by means of which the projects activities, as well as the interrelation between them, can be represented in clear form of a sequence of arrows. The arrows represent the activities of the project and the intermediate nodes, the connections between them. Along each arrow is noted the duration of each activity, and inside each node is written the finish time of the node (the day number when all arriving activity arrows are to be completed) (Project Management Institute, 2004).

Project Cost Management:

a) Stakeholders Meetings: It's most interactive way of communication between the stakeholders. This takes place initially at the planning phase, so as the planned budget to be presented to the stakeholder, and the cost baseline to be defined. It is repeated, when a discussion and approval with stakeholders participation is required about cost baseline modification or a cost variance identified.

b) Budgeting Statement Documents: It is an official analysis and final cost recording in written form, that is communicated to all stakeholders and can be used or be revised when it is necessary.

c) Spreadsheet Type Software: It is the fundamental tool for recording resources, costs, analyze data, process the respective cost, making cost calculations and creating cost baselines for monitoring and controlling the project cost.

d) ERP Type Software: It is an advanced resources and accounting management software that can be used, as powerful tool cost monitoring tools. Using this, project management team is able to record all the information details of suppliers, accounting details of materials, as well as complete material list of used/consumed resources of the project. All accounting documents, like official offers and invoices of suppliers, can be uploaded on the database of ERP, as well as cash flow directed to those suppliers can be monitored. Special alarms can be configured on the project database of ERP, so as an alarm to be triggered, when are appeared deviations on the cash flow, in relation to the supplier's payment scheduling.

Project Quality Management:

a) Stakeholders Meetings: This take place initially at the planning phase, when the quality standards to be followed and specification of the manufactured system must be defined, in agreement with the stakeholders. It is repeated, when a discussion and approval with stakeholders participation is required about potential quality deviation is identified or quality trade off must be done

b) Project Team Meetings: It take place between project team members, when quality assurance issues must be discussed, without the presence of stakeholder meetings.

c) Quality Control Metric Forms: It includes the documentation of quantitative tests made, so as the alignment with quality standards and planned specifications to be assured

d) Spreadsheet Type Software: It is used for the statistical analysis of the data collected by quantitative quality tests

e) Quality Control Checklist: It is the most clear way of conforming that the specifications of the manufactured product are identical with the planned ones.

g) Commissioning Test Form: It's the guideline of the final test should be made, before official delivery of the project to the customer.

Project Human Resource Management:

a) Project Team Meetings: It's the main way of communication between project team members, to make a decision about necessary corrective actions. On the sec tion of human resources management, the decisions taken by the meetings, are focused on the allocation of human resources, the employment of additional personnel or the outsourcing of some activities.

b) Activities Arrow Diagram: The role and structure of it, is the one described on time management area.

c) Employees Competency Assessment Forms: They are the tools for collection data about the competency level of the people involved to the project or those that are going to be involved. The result of the processed data is compared with the personnel competency requirements, according to project objectives to be achieved. So, this tool is used as decision support tool about a creating the technical staff team, that is able to execute successfully the projects activities.

Project Communication Management:

a) Meetings

b) Documentation Database

c) Specification List.

The communication form between the people involved in the project, includes some interactive ways like periodical or urgent meetings for discussing various essential issues and making respective decision. Additionally, all crucial information are communicated, by recording of official documentation in a common database accessible by part of total of stakeholders group. By means of this way, all are informed about the current and planned data of the project and are able to give their feed back about the current situation.

Project Risk Management:

a) Specialists Risk Audits: These audits can be done by internal employee of the project management organization or employee of subcontractor, responsible for such a duty. The scope of this, is to identify any risky conditions that exist or going to be appeared in the execution phase of it, and are possible to get the project completion or the life of the participated people in danger.

b) Accident-Near miss Statement Forms: these forms are filled in, by the people participated in project execution, to record either events that they were witnessed possible to happen accidents (according to their experience). The data provided by those forms can upgrade the risk assessment matrix.

c) Risk Assessment Matrix: It is the fundamental risk management tool. For implementation of this tool, any risk is recorded, as a separate row of the matrix. The columns of the matrix represent the probability of occurrence and impact of occurrence of each risk. From those columns/data the severity of each risk calculated and so need for a risk response is decided (Project Management Institute, 2004).

d) Risk Response Matrix: It's the official written notation of the way that each risk must be dealt with, depending on its severity. So on this document, for each risk/row

of the risk assessment matrix, a guideline is given about if and how the risk is mitigated or prevented, or if any trade offs on the project quality time or cost must be done, so as to lower the risk in acceptable levels.

Project Procurement Management:

a) Stakeholders Meetings

b) Budgeting Statement Documents

c) Spreadsheet Type Software

d)ERP Type Software

e) Gantt Charts

f) Activities Arrow Diagram.

These are the main tools used on project procurement management and their way of application is already analyzed.

Appendix 6. Project management evaluation methods

Cost Based Evaluation: As for measuring the performance of a project, regarding its cost efficiency, the main measuring criterion used is called Cost Performance Index (CPI), and it is expressed by the mathematical formula CPI= EV/AC. The parameter AC is the actual cost of the preformed works (total costs accumulated) until the evaluation date. The parameter EV is called earned value, and actually is the budgeted cost (total planned costs accumulated) of the works performed, until the reporting date of the evaluation results. As it is obvious, a value CPI <1 results in EV < AC and this means an efficiency lower that the planned one(Neeraj, 2015). Particularly, it means that until the moment of evaluation the project, it costs actually (AC) more than was expected, in comparison with the respective cost, according to the project management plan (EV). Additional cost evaluation parameter to be used, is cost variance (CV), expressed with CV= EV-AC and measures how much the actual cost, up to the reporting date, exceeds the planned budgeted cost (Neeraj, 2015). Exempt for the monitoring role of the cost parameters mentioned above, usage of the cost evaluation methods/parameters can be upgraded to a prediction tool of the project development progress. For this reason another estimation index called EAC ('estimated cost at completion') can have the two forms as followed:

a) EAC= AC + (BAC -EV), where the BAC is called Budget at Completion and is the value defined to be the expected final cost according to the project plan (Neeraj, 2015). In this form, it is expected that the deviation that happen up to this point, is the only that have happened to the project cost (and so it is considered that the rest phases will proceed with the planned efficiency, and so the EAC is going to be equals to BAC+CV (Neeraj, 2015).

b) EAC=BAC/CPI. In this form of the final cost estimator, it is considered that the cost efficiency of all project duration is constant and equals to the one measured the date of evaluation, and so the EAC follows the particular trend.

Time Based Evaluation: With regard to the project schedule evaluation, the most usual parameter is called Schedule Performance Index (SPI), and it is expressed by the formula SPI= EV/PV. The parameter PV is the amount of all budgeted costs, until the evaluation date. The parameter EV is identical to the one described in cost evaluation method. Considering that formula of SPI, a value SPI <1 result in EV < PV, and this means an efficiency lower that the planned one(Neeraj, 2015). Particularly, it means that until the moment of evaluation, the Earned Value is lower than the Planned Value, as the project participants didn't manage to reach the objectives completion level, that was expected according to the plan.

Quality Based Evaluation: For evaluating the project by the 'quality angle of view', a series of quality control checklist should be used, and the records should be compared with the quality standards defined by the scope management plan or the execution management plan (Project Management Institute, 2004). The quality evaluation can be quantitative, qualitative or mixture of them. If the evaluation is of quantitative type, the collected data may be processed by some statistical methods. In case of ship modification project, quality evaluation can be FAT (factory acceptance tests) or other parts of manufacturing quality control process.

Appendix 7. Shipyard's vessel modification activities

Drydocking of the Ship: Depending on the type of modification works that should take place into the vessel, this should be removed from the water, so as any area of its hull to be accessible to the technicians of the shipyard. During this process, the ship enters to a special tank, called drydock,

which is flooded with water. Secondly, the drydock is drained letting the ship to rest on a keel block structure located on the bottom of the drydock(Eyres & Bruce, 2012).

Hull Cut-Hatch Creation: The second activity that must be completed during work activities on a shipyard, is the cut of the vessels hull. This is needed to create a passage to the ''boarder'' of the ship, so as to permit the transferring of materials from the vessel or into the vessel. By means of this activity, the components to be replaced, are going to be removed and the new components to be installed, are going to transported to the final installation location into the hull.

Piping Discharge-Drain: Any old system to be replaced is connected with an existed piping network (in liquid or gas phase) of the vessel. Prior to the disconnection of the system with the particular piping, it is mandatory the piping to be drained (Eyres & Bruce, 2012). This process takes place using the drain valves existed on any piping system and the process can last few minutes to several hours, depending on the size of the piping system.

Old Piping Removal: The old piping can be manufactured with threaded connections, welded connections or a combination of them. So, this work activity is executed by the piping specialist subcontractor, who cuts pipes or loose threaded connections respectively.

Obstacle Removal: In case of a new building, all the subsystems/components are installed, following a logical order. Cause of the fact that this situation does not exist in modification projects, the system to be replaced is blocked by other components. So, during this activity all materials, components and existing equipment that blocks the passage of the new equipment to be installed, must be removed.

Wiring/Electrical Cabling Removal: In case the new equipment requires electrical power supply level, the current of which is too high to be covered by the specification of the currently installed power cable, the existed wiring must be removed. So, the work activities of cut the cabling, loose the mounting components and remove the cables out of the vessel, are 3 stages included on this technical procedure.

Removal of old Equipment: Following the piping and electrical disconnection of the system to be removed, the technical staff involved to the modification of the project must loose or cut the mounting of the old system (if the type of fixation is threaded or welded respectively). Finally, the old equipment have to be pass through all the internal passage inside the ship, up to the hatch created onto the hull.

Structural Modifications: Structural modifications includes the work activities like modification of the foundation of the unit/system to be replaced, as well as this of assistive structural elements for mounting of the new piping, so as both to be suitable to support the system to be installed.

Mounting of the New Equipment/Machinery: This technical work activity includes the transportation of the new equipment, from the hatch to the final installation position. The work activity is completed, when it is completely and permanently fixed on to the modified foundation, created for the new system.

Installation of New Electrical Support Equipment: The work activities of this category are referred to the cabling of new wires, the manufacturing of new electrical panel (if required), as well as the connection of them with the electrical power supply system of the vessel, and the electrical power terminals of the new machinery.

Installation of New Piping: The pipers of the shipyard should proceed to the manufacturing of the new piping network, executing certainly welding processes and finally connect the connection ends of this, with the flange type connections that exist to the new machinery. In the case of the chiller unit's installation, the piping networks to be connected, are both the chilled water piping, as well as the condenser cooling water one.

Recovery of Hull: When the installation of the new machinery is over, the vessel should be recovered to its initial condition. For this purpose all the components temporally removed as 'obstacles, have to be re-assembled and most importantly the cuts on the hull, used as hatches for the transfer of raw materials and equipment, must be closed again (Eyres & Bruce, 2012).

Launching of the Ship: The final activity should take place, is launching of the vessel to the water again. This is a procedure executed based on the smooth sliding of the ship onto the kneel block structure, secured by a special hydraulic mechanism, following the stage of filling up the drydock tank that hosts the ship, with sea water (Eyres & Bruce, 2012).

Appendix 8. Shipyard work sections

Supervisor Engineers: This group includes the people that supervise the execution of various works on the ships, to confirm that everything proceeds smoothly, according to the plan of works (Eyres & Bruce, 2012).

Mechanical Section: This category includes teams of fitters and other technicians, responsible for the installation, removal (and repair where is possible) of the mechanical system inside and outside the ship (Eyres & Bruce, 2012).

Naval Works Section: The works of this section is to install the piping, create the structural elements of the ship and install the wall and deck sheet metal covers. So, the participants of this section are welders, fitters, sheet metal processing specialists, etc

Riggers & Painters Section: This group includes the technical staff responsible to curry out works that take place in height over the ground, like painting and welding of external hull (Eyres & Bruce, 2012).

Technical Support Section: This group has an assistive role, but crucial role for the operation of the shipyard. Some examples of them, are electricians responsible of supplying electrical power to the other sections' of shipyard wherever is required, and firefighters that forms that safety zone for all other employees.

Quality Management Section: The presence of quality control employees is necessary to confirm that the planned manufacturing standards are followed, and that completed constructive parts of the vessels, fulfill the desired specifications. Of course, each section consists of a number of specialist, who are responsible for executing the list of activities, that are required for the completion of the project (Chryssolouris et al., 1999).

Appendix 9. Water Chiller Installation Arrow Diagram

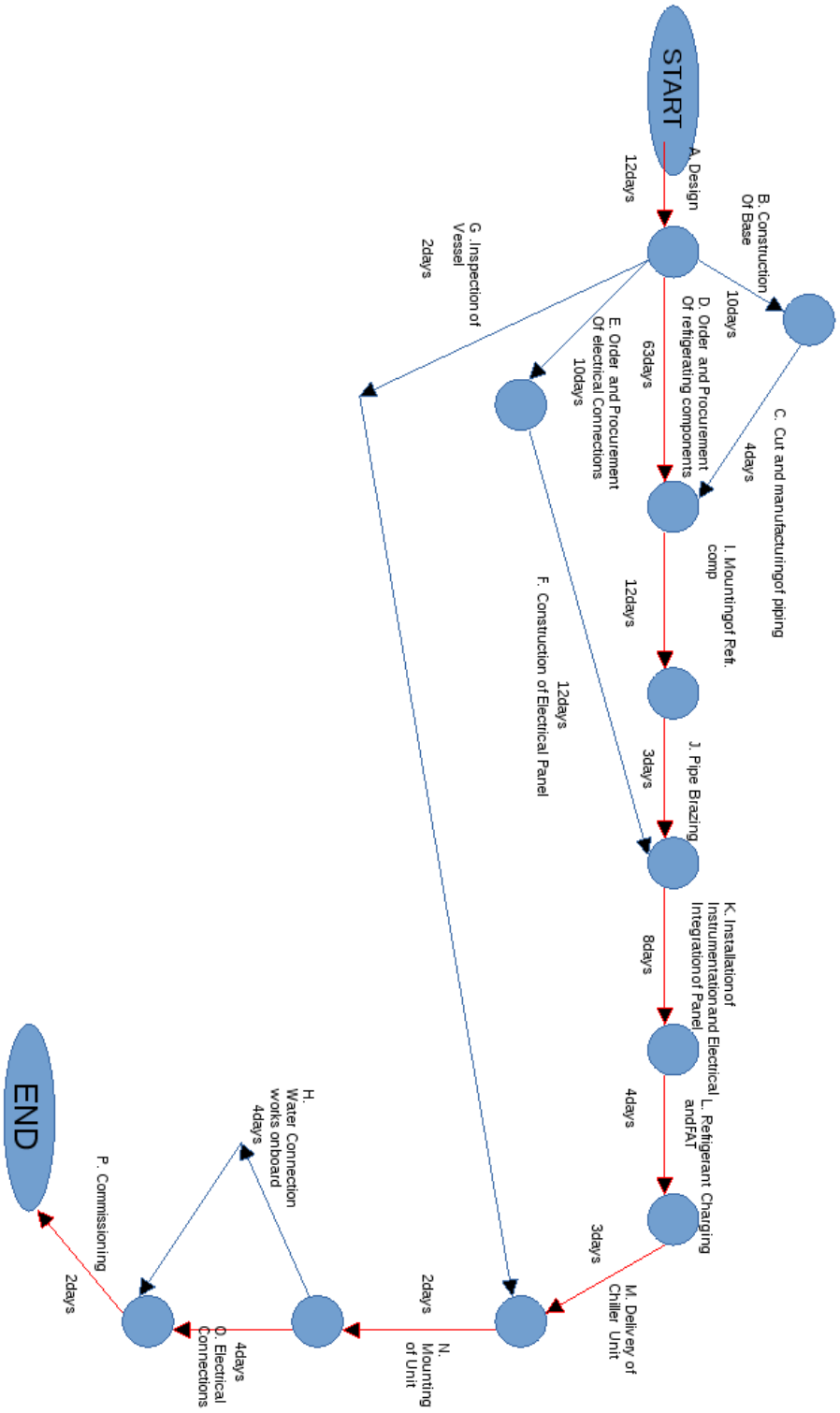

Figure 31. Water chiller project arrow diagram

Appendix 10. Shipyard resources

Manpower/Human Resources: On this resource category are included the staff of all job shops of the shipyard. The manpower of the shipyard consists of the technical personnel of shipyard's it-self, as well as the manpower of the subcontractors that shipyard cooperates with. This resource has the highest flexibility, because in case of poor time performance of a project, the administration of the shipyard can increase the outsourcing percentage of the works (Chryssolouris et al., 1999).

Machinery: This category includes all the machinery used for the accomplishment of the technical works. The level of flexibility is medium, because in case of reservation of some machinery or need for extra machinery capacity, some jobs like sheet metal processing can be outsourced. In other cases, like floating drydock reservation, such outsourcing is not available.

Material Resources: This category includes the raw materials and machine components used for the development of the project. The flexibility of this family is also medium, as some common material can be supplied by various suppliers, but some special components that require high level of know how and high delivery time, cannot be substituted by requesting them by many suppliers.

Appendix 11. Machine learning categorization

Machine Learning applications can be categorized in using 3 main criteria (Mitchell,1997):

a) Type of learning procedure: Supervised learning or unsupervised learning. This is the main categorization of ML algorithms, and it is based on the nature of interaction of the learner with the learning environment(Mitchell,1997). In case of supervised learning, the program is trained by a set of desired twins (input & desired output). So this set is used, as guideline by the program, to conclude in a specific output result for every new input. In case of unsupervised learning, the program does not receive any guidance in form of labeled data (pairs of input & desired output), but detecting abnormality concludes to its independent output results.

b) Type of learning duration and operation duration: This type of distinction is about the duration of the learning process. According to this category, the learning procedure can follow either 'online protocol ' or 'batch learning protocol' and depends on the period that the model is trained and the period that is operational. In the first protocol the learner is online, providing output, receiving input and receiving information about the performance of its output (Mitchell,1997). This means that the learner is constantly receiving new experience, as well as it is fully operated in the same time. In this case, the learner is activated in operation mode, when the training process is completed using a small training set (Shai & Shai, 2014). This practice is followed, when the first experience data is small. This benefit of this practice is that the learning process actually does not stop ever, and so the performance of the program is expected to be continuously improved. The drawback is that the operation of the program, based on the initial small training set, makes it unreliable, and so the performance on that period is really poor. In the 'batch learning protocol', the learning is out of order until a large size of training data is collected (Shai & Shai, 2014). The learner is initially 'programmed' with this training set and after proceeds to turn on of its operation. The learner cannot receive simultaneously new experience, but periodically can be again out of order, take a revision training, using a batch of extra training set, and activated for operation again. This practice is followed, when the first experience data is big. This benefit of this practice is that the initial performance of the model is quite high (as the reliability does so) and faulty outputs are prevented in a good percentage. The drawback is that the performance of the model remains constant and can be improved only periodically in case that it stops operation for 'revision training '.

c) Type of learner interaction: This categorization is made, focusing on the role of the learner during the learning process (Mitchell,1997). This role can be active or passive. In the first type, the learner interacts with the learning environment during the training time, by filtering the data or asking queries. In the second type, it lacks any interaction with the environment (Mitchell,1997). So, the learner observes and uses the training set in the original form that provided to it.

d) Type of Machine Learning Output: This grouping is related to the form that the results of the ML algorithm has. Depending on the problem that ML is going to solve, the result of the program can be quantitative or qualitative (Mitchell,1997). Actually, even in qualitative output programs, the data are interpreted in a numerical discrete form for processing purposes. The categorization of

ML algorithms according to the form of the output, is strongly correlated with the grouping of the first type (learning procedure).

Appendix 12. ML Prediction models description

Cost Prediction Modeling

As the development of model will be based on the data records of the past project, the supervised learning linear regression method will be used. In the form

$$Y= a+b1*X1+b2*X2+b3*X3+b4*X4+...+bn*Xn.$$

which the final model has, Y is the dependent value, that represents the estimated final cost of completion. As for the attributes of the particular model these are:

X1: Budget Planned Cost. This is the initial estimated cost of project's completion as derived from the project planning phase.

X2: Complexity of the Project. This attribute value range is between 0 to 100 and depends on the importance of the subsystem of the ship to be modified or replaced, as well as the complexity of it from technical perspective. If it is a main system of the vessel, the quality standard of the modification project is expected to be quite high, increasing the cost of the project. The same happens if the installation of the new subsystem needs the integration of the subsystem with a number of other ship's subsystems. For example the number of piping networks that it should be connected with, is a factor that is represented by this attribute.

X3: Age of the Ship. This attribute correlates the cost of the project's works, with the age of the ship. It is obvious that an old ship requires a number extra works to be executed, so as to be suitable for integration of a modern subsystem. Additionally, in an old ship, there is the risk of failure of a subsystem supportive to the one to be installed (for example piping, foundation, wiring), that it is possible to create extra non initially predicted costs for servicing the failure, before proceeding to the initially scheduled activities. This situation can be considered as a fact that potential project changes are possible to be more extended to an older ship than a younger one. This attribute's

range is between 0 to 100 in depending on if the age of the ship is 0 to 50 years.

X4: Experience Ranking of Project Management Team. This attribute correlates the level of competency of the project management team, with the final cost of project's completion. The main idea of this attribute is, that a project management team with high competency level and experience on similar projects, is expected to make the initial decisions and take any corrective actions, during the project's development lifetime, so as any unexpected cost to be lowered. The values of this variable are also between 0 to 100.

X5: Type of the Subsystem To Be Modified. This attribute accumulates the difficulties that appear to a vessel's modification project, and are related with the type of the subsystem to be modified. Depending of the type of this, extra risk factors like removal of obstacle-equipment or drydock procedure is required, which may lead to increased final cost.

X6: Subcontracting Works Ratio. This parameter is used, so as to be accounted the percentage of the works that are executed by the subcontractor companies. The dependency of the project administration company by subcontractors, decrease the flexibility of company to take any corrective actions with limited cost. Values given 0 to 100.

X7: Competency Level of Subcontractors. The level of competency required by the subcontractors is a crucial factor for the success of the project. The need for high competency level, means demand for high quality standards. However, such a high level requires, a respective high payment. In case that it is required extra workload by those highly qualified subcontractors, the working costs of the project are estimated to be increased. Value range is 0 to 100 with latter one to represent the high competency level.

Delivery Time Extension Modeling

The scheduling time prediction ML model has also the form of linear regression method

$$Y= a+b1*X1+b2*X2+b3*X3+b4*X4+...+bn*Xn.$$

where, Y is the dependent value that represents the extension time of delivery time. As for the attributes of the particular model these are:

X1: Planned Project Duration. This is the initial estimated time required for the project to be delivered to the final customer, as derived from the project planning phase. The measurement units used are days.

X2: Complexity of the Project. Like mentioned on 'Cost Prediction Modeling' part, the complexity of a project is related with technical issues exist in the system to be modified. As it is obvious, it is a factor that can easily create deviations from the planned schedule and specifications. This means firstly, that the special technical issues require a special process of management, that increases the planned time of completion and secondly that the alignment of specifications of the delivered product with the desirable ones, is achieved only by a number of corrective actions to be taken, during the project life cycle, that leads to a modification of achieving the objectives.

X3: Age of the Ship. This attribute correlates the duration of the tasks derived by the work breaking structure, with the age of the ship. The concept about this, is that the correlation of this factor, with the scheduling of the project is already analyzed, because it is reasonable for an older ship to appear systems' failure events and risks, that are able to cause deviations from planned objectives' delivery times. Additionally, during the Class Society's survey, that takes place in a vessel's modification project, it is possible to be identified extra misalignment of the vessel with regulations, that must be resolved in parallel with the project's main work activities. All the above can result to an extension of project delivery time, to an older ship than a younger one. This attribute's range is between 0 to 100, depending on if the age of the ship is 0 to 50 years.

X4: Experience Ranking of Project Management Team. In similar way with the 'Cost Estimation Modeling', a project management team with high competency level and experience on similar projects, is expected to make the initial decisions and take any corrective actions, during the project's development lifetime, so as the schedule deviations to be lowered. The values of this variable are also between 0 to 100.

X5: Type of the Subsystem To Be Modified. This parameter has an impact to the schedule similar with the one on the final cost.

X6: Subcontracting Works Ratio. The dependency of the project administration company by subcontractors, decrease the flexibility of company to handle any deviation in time, by increasing the shifts of its own personnel. So, this attribute, is a way to accumulate the impact of a subcontractor, to be unable to fulfill any extra work required (for project change reasons or other). For example a subcontractor has its own schedule to service a number of customers. If this is not capable of modifying the schedule for covering the demand of extra workload for a particular project, the project administration company should either compromise with the delivery time extension, or search for additional subcontractors during project life cycle. Parameter's values given 0 to 100.

X7: Competency Level of Subcontractors. The high competency level of subcontractors is a type of 'secure' for time schedule of a project. The experience of this stakeholder, has an essential impact on the SPI (schedule performance indicator). So, the involvement of a subcontractor with high competency level, is expected to decrease the estimated time of completion. Value range is 0 to 100 with latter one to represent the high competency level.

Appendix 13. ML functions in Python

pandas: This is a function library very popular for processing data sets. This module includes a group of functions for loading and exploring, preparing data like cleaning, manipulating, modeling and analyzing data (Muller & Guido, 2017). Taking into account that the pandas function library is successfully imported, the usage of this module starts from loading the CSV file of the data using the function *pandas.read_csv("A")***,** where A is the path of the CSV file in which the data used for ML modeling are saved. The initial exploration of the data, by taking information about the structure of the file, can be achieved by using functions *pandas.info()* and *pandas.describe()*. Using them, information like individual columns' data type and individual columns' description respec-

tively can be extruded. Other useful functions of pandas module in pre-processing stage of ML algorithm are *pandas.isnull()*, which return result about any missing value on the dataset, *pandas.fillna()*, which is used to fill any missing values in the dataset.

Matplotlib: This module is used for visualization of data (Muller & Guido, 2017). So, this main function *pyplot*, that is included on this module, will be used for creating a series of scatter plots of the collected data, as well as for creating graphical representation of the derived cost prediction ML model, and delivery time prediction ML model. So, a clear view of deviation of the real values from the estimated values of the model, can be done as a rough optical evaluation of the ML algorithm.

sklearn: This module is used for creating the ML prediction models of cost and delivery time. The functions that will be used from this software package are: *sklearn.model_selection.train_test_split* and *sklearn.linear_model.LinearRegression()*. The first package is used to create the training data set and the test set used for ML development. For such a purpose, the data included in the CSV are splitted using function *sklearn. model_selection.train_test_split()*. The second software package includes the subfunctions for programming the model and creating the ML algorithm (Muller & Guido, 2017). The first step, which is the calculation of the best fit linear factors(multipliers) of the linear model, is done by *sklearn.linear_model.LinearRegression.fit***.** The second step, which is the estimation values according to the derived model, is done using the *sklearn.linear_model.LinearRegression.predict* function. The last step is the evaluation of the model, for which the *sklearn.linear_model.LinearRegression.score* function is used.

numpy: This module is specially developed to be able to process multidimensional array objects. Particularly, this function family can make mathematical and logical operations on arrays, as well as operations, relative about linear algebra (Muller & Guido, 2017). In our project case, it is certainly used for calculation of statistical quantities like mean value, useful for making conclusions about the efficiency of a vessel's modification project execution

Appendix 14. Project thesis implementation analysis

For the first part of the methodology, the study, it was based on reading of books and papers, certainly in electronic form, focused on subjects like project management principles, shipyard practices and ship repair procedures. Additionally, it was studied the handbook guidelines of ABS, about the class society rules, that should be followed in the case of such a project, for the specific type of vessel. Finally, for the implementation of ML, is required the study of bibliography about machine learning and artificial intelligence, as well as tutorials of ML implementation tools, like books with subjects as Python programming techniques for ML & AI applications.

The second part of methodology includes the data should be collected for analysis of the particular project, like lead times of intermediate manufacturing stages, materials costs, quality control measurements, etc. For data collection part, a mix of personal observation, survey and interview and questionnaires was used. The first method that was followed, was author's personal observation of project's execution process of the company Psyctotherm. Because of the fact that author was member of the engineering/manufacturing department of the company, who is certainly involved in execution of higher budget orders of the company, like projects, there was a clear general view of the projects' accomplishment procedures of Psyctotherm. Particularly, rhere was familiarity with the sequence of the procedures that take place for project in taken over by the company, from the stage of the customer's request and the offer submission, until the delivery of the order. Considering all the above, there was the ability to 'sketch' a rough diagram of the organization process.

Additionally, because of role of thesis' author as project engineer as well as production engineer in the company, there was knowledge of partial procedures of the engineering/manufacturing department (stages from design to construction and information transfer ways from design to the production line initiation, quality controls), as well as all the documents are used on these departments. Those personal observation was recorded in weekly base, by means of the weekly project reports where information about problems, cornerstones and project evolution details were documented. Survey, interview & questionnaires are the other research methods, that were used to ''complete'' the required information frameworks, to proceed to the analysis of vessel modification project, and collect the data required to be used as training and test set to the implementation of ML algorithm. The personal survey and project implementation team's interviews was the

procedure that was followed to confirm that the need manufacturing procedures of ABS from perspective of quality standards, was followed during manufacturing and installation of the chiller unit. Additionally, these two ways of qualitative type information collection, were used to make a search about the way of improving the efficiency of similar project in the future. The survey also included collection of material and components invoices, so as the cost analysis of the project to be achieved. The questionnaire form of data collection method, was mainly used in the collection of quality control forms, that were filled in by the technical staff involved in the various stages of the manufacturing and installation process.

For the analysis of the data, which is the third stage of the methodology, they were used qualitative methods for the analysis of the quality type data, but the majority of the analysis was quantitative ones, as there were a series of calculation implemented in manufacturing lead times or the partial costs of the project, so as to conclude to some numbered results about the project's efficiency. Other data analysis method, included the filtering of the quantitative data and the forming of them to a feasible matrix form. so as to be used as input in the ML algorithms.

As a result of the methodology steps above, the thesis completed with a series of results and conclusions, as they are presented to the conclusion chapter of this report.

Appendix 15. Water chiller installation project phases description

Phase1-Offer: The first phase starts with the request of the customer. On this stage the Sales Department of Psyctotherm processes the request of the customer. A meeting with the customer is arranged by the company, so as any details of the request and requirements of the project to be clarified. The Sales Dept. proceeds to a conference with the Engineering/Manufacturing Dept. of the company, so as to discuss about the request of the customer and the potential solutions/proposals to be recorded. The Engineering/Manufacturing Dept. initiates a study of the project proposals, analyses the technical parameters, as well as other various constrains of it, and the optimum technical proposal is developed. The technical data sheet and information about the optimal technical proposal are forwarded to the Sales Dept., and this creates the economical offer to be submitted to the customer.

A ''feedback focused'' meeting is fixed, between the customer and the sales engineers of the company, so as to be discussed if any modifications of the proposal are required or the proposal covers the requirement of the customer. In the former case, the technical specifications of the proposals are processed by the Engineering/Manufacturing Dept., followed by a revised offer's submission. In the latter case, the customer replies to a confirmation of the offer and an official order of the project, taking into account the payment terms of the offer, are also approved.

*Phase2-Planning & Design***:** The second phase includes planning processes of the project, according to the project management principles, like time scheduling, human resource planning , cost planning, as well as engineering processes like design of the chiller unit, planning of manufacturing processed, creation of BOM list and purchasing processes of the required equipment.

Particularly, the Engineering/Manufacturing department proceeds to detailed engineering calculations and necessary drawings, according to the approved technical proposal. All this initial technical documentation, is issued, so as to be provided to the technical staff of the production line in the next phase of the project. The BOM list is also issued and information of the specified components of the chilled unit to be constructed, are passed to the Purchasing Dept. of Psyctotherm, so as to start communication with the suppliers, and quotations are asked for the necessary equipment/components. In the meanwhile, the initial plans regarding time scheduling and human resource management, are created based on estimated parameters (delivery time of spare parts, efficiency indexes of production line to similar past projects) by the Engineering/Manufacturing Department. When the Purchasing Dept. receives the replies of the suppliers, the assessment of the offers take place.

The next activity of the 'Purchasing' is to order the approved suppliers' economical proposals, in combination with the payment processes, that are taken over by the Accounting Dept. of the company. The actual delivery times of the ordered components, are used for the revision of the time scheduling and plans. Moreover, any revisions of the drawings and the construction guiding documentation are done, and the updated versions of the documents are ready to be used, in the next phase of the project.

*Phase3-Execution & Monitoring***:** The third phase is the one in which the plans of construction of the chiller unit, the drawings and the designs of it, pass to the materialization stage. Actually, the largest percentage of this phase is carried out by the Engineering/Manufacturing Dept. During this phase the equipment/components of the system to be produced are delivered one by one. So, the manufacturing department of Psyctotherm collects all the necessary documentation for the construction of the ordered system, that was prepared during the phase 2, and analyses in further detail the initial production plan and initial time scheduling that has been developed, and divide the plan to shorter production line activities. Particularly, the main deliverable of the project, which is the construction the ordered chilled water system, is splited to many smaller deliverables. In a similar way, the jobs (production line activities) required for the completion of the product to be manufactured, are splited and distributed to the various workstations of the company. By means of this principle, the many smaller deliverables of this phase are taken over by a particular workstation(or at least a small group of them). This makes the control and monitoring of the partial deliverables, much more easier and so the accomplishment of them manageable and significantly effective, as this strategy is in agreement with the ''project management fundamentals''.

The workline of the chilled water system under manufacturing, is arranged according to the reasonable connections and correlations of jobs to be carried out, as it happens with any other production line. This means that some production activities are proceeding in parallel and independently, but some other production activities operates in series, and so the deliverable(output) of the earlier activities, is used as start(input) to the later activities .Of course between these interconnections of production activities, workstations and deliverables of the project evolution, always exist 'check points' and controls, so as the whole procedure to be controlled and monitored, so as to be assured that the evolution of the construction of the system 'flows', as it is designed.

Most importantly, the phase3 in general, is a continuous control and monitoring period for the whole project. To be more specific, during this phase the efficiency of the procedures is actually measured, as well as the agreement of the evolution of the project with the project plans and designed specifications, has always to be confirmed. Measurement like current production time, current production cost and quality controls, are of great importance for control & monitoring

needs of the project. The end of a successful phase 3, is certified by the final quality control of the produced system, as well as the FAT (Factory Acceptance Test) during which the system runs test operation in conditions that are as close as possible to the normal operating conditions of the vessel.

Phase4-Installation & Closing **:** This is the final phase of the project. On this phase, the constructed chilled water system, is transported from the facilities of Psyctotherm onto the vessel to be installed. The larger group of activities of this project's stage, is executed by the Technical Department of the Psyctotherm. As it is obvious, the group of activities is targeting to the installation of the system onto its final/mounting position in the Engine Room of the vessel. The technical staff start its duties with the mounting of the system's frame/base onto the foundation constructed, onto the Engine Room deck. Secondly, the technicians connect the existed fresh water piping of the ship with the water connection points (flanged connections) of the chiller unit. Finally, the electrical connections and cabling should take place before the unit's final tests (HAT-Harbor Acceptance Test), with presence of customer's representatives. If the HAT is successful, the projects' delivery enters to the final stage.

The final stage of project, delivery, includes the writing of operational & maintenance manuals, spare parts list, etc. of the delivered system by the Engineering Department, the collection and archiving of the documentation of chiller unit's components, the cooperation of Purchasing Department with the respective suppliers and the arrangement of any payment issues with the communication of Psyctoherm's Accounting Department with the accounting authorities of the customer. When all the above duties are over, an official delivery confirmation of the project is issued.

Appendix 16. Vessel modification project's data description

Budget Planned Cost: This value is collected by the Project Management plan of each project, in which the results of a rough cost analysis of project is documented.

Complexity of the Project: This is a calculated value by an algorithmic formula derived, to conclude to a normalized result ranged from 0 to 100. This formula used for this purpose is: CP= 0.1*HT +0.4*SP+0.25*NP+0.25*DD, where CP is complexity of the project, SP is severity of the project (SP=1 if subsystem to be modified is main system of ship, or SP=0 if it is not main system), NP is

the number of piping networks the system must be connected parameter(NP =1 for connection with 2 or more piping networks, NP =0,6 for connection with 1 piping network , NP=0,2 for connection with 0 piping networks), DD is the drydocking requirement parameter (DD =1 is drydocking is required or DD=0 if drydocking is not required),HT is the requirement parameter for creating new hatch/hull cut (HT =1 if is new hatch is required or HT=0 if new hatch is not required).

Age of the Ship: This value is the age of the ship, and it is easily collected by the information provided by the class society of the ship, in which the modification project executed.

Experience Ranking of the Project Management Team: This is also not an objectively measured value, but a calculated one that takes into account the competency level of all the members of the project management. The calculation formula of this attribute is: EXPMT=0.5 * MXY + 0.5 X PMY, where the EXPMT is Experience Ranking of the Project Management Team, MXY is the normalized mean year of experience of the team. This value has an algorithmic form MXY= summing year of experience of team members/number of members /20, if summing year of experience of team members/number of members <20, or MXY =1 if summing year of experience of team members/number of members >=20. PMY is the summing of projects executed by all team members/(number of team members*sum of years of experience)/2, if summing of projects by all team members/(number of team members*sum of years of experience <2, or PYM=1, if summing of projects by all team members/(number of team members*sum of years of experience) >=2. The data/parameters included to the calculation formula are derived by the information, that human resources management department of the project administration company collects and record.

Type of the Subsystem to be Modified: The type of the subsystem to be modified, contributes essentially to the completion, taking into account the special technical procedures that should be followed on each case, as well as the special quality standards that are demanded by the class society.

Subcontracting Work Ratio: This attribute can be calculated as following: SWR= SDT/TDT*100, where SWR is the Subcontracting Work Ratio, SDT is the total time required for the completion of

the work activities executed by subcontractors, TDT is the total time required for completing all the work activities included to the project's WBS.

Competency Level of Subcontractors: This is also a calculated attribute for using as input to the ML model of vessel's modification projects. The calculation formula of this attribute is: CLS=0.5 * MXYS + 0.5 X PMYS, where the CLS is Competency Level of Subcontractors, MXYS is the normalized mean year of experience subcontractors. This value has an algorithmic form MXYS= summing year of experience of all subcontractors/number of subcontractors /20, if summing year of experience of team members/number of members <20, or MXY =1 if summing year of experience of team members/number of members >=20, PMYS is the summing of projects by all subcontractors included in the project/(number of subcontractors *sum of years of experience)/2, if summing of projects by all subcontractors included in the project/(number of subcontractors *sum of years of experience <2, or PYMS=1 if summing of projects by all subcontractors included in the project/(number of subcontractors *sum of years of experience>=2. The data/parameters included to the calculation formula, are also derived by records of human resource management department of the project administration company, such one is the 'Experience Ranking of the Project Management Team' independent variable.

Planned Duration of the Project: This value is collected by the project management plan of each project, in which the results of work breaking structure analysis of the work activities and the delivery time estimation of each work activity of the project is documented.

Appendix 17. ML prediction models detailed analysis

STEP1-Input file loading for cost estimation model and time estimation model *import pandas as pd*

df1=pd.read_csv('Cost_Model.csv')

df2=pd.read_csv('Time_Model.csv')

STEP2-Data files exploration and suitability or error detection

df1.describe

df2.describe

df1.info

df2.info

df1.isnull

df2.isnull

STEP3-Visualization of imported data

import matplotlib.pyplot as plt import seaborn as sns

Lets consider that we would like to visualize the relation of planned project duration time vs age of the ship, and the relation of the planned Budget planned cost vs the age of the ship. We will use a scatter plot for this, and so it should be run the functions:

sns.scatterplot(x='Age of Ship', y= 'Planned Budget Cost' ,data =df1)

plt.title('Planned Budget Modification of Ship vs Ship Age')

plt.show()

sns.scatterplot(x='Age of Ship', y= 'Planned Project Duration' ,data =df2)

plt.title('Planned Duration of Ship's Modification vs Ship Age')

plt.show()

STEP4-Split data to training set and test set using 85% train to test ratio

from sklearn.model_selection import train_test_split

X_train_cost , X_test_cost , Y_train_cost, Y_test_cost = train_test_split(df1.drop('Budget Planned Cost' ,axis=1), df1['Budget Planned Cost'], train_size=0.85, random_state=25)

X_train_time , X_test_time , Y_train_time, Y_test_time = train_test_split(df2.drop('Planned Project Duration',axis=1), df2['Planned Project Duration'], train_size=0.85, random_state=25)

STEP5-Fit parameters of linear regression

from sklearn import linear_model

regr_cost=linear_model.LinearRegression()

regr_time=linear_model.LinearRegression()

regr_cost.fit(X_train_cost , Y_train_cost)

regr_time.fit(X_train_time , Y_train_time)

STEP6-Make predictions on test set using linear regression model

Y_cost_pred=*regr_cost.predict(X_test_cost)*

Y_time_pred=*regr_time.predict(X_test_time)*

STEP7-Make evaluation of the model

plt.scatter(*X_test_cost , Y_test_cost ,color="black"*)

plt.plot(*X_test_cost , Y_cost_pred ,color="blue"*)

plt.show

print(regr_cost.score(*X_train_cost , Y_train_cost*))

plt.scatter(*X_test_time , Y_test_time ,color="black"*)

plt.plot(*X_test_time , Y_time_pred ,color="blue"*)

plt.show

print(regr_time.score(*X_train_time , Y_train_time*))