Value Stream Mapping in Project Management: A Case Study

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VALUE STREAM MAPPING IN PROJECT MANAGEMENT: A CASE STUDY

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A brief justification of the appropriateness of the paper for publication in the Project Management Journal:

This study tries to integrate MRP logic in the materials procurement management system of a company which is specialized in Engineering, Procurement and Construction (EPC) projects, without eliminating the existing management system.
Methodologies such as Business Process Re-engineering, Activity-Based Costing and Activity-Based Management, Enterprise Modeling, Benchmarking and Best Practices are part of the toolsets used in order to analyze, design, improve and evaluate different business processes.

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Figures and Tables

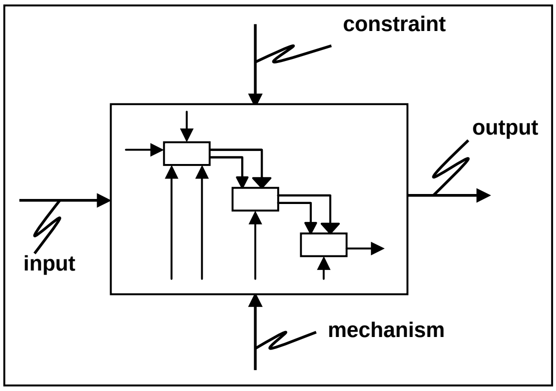

Figure 1. Graphic representation of activities

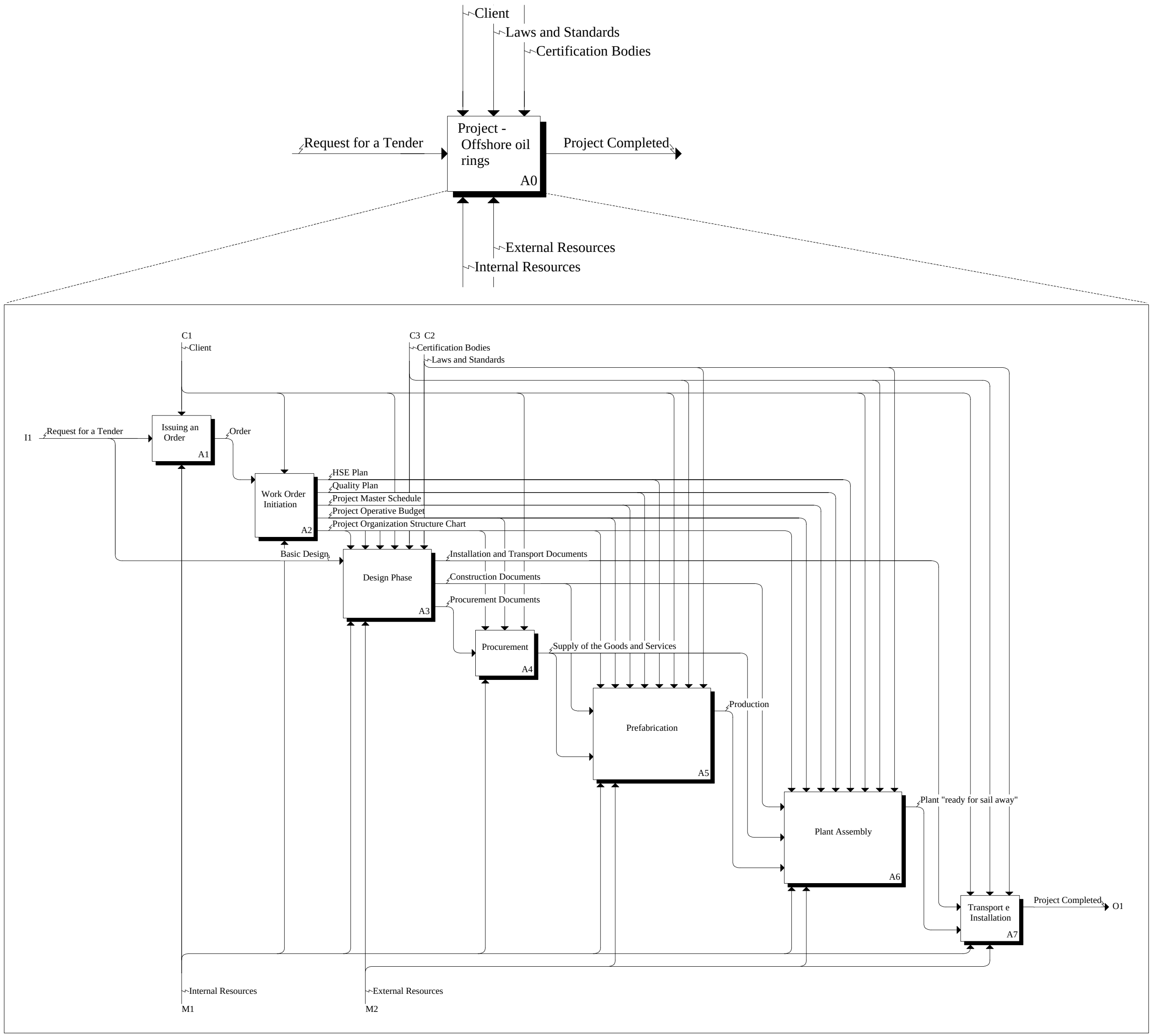

Figure 2. IDEF0 model of the typical work order of the company analyzed.

A1	The activity of issuing an order includes all those stages that go from the first receipt of the request for a tender to final adjudication of the contract. The main monitoring is carried out by the Client, while the mechanisms which intervene are exclusively internal resources.
A2	Work order initiation involves the activities which are carried out in order to organize the development and execution of the entire project; amongst other things the work organization structure chart must be fixed and the budget and final Project Master Plan must be drawn up.
A3	During the design stage activities both the construction and detailed engineering activities are developed, carried out using both internal and external resources. It must be underlined that the subsequent activities, that is the management of purchases and prefabrication, partially overlap the design activities. Obviously the design starts as soon as possible for the highly critical items; the design of the secondary items is left to as late as possible so as to avoid any waste of resources during the initial stages of project execution. The design activities are very closely monitored, mainly by the Client who must approve all the solutions adopted during the development of the activities. In some areas approval by Certification Bodies (DNV) is also necessary, and the technical content must respect national and international laws and regulations. Further monitoring is carried out internally using tools such as the work order budget, the Project Master Schedule, the Quality Plan and the HSE Plan.
A4	The purchasing and supply activities include the management of external supplies of materials, equipment and services necessary for the on site execution of the project. According to the value of the goods purchased, the internal procedures used to approve the purchases may vary considerably; the number of steps which must be taken and the people responsible for approval may change. Monitoring of purchasing activities is mainly carried out by the Client, who may draw up a list of the suppliers to contact. An additional tool for monitoring is the operating budget of the work order, which sets the expense limits applicable for the purchase and supply of goods and services. The mechanisms of this activity include external resources, since they are involved in the supply of the goods purchased.
A5	Prefabrication activities include the production of the components to be prepared for subsequent assembly on the plant. Structural components (beams, points and bracing) are produced inside the company as well as metal structural plant-bearing components; commercial supplies and highly technological components, for which specialized know-how is required, are produced outside the company itself. These activities are well-controlled both outside and inside the company. External monitoring is carried out by the Client and by the DNV, as well as in conformity with current laws and regulations. Internal monitoring is carried out through the Quality Plan, the HSE Plan, the work order operating budget and the work order organization structure chart. The mechanisms which intervene are internal resources, as far as prefabrication activities in the company workshop are concerned, and external resources provided by the external prefabrication workshops.
A6	Plant assembly activities include the construction on site of the plant and the installation of the plant systems. This heading also includes pre-commissioning activities and general tests required by legislation, which are very important. As in the case of prefabrication activities, monitoring is carried out both by the company and by external agencies.
A7	Finally, transport and installation includes all those activities of transport to the final destination and the final installation, together with final commissioning tests. The monitoring of these activities is carried out by the Client, who must always approve the documents concerning the procedures to be followed for transport and installation. The operations to be carried out offshore must also be monitored and approved by the competent maritime authorities; approval by the certification body is also necessary in order to obtain the insurance cover for the activities carried out.

Table 1. Description of the activities at Ai level

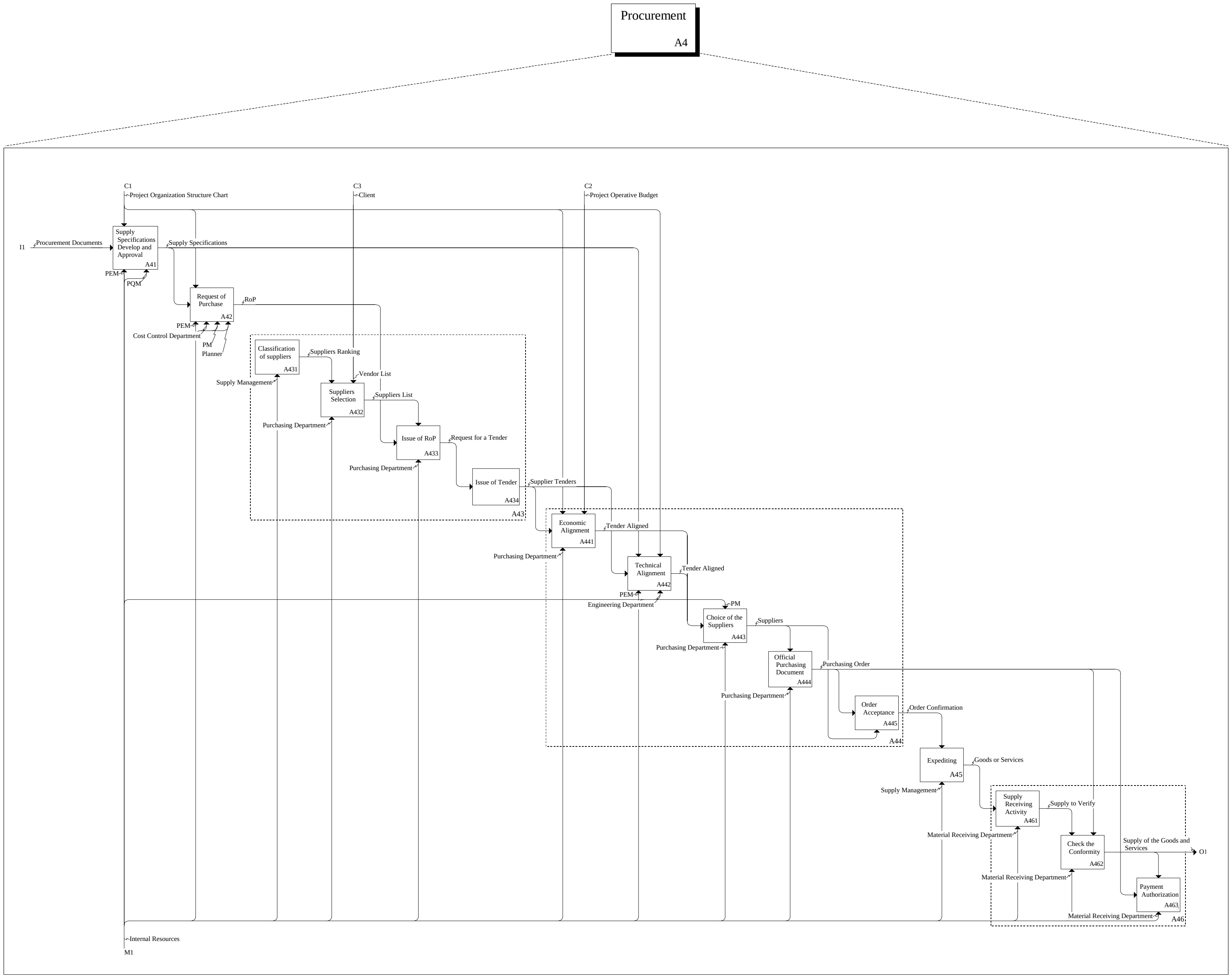

Figure 3. IDEF-0 model of the As-Is procurement process.

A41	When it is necessary to purchase a special item the Project Engineering Manager (PEM) draws up the Supply Specifications (SS); this is used to set the technical specifications which the purchased goods must satisfy. The Supply Specifications must be approved by the Project Quality Manager.	
A42	The Request of Purchase (RoP) is officially issued. This is a document internal to the company which identifies the need for goods or services. The procedure for drawing up the RoP varies according to the commercial value of the item. The RoP is sent to the Purchasing Department.	
A43	*Ordering procedure*	
	A431	At the same time as the other activities a classification of the suppliers is carried out by the Supply Management Department, on the basis of company strategy and the characteristics of the market. In the event of special supplies an *ad hoc* classification of the suppliers may be carried out.
	A432	Supplier classification leads to the drawing up of a list of qualified suppliers; on the basis of the list of qualified suppliers drawn up by the company and those indicated by the client in the Vendors' List, possible suppliers are chosen who will be sent the Request for Tender (RfT) for the purchase in question.
	A433	Once the RoP is ready and the possible suppliers have been chosen, the Request for Tender (RfT) may be issued. For the most important goods and services the RfT must be sent to at least three suppliers.
	A434	This activity is carried out by the suppliers who submit tenders for the goods and services required.
A44	*Analysis of the offers*	
	A441	The purchasing department is responsible for the economic alignment of the tenders made. Terms and conditions of payment are compared as well as the services included and the expenses to be charged to the company.
	A442	The Project Engineering Manager (PEM), and if necessary the Engineering Department, is responsible for the technical alignment. The supply specifications, which may be different from those required, are compared and the salient points and main strengths and weaknesses of each supply are highlighted.
	A443	The head of the Purchasing Department is responsible for the choice of the supplier. The PM solely responsible for the execution of the project becomes involved for the final approval of the chosen supplier.
	A444	The Purchasing Department draws up the Purchasing Order for the chosen supplier. This is the official purchasing document and is forwarded to the Client.
	A445	The supplier confirms receipt of the order and accepts it. This is not automatic since the supplier may withdraw the offer previously considered valid. In this case it is necessary to contact another supplier.
A45	Once the Contractor has received confirmation of the order, the expediting activity starts. The supplier is then monitored and controlled for the state of the supply in question, for the expected delivery times and any delays concerning dispatch or transport.	
A46	*Receiving Procedure*	
	A461	When the product arrives at the construction site the supply receiving activity starts. The arrival of the materials is registered and included in the central computer database.
	A462	The Material Receiving department is responsible for checking the conformity of the supply with the specifications indicated in the Purchasing Order.
	A463	If the supply is in conformity it is registered and payment is authorized by Administration which will also be responsible for registering the invoices and making the necessary payments.

Table 2. Description of the activities at Aik and Aikj levels of the procurement process.

VALUE	LEAD TIME: High	LEAD TIME: Low
High	- Standardization - Material Take Off	- Standardization
Low	- PUSH management - Comakership, Partnering	

Table 3. Risk Matrix for components purchased

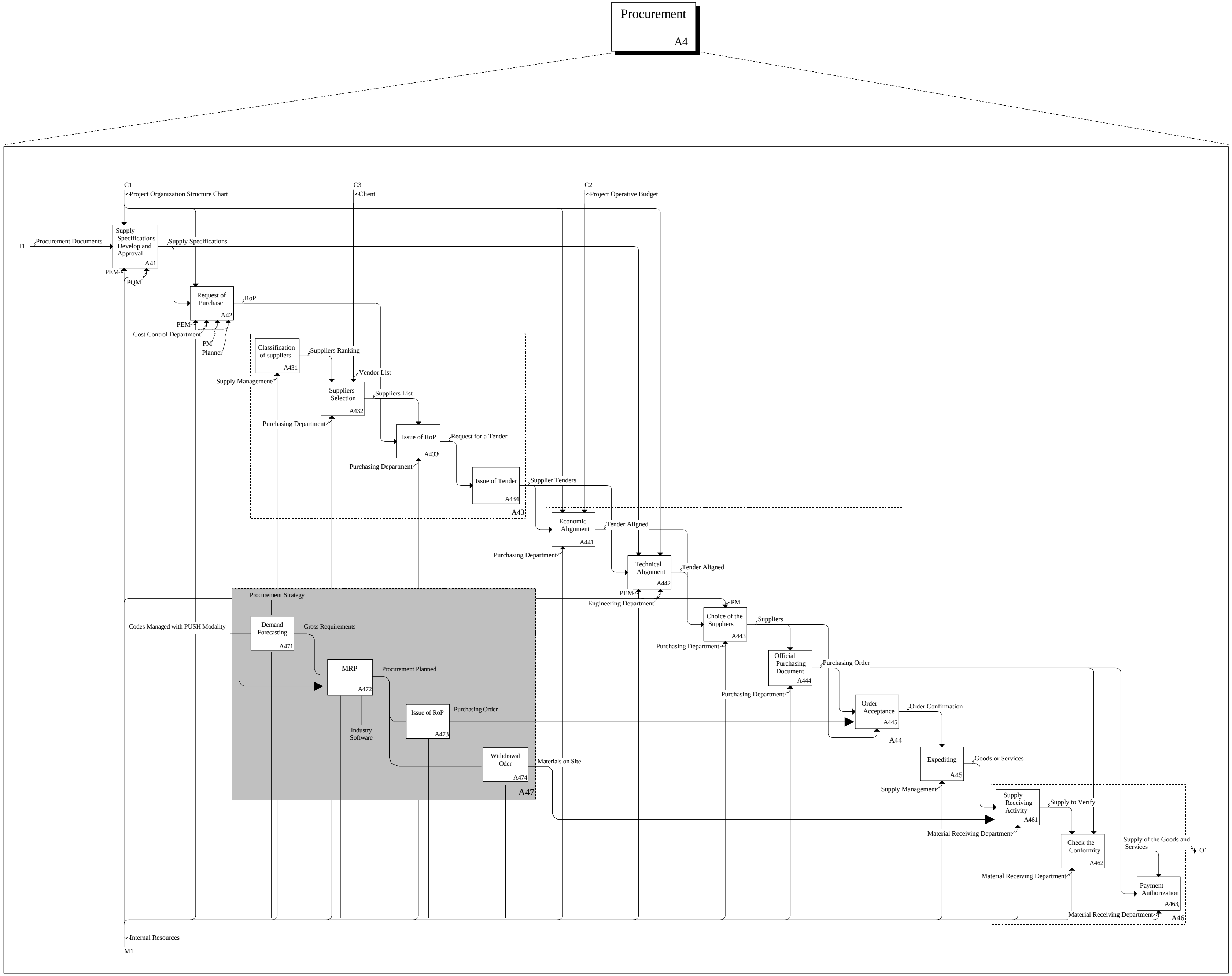

Figure 4. IDEF0 model of the To-Be procurement process.

A47	*MRP processes*	
	A471	For the codes with the longest lead time to be managed with PUSH modality it is necessary to make predictions of consumption using the Winter technique for the codes which are subject to seasonal consumption and using the Exponential Smothing technique for the other codes (see appendix 3). The prediction threshold for each code must be at least equal to its procurement lead time. The head of the Purchasing Department and the head of the Sales Department are together responsible for developing these predictions.
	A472	On the basis of the predictions and the orders confirmed by the clients, the gross requirements will be estimated and the procurements will be planned according to MRP logic.
	A473	The following step is to issue the Request of Purchase (RoP) using the same procedure indicated for the As-Is process according to the previously drawn up plan.
	A474	If the codes are in the inventory a withdrawal order is issued and the materials will be sent to the site.

Table 4. Description of the new activities at Aik and Aikj levels of the procurement process.

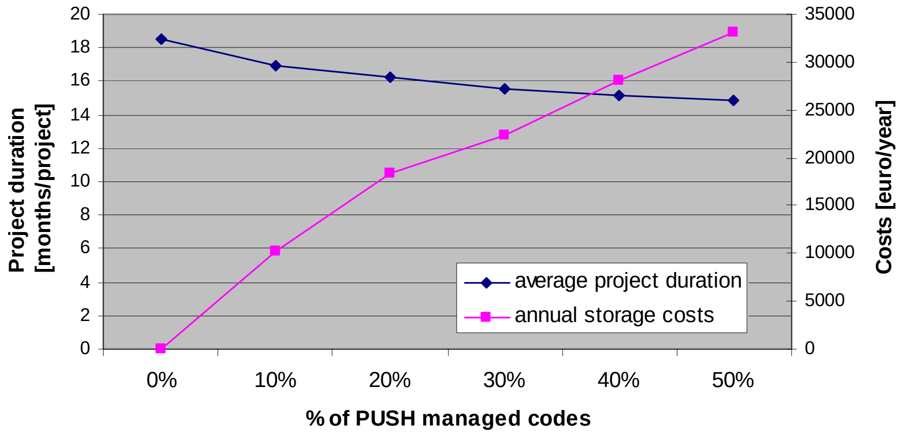

Figure 5. Correlation between PUSH management, Project duration and Costs

	Personnel cost	Administrative cost	Cost of equipment	Annual Activity cost	Activity cost per project
Activity-based costing: As-Is					
(A41) Supply Specifications and Develop and Approval	32,150	0	0	32,150	4,940
(A42) Request of Purchase	10,380	0	710	11,090	1,700
(A43) Ordering procedure	30,640	3,550	4,500	38,690	5,950
(A44) Analysis of the offers	50,900	6,270	3,080	60,250	9,260
(A45) Expediting	36,020	1,890	10,780	48,690	7,490
(A46) Receiving Procedure	28,700	16,980	5,670	51,350	7,900
Total category costs	188,790	28,690	24,740	242,220	37,260
Activity-based costing: To-Be					
(A41) Supply Specifications and Develop and Approval	32,150	0	0	32,150	4,170
(A42) Request of Purchase	10,300	0	710	11,010	1,420
(A43) Ordering procedure	20,800	3,130	4,320	28,250	3,660
(A44) Analysis of the offers	46,910	5,480	2,940	55,330	7,180
(A45) Expediting	36,500	1,890	10,780	49,170	6,380
(A46) Receiving Procedure	28,700	16,980	5,670	51,350	6,660
(A47) MRP processes	29,600	0	26,200	55,800	7,240
Total category costs	204,960	27,480	50,620	283,060	36,760

Table 5. Activity-based costing results

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ABSTRACT

This paper describes the application of Value Stream Mapping (VSM) to analyze and redesign the way of managing the materials procurement stage of a project. A framework based on IDEF methodology, the stream analysis approach, activity-based costing (ABC) and discrete event simulation is presented.

The stream analysis approach is used to analyze, diagnose and manage process changes represented using an IDEF model. A dynamic simulation is used to evaluate the impact of the changes considered, to support the analysis of the process, and to model the performance of the proposed process.

The overall methodology is demonstrated by applying it to a company whose core business is the design and construction of offshore oil rigs. The company is specialized in Engineering, Procurement and Construction (EPC) projects and has an annual portfolio of about 6 projects.

Many of these projects have features in common in terms of design and components and they are all also characterized by a short "Time to Delivery". For this reason this study was aimed at assessing the possible effects that the application of new materials management policies could have on reducing both project completion time and the resources required.

KEYWORDS: Project Management; Value Stream Mapping; IDEF methods; Project Materials Management; Material Requirement Planning (MRP)

1. INTRODUCTION

The parameters for the success of any project are time of completion, within a specific budget and with requisite performance (technical requirements). Unfortunately, current project management does not always ensure success in these areas (Kumar Dey, 1999).

Midler (1993) showed that, more than by overlapping the stages of the project, delay reduction depends on how the relationships between these stages are managed.

This study examines a company which is specialized in the offshore sector. In this field the tenders are usually international and the parties involved, that is to say the Client, the Contractor, the Certification Bodies and the external suppliers of goods and services, are often from different countries. The most widespread types of contract are Engineering, Procurement and Construction (EPC) ones. With an EPC contract, the Contractor undertakes to deliver to the Client a whole plant, or a plant system and to carry out all the pre-commissioning activities. The Contractor therefore has greater responsibility for the production process, and at the same time has to cover the total costs of any consequences deriving from both internal and external mistakes or delays. The need to use EPC contracts is due to the fact that the parties representing the Client are less and less willing to carry out the engineering and procurement themselves, given the high cost and the great difficulty in managing and controlling these activities. The Client therefore also delegates the development of the engineering and procurement to the Contractor, who must provide these services using either internal resources or external sub-contractors. As well as developing the engineering, the Contractor must procure the resources, the most important of which are the materials and specialized supplies (above all the machinery, the piping, the equipment and the actuators).

Various authors (Mahmoud-Jouini et al., 2004) have shown that in EPC projects, customers can consider time as a resource and, in that case, they will encourage the contractor to reduce the project duration. In the case of Engineering, Procurement and Construction (EPC) projects the time factor plays has an important role in two ways of generating profit: reducing delays can lower costs by the reduction of the financial immobilization (Rosenau, 1988) and, based on an economic analysis of first mover advantage (Lambkin, 1988), may also create value in markets where obsolescence is central. The importance of proper management of materials is highlighted by the fact that they account for substantial portions of project cost and time. Expert estimates and historical data analyses indicate that materials account for 50-60% of project cost (Stukhart and Bell, 1985) and control 80% of its schedule (Kerridge, 1987).

In this work the Value Stream Assessment (VSA) approach is used to assess the strengths and weaknesses of a project value stream for the express purpose of creating a value stream driven solution. VSA is a way of looking at an enterprise's business problems, within the context of the enterprise's value stream(s), with the aim to rapidly find a comprehensive solution for identified business problems. A framework based on IDEF methodology, the stream analysis approach, activity-based costing (ABC) and discrete event simulation is used to define and analyze the current state of a project value stream and design a future state focused on reducing waste, improving lead-time, and improving workflow.

The rest of the paper is organized as follows. Section 2 presents a bibliographical analysis of existing works on Project Materials Management and the methodology for analyzing the case study proposed in Section 3 which concerns a company specialized in the offshore sector. In Section 3.1. a project mapping is performed, examining the procurement stages in detail. On the basis of the problems which come to light in the As-Is model, section 3.2 proposes and assesses a new way of managing the inventory. Finally, a discussion of results and the conclusions are presented in Section 4.

2. MATERIAL AND METHODS

The issue of Project Materials Management has also been dealt with by other authors. Kumar Dey (1999) presents a methodology for re-engineering the Project procurement processes by eliminating non-value added activities, taking up activities concurrently by applying information systems rigorously and applying risk management techniques throughout the project life cycle.

Some works have used mathematical models (Silver, 1989; Keith and Willoughby, 2001) and dynamic programming models (Teisberg, 1981) to examine the inventory management problem within a large-scale project context.

Other authors have tried to integrate ways of managing materials which are traditionally used in manufacturing industries into Project Management. Ibn-Homaid (2002a) analyzed three alternatives for managing materials in large or complex projects: inventory management, material requirement planning (MRP) and Just-in-time (JIT). This author found that a comparison of the materials management processes in manufacturing and construction reveals both similarities and differences. The differences arise mainly from the respective environments in which the two systems operate. Homogeneity and standardization of construction materials are lower than those for manufacturing. The number of items involved in constructing a project is considerably higher than in manufacturing a product. The processes in manufacturing enjoy accuracy and completeness of input data that are uncharacteristic of managing project materials. The process variables are less controllable in projects than in the manufacturing environment. Despite these difficulties the planning and monitoring of the materials required to manufacture a product is not so different from what is involved in construction. Other studies (Ibn-Homaid, 2002b) reveal that MRP and JIT systems are, respectively, more or less similar to project materials management systems. An MRP system is more appropriate when demand is discontinuous, dependent, and non-uniform. Although a complete application of an MRP system is not generally feasible, many ideas and principles can be adapted and some of the techniques involved can be readily applied to project materials management.

On the basis of these considerations this study tries to integrate MRP logic in the materials procurement management system of a company which is specialized in EPC projects, without eliminating the existing management system.

Methodologies such as Business Process Re-engineering, Activity-Based Costing and Activity-Based Management, Enterprise Modeling, Benchmarking and Best Practices are part of the toolsets used in order to analyze, design, improve and evaluate different business processes.

2.1. STREAM ANALYSIS APPROACH

The stream analysis approach is based on the systems theory and it assumes that a process is open, consisting of subsystems, each including a stream of variables, with many of these variables connected either causally or merely relationally within the same stream or across streams (Porras, 1990). The actions that change one variable are resisted by connected variables, and at the same time, the connected variables are affected by changes in the original variables.

Of the systems analysis (SA) techniques available, the IDEF series is frequently used for manufacturing systems (Hill and Robinson, 1995; Colquohoun, 1996).

IDEF-0 is a language for describing activities or processes and how they relate. Since understanding hierarchy is important in comprehending complex systems, IDEF-0 is particularly useful because it includes hierarchy as an element of its modeling capability.

Insert figure 1 about here

There have been a number of attempts to employ IDEF in manufacturing (Kusiak et al. 1994; Bradley et al., 1995; Gong and Lin, 1994). The major drawback of these SA techniques is that they attempt to represent a dynamic system with a two-dimensional static image, although they can be useful in the analysis and design stage when building a simulation model (Lee and Elcam, 1996; Giaglis et al., 1998; Ip et al., 2000; Dewhurst et al. 2001; Bevilacqua et al. 2003).

In IDEF-0, the activities are graphically represented by boxes containing an indication of their name and number (Fig. 1). The concepts graphically represent the inter-functional relationships between the activities comprising the model. They can be distinguished as follows:

- ⇒ Input: information or object needed to implement the activity;
- ⇒ Output: information or object achieved as a result of the activity;
- ⇒ Constraint: condition or circumstance governing the performance of the activity;
- ⇒ Mechanism: person or means conducting the activity.

IDEF methodology has a descriptive power to represent the process structure. However, most process modeling methodologies, including IDEF, are based on informal notation, lacking mathematical rigor, and are static and qualitative, thus making it difficult to use them as tools for analysis. This paper presents the stream analysis technique and dynamic simulation approach for the analysis and re-engineering of processes represented with IDEF models. Stream analysis is used to analyze, diagnose, and manage the change process and a dynamic simulation model is developed to evaluate the impact of the changes considered.

Simulation is a tool that characterizes a system, and provides means for evaluating potential results depending on changes in environmental variables (Schriber, 1987). The performance criteria examined with simulation are process cycle times, queue times and resource utilization. The development of simulation models is an important way to learn about complex system evaluation. Several authors (Tumay, 1995; Paul et al., 1999a; Paul et al., 1999b) have argued that the failure of business change projects is sometimes due to a lack of simulation model development to evaluate the effects or design solutions before implementation. Mistakes brought about by changes in business processes can only be understood once the redesigned processes have been implemented, when it is too late, costly, and probably impossible, to correct wrong decisions. (Tatsiopoulos et al., 2002).

In this study the results of the simulation analysis are combined with Activity-Based Costing techniques. The flexibility of the simulation approach permits the calculation of a variety of performance indicators related to time, cost or quality. Activity-Based Costing uses the outputs of simulation runs and translates them into financial terms. ABC is essentially an approach to cost management which is based on the vision of business as a series of activities, each of which absorbs resources. It aims to reinterpret the traditional concept of industrial accounting according to which products consume resources (and have costs which are proportional to the resources), substituting it with a new theory which suggests that activities consume resources while products consume activities.

3. CASE STUDY

This paper analyzes the way projects are managed by a company whose core business is the design and construction of offshore oil rigs. The typical work order of the company examined, on which this study and therefore the simulation is based, concerns the construction of an offshore oil rig made up of three modules: a single pile jacket, topside production facilities, and a topside accommodation module.

The type of contract drawn up is usually an EPC one, therefore involving the development of the basic and detailed engineering design of each module, the planning and implementation of materials and main items procurement activities, construction, pre-commissioning and commissioning. The plant is delivered to the Client *performance tested,* that is to say hot-tested (with the machinery running and operating) but without the process fluids (therefore tested with water and/or pressurized air).

3.1. PROJECT MAPPING

The most significant stages in any measures to improve processes, regardless of their nature, are the diagnosis of the *As-Is* situation and the redesign proper. The process diagnosis phase is aimed at pinpointing which components and which related activities are involved in the most critical situations and what they consist in, and also at deciding which measurements can be used to quantify these situations. An important aspect of the analysis of the *As-Is* situation lies in determining the time, cost and proportion of resources associated with each activity.

The IDEF-0 model developed is described below, listing all the activities considered. First of all the first level activities, all those with an Ai code, are indicated (Figure 2) and the main activities which come into play are described (Table 1). Subsequently the more detailed activities, the second level ones indicated with the code Aik, are described, and so on until all the levels have been considered. In the following figures, so as not to take up too much space, only the activities which refer to the procurement stage are indicated (Figure 3 and Table 2). This stage will be taken into consideration for redesign in the second part of this chapter.

Insert figure 2 about here

Insert table 1 about here

Insert figure 3 about here

Insert table 2 about here

The development of the IDEF-0 models was carried out by a panel of experts. This panel was formed in order to encourage communication and meetings during which the members could contribute their knowledge and information about the processes. It was made up of 12 participants, and included 3 academics, whose research studies are mainly focused on Business Process Re-engineering and Operation Management, 2 Project Managers, 3 Managerial Operators involved in Project Processes and 4 Suppliers involved in Project Procurement. This number of participants, which at first sight may seem rather large, derives from the Delphi technique (Linstone & Turoff, 1975) adopted for working with panels. The Delphi technique is a structured process which investigates a complex or ill-defined issue by means of a panel of experts. This methodology proves to be an appropriate design for this type of research and permits individual opinions to be obtained within a structured group and using a communicative process. The panel worked for a period of about two weeks, and the sessions were planned on a three-round Delphi process. At first a series of statements concerning the requirements of the Project processes was generated individually and anonymously by the experts. All the statements were then collected and delivered to the members of the panel, who were required to indicate their level of agreement; answers were finally fed back to the panel.

Using this work methodology it was possible to identify a number of areas for improvement: planning and engineering, materials procurement process, supplier selection, etc.

The rest of this work is aimed at illustrating how the problem of materials management was dealt with. The main difficulty found was the extremely limited time available: a procurement plan must be drawn up by a certain date, otherwise the materials will not arrive in time for the construction, even if within that date little or no information about the detailed engineering design is available.

At this point it must be underlined that the offshore sector market is becoming more and more demanding. The construction of a work order with an overall weight of about 5000 tons is supposed to be carried out in only 15.5 months, when, according to the schedules usually followed, 18 months would be required, considering that it may be necessary to wait 3 months for some types of beams or even 10 months for some particular types of valves.

The group of experts identified a number of steps which are necessary in order to deal with this situation:

- Initially an analysis of procurement lead time and value was carried out for all the codes for raw materials and components purchased from external suppliers so as to identify 4 risk classes for the different codes (Table 3). Attention was then focused on those codes which had the longest lead time.

Insert table 3 about here

- For the high risk codes, with the longest lead time and the highest value, an attempt was made, in collaboration with the suppliers, to find an alternative product, with standardized specifications, which allowed the construction and delivery times to be reduced. The selection of vendors of critical items must not be based on the "lowest cost" criterion.
- Another possible resource, for the highest risk codes, could be the *Material Take Off* (MTO) of the Client. During endorsement the Client in fact submits all the engineering developed up to that time. If some preliminary MTO has also been defined, it will be given to the Contractor for information purposes only. Despite the risk of under or over approximations it is possible, on the basis of this MTO, to make an initial

approximation of the quantity and type of material to order and to carry out a preliminary market research. For example, for the structure, *ready-made* (pre-shaped) or *sheet metal* beams, may be purchased. It is necessary to assess the risk of ordering these materials on the basis of this MTO information, considering how much possibility there will be to use any leftover materials, resulting from procurement strategy errors, at a later date for subsequent projects.

- The assessment of a PUSH type inventory policy was considered for medium/low value codes and long lead times. In this way the material is purchased before confirmation of the order by the client and it will therefore be necessary to make forecasts about the codes and implement an "as-needed" management according to an MRP logic.
- In order to make these management choices for long lead time codes more efficient co-makership policies, or in some cases partnering with the suppliers, may be adopted.
- Finally, to make sure that these modifications are beneficial, during the contractual phase it is necessary for the sales department to try to arrive at agreements with the clients so that the design solutions and specifications of the components are as standardized as possible and therefore have shorter lead times. As a result of this type of cooperation the company will be able to guarantee shorter delivery times for the project.

Identifying the above-mentioned "gaps" is particularly important because they provide the input for the redesign phase (*To-Be*).

The correct approach to a *To-Be* project is supported by a series of fundamental principles.

✧ It is a design effort that is principally of an inductive nature; we initially consider an arrangement similar to the one currently used, then we add a series of suitable changes that will lead to the new situation. This implies the need to rely on an in-depth understanding of the environment in question so that we can adequately consider all the possibilities.

✧ *Object design* plays a fundamental part in the To-Be project: since every process produces outputs by elaborating its inputs, it is important to focus attention on these inputs and outputs, establishing which cannot be moved or changed in a given process, and which are uncontrollable or independent, in order to characterize them completely.

✧ It becomes particularly important to break down the processes into sub-processes to enable an efficient and flexible allocation of the resources available at the executive stage.

- ✧ It is equally fundamental to analyze potential failures (*failure management*): we need to evaluate the various different failures that may be encountered and determine their effects, so as to plan sub-processes suitable for managing them.
- ✧ The project must be conducted bearing in mind that, in addition to the desirable outputs, the processes also produce some unwanted outputs and these must be suitably handled in specific phases of the processes concerned.

3.2. TO-BE MODEL

The company analyzed in this study has an annual portfolio of about 6 projects. Many of these projects have features in common as far as design and components are concerned and they are also all characterized by a short "Time to Delivery". For this reason we decided to assess the effect that the application of new materials management policies could have in terms of reducing both the project completion time and the resources required.

On the basis of the observations made in the previous chapter and summarized in Table 3, the procurement process was re-designed as indicated in Figure 4 and described in Table 4. We then tried to understand what was involved in changing from supply management based totally on the information provided by the detailed design to a PUSH type management, that is to say management which involves the purchase of materials and components before confirmation of the order by the client. For the latter solution we try to assess the positive aspects (mainly the shorter duration of the project) and the negative ones (an increase in indirect and inventory management costs).

Insert figure 4 about here

Insert table 4 about here

Since an IDEF model is static and qualitative it is difficult to use for analyzing the change process and cannot be manipulated to derive quantitative and meaningful results for process analysis (Busby & Williams, 1993). The model does not provide any information on how the initial level of personnel impacts the hiring/firing policy of the company, or how the process behaves under different initial inputs, or how many tasks are completed within a certain time interval. In order to improve the power of an IDEF model from the quantitative point of view a dynamic analysis of the process is proposed not only to determine the behavior of the system under different initial inputs but also to perform repeated experimentation with the process and to alternate the management policies. Discrete event simulations replicate processes as a sequence of events where each event has a starting point and an ending point usually measured by time. State variables, that measure the state of the process being simulated, are associated with these discrete points in time. Therefore, as a simulation proceeds through a series of events, the process under simulation will be viewed as a series of state changes. Analysis can focus either globally or locally as designed for any particular simulation. After the construction of an accurate model that presents reality in a satisfactory way, the simulation run takes place and is repeated for a number of times that can guarantee statistically acceptable results.

Management needs a sufficient analysis of the expected benefits in order to justify the necessary capital investment. Moreover, it is of great importance to predict the performance of the new processes as far as throughput, lead time, and utilization are concerned. These three indicators were selected by top management as being the most appropriate for process monitoring.

A simulation model was built in order to roughly estimate the effects of the new process on two predefined performance indicators: project lead time and the cost of related activities.

In order to develop the simulation model the Simulation Software iGrafx© was used. The model was run for 36800 h (20 calendar years) with a warm-up period of 5000 h.

The most important assumptions made in the simulation model are the following:

- The time between two successive projects is exponentially distributed. The distribution parameters were estimated on the basis of past observations (historical data).
- The duration of the activities was estimated using beta type distribution functions in which the optimistic, pessimistic and most likely values were identified by a panel of experts using the Delphi method.
- The users work 8 h a day. They stop work at the end of each working day or week and they continue their work the next day, or Monday if there is a weekend in between, from exactly where they left off.
- The prediction error is 27%. This value was obtained using tests on the historical data.

The codes for the raw materials and for the components purchased from suppliers were put in decreasing procurement lead time order. The simulation of the project was then repeated with an ever increasing number of codes managed in PUSH modality, starting from the codes with the longest lead-time.

As can be seen in Figure 5, as the number of codes managed in PUSH modality increases so do the annual storage costs, but at the same time the project completion time decreases. If the prediction models were correct there would be no inventory of materials since, by means of an MRP logic (with a lot-sizing lot-for-lot policy), any materials needed would only be ordered exactly when required. This hypothesis is never verified since the prediction models make approximations. Moreover the duration of the project activities is not deterministic and is not always respected. Finally, the clients do not always accept the standard project.

By means of the simulation it was possible to estimate the average time that the materials were held in the warehouse and therefore the average warehouse inventory.

The annual holding cost was estimated as a percentage of the cost of the material and component codes.

The cost of capital, that is the most important component of the holding cost (Brealey & Myers, 2000), was evaluated using the Weighted Average Cost of Capital "WACC" (see appendix 1)

Insert figure 5 about here

Activity-Based Management complements Business Process Simulation by using its results in the analysis of processes to recognize inefficiencies and non-value added activities, and thus allowing opportunities for cost reduction or profit enhancement to be identified. It deals with effectively managing activities to yield continuous improvement by answering ‘‘why’’ and ‘‘how well’’ activities are adding value to a project.

The simulation results, combined with future cost estimations, provided the necessary information for the development of an Activity-Based Costing study. A detailed analysis of the costs, using the ABC methodology, allowed us to establish the extent to which the resources are absorbed by the process and to link the resources with their relative costs. In order to trace the costs to be attributed to procurement the percentage amount was identified with reference to the single procurement activities with respect to the whole work schedule; for an optimal allocation of the costs the times of the various micro-activities involved in the process were also determined (see appendix 2).

The results of this study (in Euro per year and per project) are summarized in Table 5 and refer to 30% of the codes managed in PUSH modality. The activities included in the calculations in Table 5 correspond to the activities depicted in the IDEF-0 diagrams in Figures 3 and 4.

Three cost categories were used for the calculation of the process costs. As can be seen in Table 5, with the new type of management the annual personnel, administrative and equipment costs increase. These increases are however compensated for if we consider the costs per single project. In fact, by reducing the delivery times the company manages to complete a greater number of projects per year and therefore to spread these indirect costs over a greater number of projects.

Insert table 5 about here

4. DISCUSSION AND CONCLUSION

Implementing changes in organization is an effort that is prone to failure. To increase the likelihood of successful change a comprehensive modeling tool is required. This study provides a methodology that utilizes the newly-developed concepts based on stream analysis and dynamic simulation for the effective re-engineering of processes. The stream analysis approach was used for the analysis, diagnosis, and management of the change process.

Stream analysis is procedural in nature and it outlines the necessary steps and procedures needed to carry out the change process. It enables us to chart out the problems identified in the key variables of the underlying process.

In order to evaluate the impact of the changes considered, to support the analysis of the process, and to model the performance of the proposed process, a dynamic simulation model was developed.

The ABC study results showed that the implementation of the new system will not induce a significant decrease in the cost of the process. Some additional costs must be taken into consideration: immobilization of material; risk of obsolescence due to non-use of material; occupation of space. However this limited increase in the costs is balanced by the possibility to considerably reduce the duration of the project. Moreover the greater administrative, personnel and equipment costs tend to go down owing to an increase in the number of projects carried out per year.

Based on the simulation results and the ABC calculations, it was possible to forecast the payback period of the investment. Taking into account that the expected annual increase in the margin of contribution resulting from an increased number of annual work orders which will be acquired thanks to the reduction in the time to market of the projects will be of €75,000. With an investment cost of about €50,000, necessary to purchase the software system and to train the personnel, and having an increase in the annual indirect costs of €40,840 (283,060 – 242,220, see table 5) and an increase in the inventory management costs of about € 22,378 (see Figure 5), the payback period can be calculated as 4.62 years (considering a 5% rate of updating). This return of investment was calculated in the design phase and justified the strategic selection of this type of solution.

This new procedure requires all those involved in designing the new processes to be uninfluenced by the way in which these processes have been conducted to date: in fact, a knowledge of the present situation (As-Is) can have a negative fallout on the development of a new operational plan, acting as an impediment to the search for improvements and innovation.

The management solution used in this study to reduce the duration of the project does not depend on the reduction of the activities but rather on an alternative way of managing the inventory. The management criterion used is not applicable to all types of companies which work with projects for different reasons:

- Lack of materials and components which are common to several projects
- Lack of a portfolio of projects which are similar and repeated

- Lack of financial resources available for the creation of a warehouse.

The upkeep of the resources necessary to carry out the activities involved in the construction of offshore plants is convenient if these resources are adequately exploited; EPC Contractors therefore manage to make the most profit if they acquire work orders in such a way and with such timing as to saturate their operational capacity.

The ability to pursue continual innovation so as to better respond to and predict the new market requirements is indispensable to give added value to the product offered. This is much more evident with EPC contracts, where the Contractor has greater responsibility for the overall execution of the project.

On the one hand change represents growth, opportunity and development while on the other it represents threat, disorientation and upheaval. In such a context, restructuring alone is proving to be increasingly inadequate in achieving and sustaining the improvements needed to remain competitive. The business world today has acquired an aggressive momentum and has entered an era of fundamental and accelerated changes. Sustaining growth and remaining competitive are the greatest problems that management has to face.

APPENDIX 1

The cost of capital takes into account the return demanded on the firm's equity and the amount of debt and equity financing that the firm has. It was evaluated using the formula:

$$WACC = \frac{E}{D+E}\left(R_f + \beta \times MRP\right) + \frac{D}{D+E} R_b (1-t)$$

where:

E = amount of equity; D = amount of debt; R_f = risk-free rate of return; β = the firm's beta; MRP = Market risk premium; R_b = rate at which the firm can borrow money; t = tax rate.

Most of these figures were found in the company's annual report and in the equity report on the company. The borrowing rate came from tables listing the rates charged for bonds from firms with the same credit ratings. The risk-free rate is the return on Italian treasuries, and the market risk premium is the return of the market above the risk-free rate.

APPENDIX 2

To determine the resources absorbed by each activity in percentage terms (Resource Driver) the following formula was used: $\frac{t \cdot f}{h \cdot 60 \cdot T_l \cdot N_t}$ where:

t = time to carry out the activity; f = frequency of the activity each day; h= hours of work for personnel responsible for procurement; T_l = work shifts; N_t = number of people per shift.

This formula represents the relationship between the time taken up by the activity and the total work timetable available in the procurement department. In order to calculate the Resource Driver the cost driver chosen was that referred to the time taken to carry out the activity. The data necessary in order to calculate the costs were obtained through interviews with the department personnel. In calculating the times, so-called "process disturbances" were also considered. That is to say, all the possible interferences which may in some way influence the linearity of the process itself (e.g. overcrowded network, telephone communications during an activity, changing from one activity to another).

APPENDIX 3

- Exponential smoothing forecasting method: $F_{t+1} = aD_t + (1- a)F_t$

  where: F_{t+1}: Forecast for period t+1; D_t: Demand for period t; F_t: Forecast for period t; a: smoothing constant

- The Holt-Winters forecasting method constructs three statistically related series, which are used to make the actual forecast. These series are:

  2. The smoothed data series, which is the original data with seasonal effects and random error removed.
  3. The seasonal index series, which is the seasonal effect for each period. A value greater than one represents a seasonal increase in the data for that period, and a value less than one is a seasonal decrease in the data. The Holt-Winters method allows seasonal effects to vary over time, so there is a seasonal index value for every historical period.
  4. The trend series, which is the change in the data for each period with the seasonal effects and random error removed. The Holt-Winters method allows the trend effect to vary over time, so there is a trend value for every historical period.

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