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INTEGRATING PROJECT MANAGEMENT, CONCURRENT ENGINEERING, AND ENGINEERING DESIGN TO IMPROVE SHIP DESIGN

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Abstract:
There are different perspectives among the design and development research community. Past research shows that there are at least four common perspectives addressing this issue. Furthermore, there are significant differences among papers within each of the perspectives, not only in the methodology used and assumptions made, but also in the conceptualization of how product development is executed. Project Management, Concurrent Engineering and methodologies of Engineering Design are examples of those perspectives and are usually treated as isolated disciplines. However, there are many interactions among the tasks related to them. We investigate these interactions, common tasks and concepts. Our research integrates these viewpoints with the main concepts, tasks and decisions providing a comprehensive understanding of ship design.

Keywords: Product Development Process, Design Methodology, Ship Design.

1 Introduction

There is no single theory to the product development process. The differences of products developed by firms result in particular methodologies with emphasis on certain aspects of the product. Krishnan and Ulrich (2001) show that there are at least four common perspectives addressing the product development process: marketing, organizations, engineering design, and operations management.

However, the authors observed that the decisions made during the process seem to remain consistent at certain level of abstraction for all firms. This is a common point of all product development processes. Moreover, there are familiar characteristics of the product development process independent of the product to be designed.

Project Management, Concurrent Engineering and Engineering Design are examples of those perspectives. However, there are many interactions among the tasks related to them. Some of these tasks are repeated over the particular methodologies. We must know these interactions in order to improve understanding of Ship Design.

This paper presents a study of Ship Design. We use the Design Structure Matrix (DSM) to this purpose. We map the interactions among the main activities accepted by the literature related to the Project Management, to the Concurrent Engineering, and to the Ship Design, and with DSM establish a sequence of realization of them. It resulted in a single way to visualize the Ship Design and the main tasks involved in it. We show that this representation helps the Project Manager to take strategic decisions about Communicational and Organizational Planning and Program Management Tasks.

2 Product Development Perspectives

Krishnan and Ulrich (2001) present four different perspectives of the Academic Communities about the Product Development Process (PDP). The perspective on product, typical performance metrics, dominant representational paradigm and decision variables are different for each field. Despite the differences presented by each group, there is a certain consistence about the decisions made during the design. Those decisions seem to remain regular at certain level of abstraction for all product design.

However, the first point to be observed is that the decisions are time dependent. They are made during several points of the PDP and are a result from the different level of participation of each field during the PDP. For instance, the Marketing Team has a great level of decisions made during the first step of the PDP, despite its contribution to the whole design cycle. Other point to be addressed is that many perspectives and decisions are inserted in methodologies and theories of Project Management, Engineering Design, and Concurrent Engineering. Those disciplines are usually treated in an isolated way. However, those disciplines are complementary.

According to PMBOK (2000), projects are compound by processes, and a process is a succession of actions that conducts to a result. There are two types of process: project managerial process and product oriented process (PMBOK, 2000). The first one is related to the description, organization and conclusion of the work and is the main focus of project management. The second is related to the specification and creation of the product and is called Engineering Design. In the case of ship design, the "product oriented process" is usually addressed by technical ship design process. Despite this differentiation, there are interactions between these processes. They interact during the whole design cycle. For instance, the time management cannot be defined without the knowledge of the activities of the ship design.

Concurrent Engineering incorporates that group of processes by means of new requirements (that insert new activities to address them) and parallel planning of activities execution. Concurrent Engineering strives to do the right job right the first time and is based on two fundamental observations (ZANGWILL, 1992). The first is that changes become more and more costly, the later they are done in a project, and the second is that doing in parallel the different steps of a project make the project done more quickly then doing the steps sequentially. The consequences are that new requirements of production, maintenance, operations, etc. must be addressed during the earlier stages of design and the dependencies among them must be analyzed in order to execute the activities in parallel.

Today the representation of the ship design process is made in a macroscopic level, generally in a system level. It masks some particularities of the process. When we analyze the process in the activity level we obtain a better understanding of the process.

3 Ship Design

To illustrate an engineering design methodology we present the ship design spiral (figure 2). The concept of the design spiral was introduced in 1959 by Professor J. H. Evans of MIT (Evans, 1959), and is the most widely accepted methodology of the ship design (LAVERGHETTA, 1998).

The spiral describes the process as a sequence of specific design disciplines, both of synthesis (e.g. hull geometry, arrangement) and analysis (e.g. stability, seakeeping) in order to achieve a balanced design that meets the requirements. The spiral depicts important characteristics of the design like the iterativeness and the progressive elaboration of the design. However, the spiral represents the process in a macroscopic level. Some of those disciplines incorporate hundreds of activities.

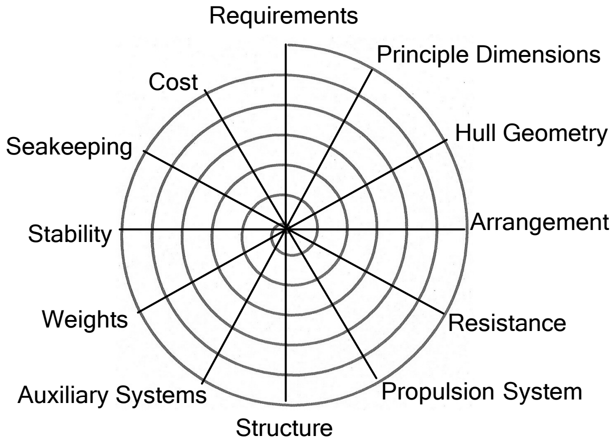

Figure 1: Generic Ship Design Spiral

When we group the activities into disciplines we mask the interactions among the activities portraying the design process as linear. This is not the case. The process is better described as "quasi-linear" (LAVERGHETTA, 1998). As point Laverghetta, design activities within the spiral rely on input from and provide output to almost every node of the process. As such, engineers and designers must have access to information (whether actual or estimated) from each design discipline and they must be acutely aware of the potential feedback effects caused by the changing output from their own products. To control it, managerial activities play a capital role into the process. However, it is necessary to map the activities interactions of the process.

4 Integrating methodologies and theories

4.1 Concepts of Design Structure Matrix

To analyze the interactions we use the design structure matrix (CHO, 2001). We use DSM because the tools indicated by PMBOK are based on diagrams and, for complex systems, is difficult to analyze the interactions as it will be shown later. Browning (2001) provide a literature review of the use of DSM and Eppinger et al (2004) provide the concepts of DSM.

The DSM is a square matrix in which is assigned the tasks identically ordered at row and columns. The initial process is to mark the cells to identify when a row receives information from a column. Figure 4 shows that the original DSM (left matrix) presents a series of tasks ordered according execution sequence both at rows and columns. Note that the row A has the number 1 marked at columns C and E. It means that the execution of task A needs information from tasks C and E. On the other hand, looking at column A, one can note the number 1 marked at rows B and C. It means that the task A gives information to tasks B and C. Above diagonal marks has a relevant significance: it indicates that an earlier task is dependent on a later task. The original DSM (left matrix) shows that task A depends on information of tasks C and E that were not executed yet.

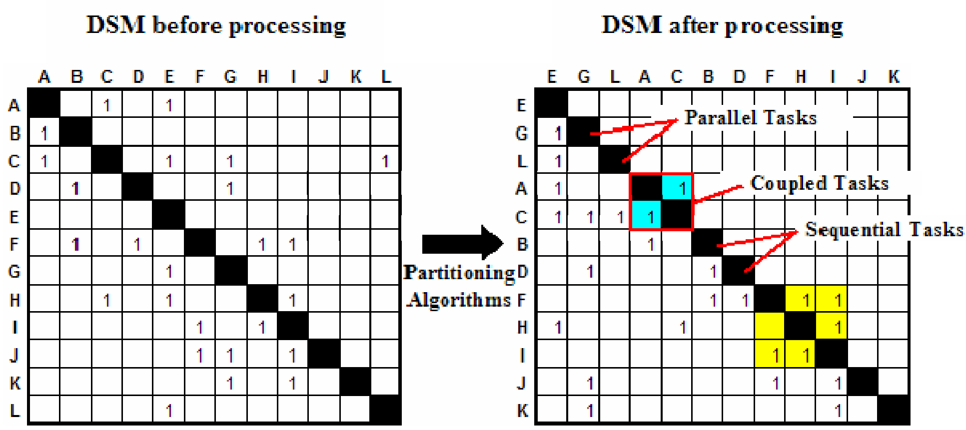

Figure 2 - Example of optimization process with the DSM.

After concluding the establishing of marks of the original matrix it must be executed partitioning algorithms to reorder the sequence of tasks to reduce the number of above diagonal marks. It permits that all non-necessary iterations were retired of the process. It can be verified by lessening marks equal number 1 above the diagonal. On the other hand, tasks with necessary iteration were grouped, as noted in the right matrix of figure 4 (tasks A and C; tasks F, H and I). This type of grouping has special importance for team organization grouping persons who necessities an intense changing of information. Also, note the presence of tasks that can be executed in a parallel way, as tasks G and L. Task L does not depend on information from task G and vice-versa.

Finally, task D depend on information from task B to be executed and it is called sequential tasks.

4.2 Planning Activities interaction analysis

First of all, we analyze the planning activities interactions of a project. It will define the best order of execution of planning activities. To analyze the interaction among those activities we base on PMBOK (2000). The PMBOK lists the main activities related to the project management and indicates information input and output for each activity. Based on the interactions, we insert the data on the DSM (figure 3) and process it (figure 4). Activities of Quality Management, Risk Management and Integration Management are retired of the process because they provide and receive information of almost all activities. Consequently, they play a role of integration activities and must be considered along the process. Other information input related to historical data, premises and restrictions depend on the office and the product to be developed and must be considered accordingly to the office.

After mapping the interactions among the activities (figure 3) we process the DSM and it result in the best order of execution of the activities (figure 4). The new order of execution diminishes iteration processes as can be observed looking above diagonal marks. The only iteration process is that necessary to the execution of the planning, where there are mutually dependencies. Indeed, resource planning and activity duration estimating are mutually dependent. For instance, the activity of ship weight estimating can be performed by one or more engineers. The greater the number of engineers allocated to the activity the lesser the time of execution.

Task Name		1	2	3	4	5	6	7	8	9	10	11	12	13
Scope Planning														
Scope Definition	2	1												
Activity Definition	3	1	1											
Activity Sequencing	4			1										
Resource Planning	5	1	1							1				
Communications Planning	6				1	1		1						
Organizational Planning	7				1	1								
Staff Acquisition	8							1						
Activity Duration Estimating	9			1		1								
Cost Estimating	10		1			1				1				
Schedule Development	11				1	1				1				
Cost Budgeting	12		1								1	1		
Project Plan Development	13	1	1	1	1	1	1	1	1	1	1	1	1	

Figure 3 - DSM before processing.

Task Name		1	2	3	4	5	6	7	8	9	10	11	12	13
Scope Planning	1													
Scope Definition	2	1												
Activity Definition	3	1	1											
Resource Planning	4	1	1			1			Block1					
Activity Duration Estimating	5			1	1									
Activity Sequencing	6			1										
Organizational Planning	7				1		1							
Cost Estimating	8		1		1	1								
Schedule Development	9				1	1	1							
Communications Planning	10				1		1	1						
Staff Acquisition	11							1						
Cost Budgeting	12		1						1	1				
Project Plan Development	13	1	1	1	1	1	1	1	1	1	1	1	1	

Figure 4 - DSM after processing.

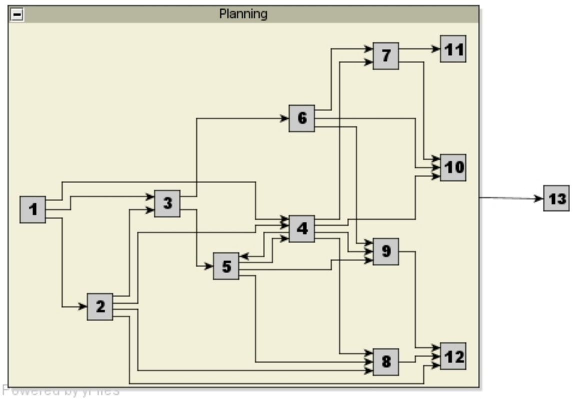

Figure 5 - Activities Precedence Diagram based on figure 4.

Before analyze the activities of ship design following the order provided by figure 4, some conclusions can be taken from the analysis of the planning activities.

The first one is that interaction analysis plays a vital role to the project. The interaction analysis is inserted in the Activity Sequencing. Looking the figure 4 we observe that Communications Planning, Organizational Planning and Schedule Development are dependent on Activity Sequencing. Therefore, we need to define the activities of engineering design and map the interactions among them to analyze and define the communications and organizational planning such as the schedule development. It will be demonstrate later.

The second point is that managerial activities must follow the progressive elaboration of the design. After the first step of design - that is called of conception development - the technical activities for the next step will change. Some of the technical activities will remain the same like stability analysis. Others will be added because of the increasing specification of the product, like structural detailing, electrical system detailing and others. If the scope detailing changes, new activities will be addressed and is necessary to map the interactions among those activities. Consequently, communications planning and schedule development will change. Despite organizational planning might be affected, it may be not important to change it. It must be analyzed. Consequently, at each step of development we must reevaluate the planning of the project.

The third point to be observed is that the principles of Concurrent Engineering are contained inside of the Scope Detailing and Definition, of the Activity Definition and Sequencing, and of Schedule Development. Consequently, changes in the scope detailing and definition and in the activity sequencing affect practically all the activities, including Communications Planning, Organizational Planning, Resources Planning, Schedule Development and others. With the implementation of the concepts of Concurrent Engineering new activities will be defined and it is necessary to map those interactions. It will affect all planning activities.

4.3 Engineering activities interaction analysis

Following the order of activities defined by figure 4 to execute the engineering design, the first step is to plan and to define the scope of the design. To the purpose of this paper the scope is to design a generic ship. The requirements of this ship are that common to almost all ships, like velocity, stability, seakeeping and others. There are specific activities to address those requirements. To define the activities and to map the interactions among them, we base on the Principals of Naval Architecture (Lewis, 1989), traditional book of Naval Engineering, on Laverghetta (1998), and on Bogosian Neto (2005). At least all activities listed on this paper must be executed to design ships. However, each ship has its own requirements and it must be translated into activities to address them. The manager must know how these activities interact with the others activities listed on this paper.

After the activity definition, looking at figure 4, the next two steps are resource planning and activity duration estimating. However, we observe that activity sequencing does not depend on those activities and must be performed in a parallel way. Therefore, we analyze the activity sequencing, mapping the interactions of the activities because of the scope of this paper.

Figure 6 shows the DSM before the processing listing the activities needed to execute the ship design and mapping the interactions among them as explained earlier. Figure 7 shows the DSM after the processing. Figure 8 shows the precedence diagram of the activities based on figure 6.

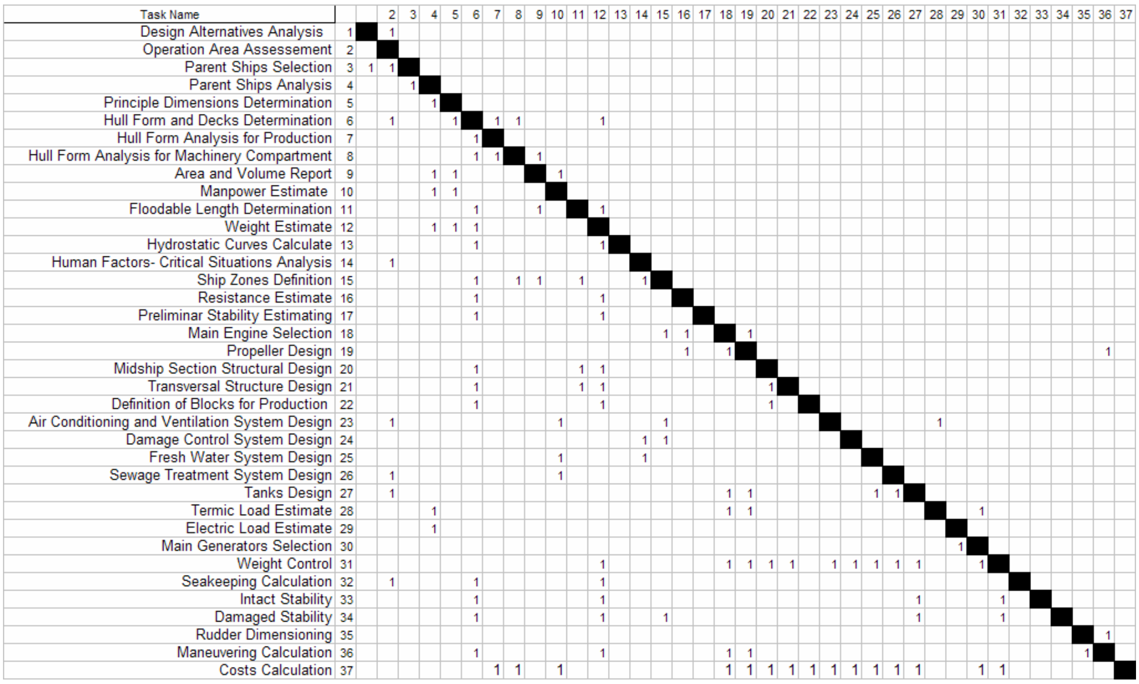

Figure 6 – DSM before processing.

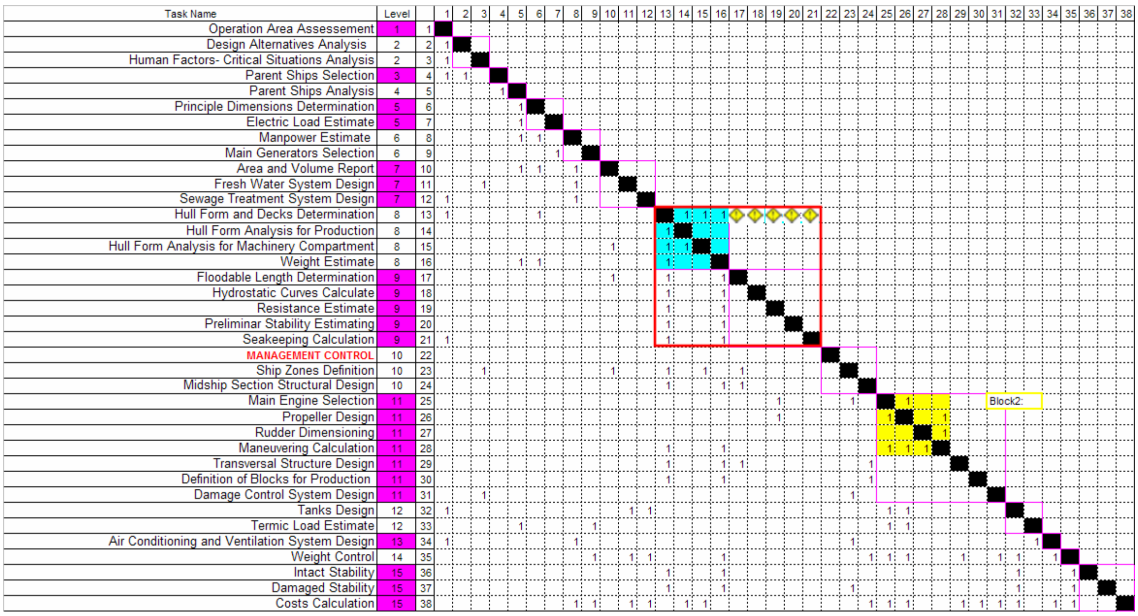

Figure 7- DSM after processing.

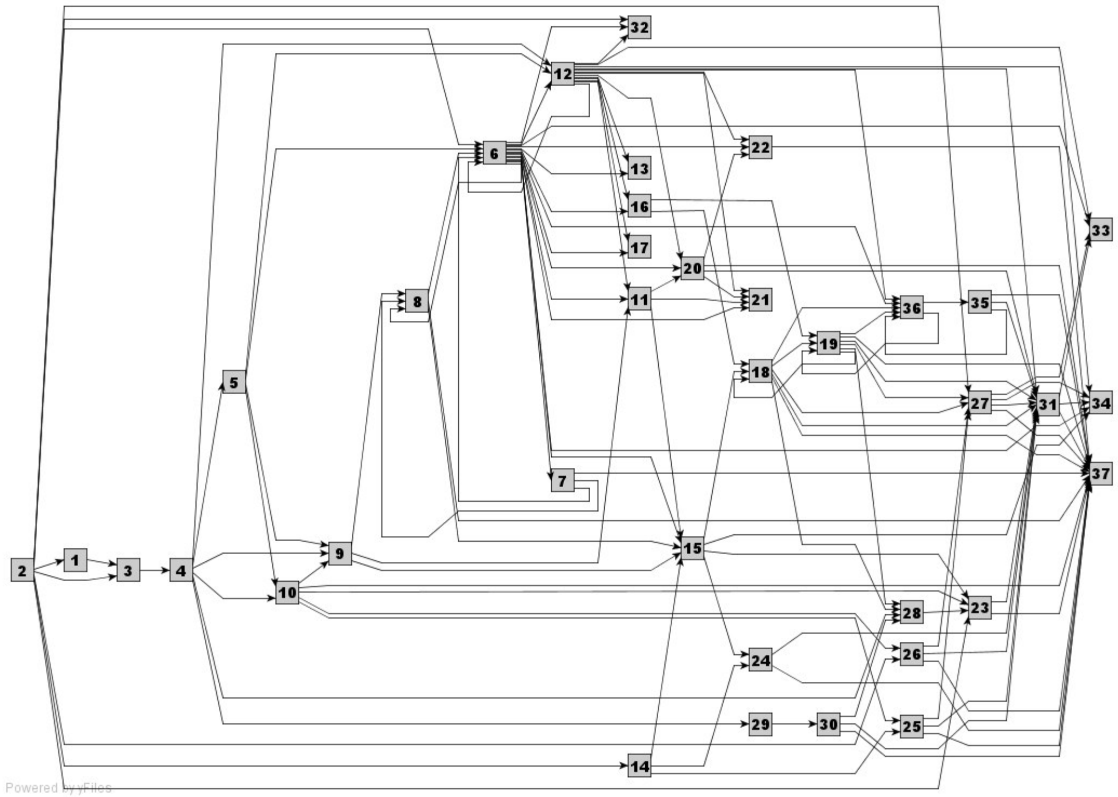

Figure 8 – Precedence Diagram based on activities of figure 6.

We observe that DSM after the processing reordered the sequence of accomplishment of activities that diminished the number of iterations of the project, what it can be visualized by the number of markings above of the main diagonal line in the comparison of figures 6 and 7. Also, observing the DSM after the processing, we notice the sprouting of two blocks that need an iterative process of resolution. These are the called planned iterations of the process and are necessary to the project.

When identified those coupled activities the manager must be aware of the time scheduling to execute major loops on the process (e.g. activities from 13 to 21 of figure 7). Sometimes, despite meeting the requirements, with other loops one system can be optimized. However, there is a time limitation. This is one point of managerial decision (Management Control – figure 7 – line 22). Also, it can be discovered errors, new information, and other unplanned troubles (e.g. bad estimative) that necessity to reevaluate some technical activities creating major loops. Quality and Risk Management must be aware of these facts creating activities of control. The others managers like Time, Scope and so on must be informed of the decisions made in order to reevaluate their plans and make decisions about the execution of the design.

Identifying iteration loops plays a strategic function to the office. Some kind of planned iteration can be performed by specific software. It can be purchased by the office or even developed. It will depend on the objectives of the office. Sometimes a low investment can better the quality and can accelerate the design, diminishing risks. Once identified the iteration group it must be analyzed.

Also, analyzing the interactions we can plan the communications of the design. It is easy to identify who needs information and who provides information as well it is easy to identify when the information must be available. Observing the column named level figure 7 we identify colored groups of activities. If those groups are not associated with planned iteration, it means that those groups can be performed in a parallel way, because they do not depend on information of each other. For instance, it can be seen looking at activities 10, 11 and 12. They can be performed in a parallel way. However, activities 13, 14, 15 and 16 are associated with a planned iteration that can be seen looking the blue block inside the matrix. They must be executed by means of iteration.

Other point to be observed is the simplicity of representation of interactions using the DSM. Figure 8 represents the precedence diagram of the interactions illustrated in figure 6. We notice that is complicated to analyze the interactions of project by means of precedence diagram indicated by PMBOK (2000). Observing figure 7 we easily distinguish which are the activities that can be executed in a parallel way. Also, accordingly to the principles of Concurrent Engineering, sequential activities can be done with some degree of parallelism or overlapping, but it must be analyzed. In order to use the overlapping, Yassine et al (1999) affirm that it is important to estimate two characteristics: upstream information variability and downstream task sensitivity. To do it is necessary map the interactions. Therefore, to map the interactions is vital to the establishment of some principles of Concurrent Engineering.

Finally, the activities listed in DSM unmasked the simplicity of the Ship Design Spiral. To address the characteristics listed in the Spiral we necessities many activities and there are a lot of interactions between them. Therefore, it is necessary to explode the Spiral into activities to manage the design. Furthermore, the activities listed are that of the first cycle of the spiral. For other cycles, the number of activities will be greater and the most of them will change, requiring analyzing the planning of the project.

5 Conclusions

This paper integrates the concepts and activities of three methodologies and theories about PDP: Project Management, Engineering Design and Concurrent Engineering. Also, we show that interaction analysis based on necessary activities to accomplish the design plays a vital role on the project. It is the first step to improve ship design methodology.

However, this paper only presents some examples of analysis and conclusions about interaction and the model presented. Many other conclusions can be taken from interaction analysis. A longer work could explore the establishment of requirements and analyze the necessary activities to accomplish those requirements. Also, communications and organizational planning can be deeper analyzed by means of interaction analysis. Finally, the concepts presented can be extrapolated to other product development process.

Acknowledgments

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References

BROWNING, T. R. (2001) - Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions. IEEE Transactions on Engineering Management. Vol. 48, n.3, p.292-306.

BOGOSIAN NETO, S. (2005). Projeto de Concepção de um Navio Patrulha de Formas Não-Convencionais com Características Submersíveis: Viabilidade e Manobrabilidade. Portuguese. 410 p. Thesis (Doctor of Science in Ocean Engineering). UFRJ, Rio de Janeiro.

CHO, S. H. (2001). An Integrated Method for Managing Complex Engineering Projects Using the Design Structure Matrix and Advanced Simulation. Dissertation (Master of Science). Massachusetts Institute of Technology.

EPPINGER, S.D., WHITNEY, D.E., YASSINE, A.A. (2004) - The Design Structure Matrix – DSM home page. <http://www.dsmweb.org>.

EVANS, J. H. (1959) - Basic Design Concepts. Naval Engineers Journal. Nov., p. 671-678.

KRISHNAN V., ULRICH K. T. (2001) - Product Development Decisions: A Review of the Literature. Management Science. Vol. 47, n.1, p.1-21.

LAVERGHETTA, T. A. (1998) - Dynamics of Naval Ship Design: A Systems Approach. 187 p. Dissertation (Naval Engineer e M.Sc. in Ocean Systems Management). Massachussets Institute of Technology.

LEWIS E. V. (Editor) (1988). Principles of Naval Architecture. Vol. I, II and III. Second Edition. The Society of Naval Architects and Marine Engineers, New Jersey.

PMBOK (2000) - Project Management Body of Knowledge. Portuguese Version. V. 1.0. 159 p. Project Management Insitute. Minas Gerais. Brazil.

ZANGWILL, W. I. (1992). Concurrent Engineering: Concepts and Implementation. IEEE Engineering Management Review. Vol.20, n.4, p.40-52.

YASSINE, A., BRAHA, D. (2003) - Concurrent Engineering and the Design Structure Matrix. Concurrent Engineering Research and Applications. Vol.11, n.3, p.165-176.