Multi-Project Planning in Shipbuilding

Roelof van Dijk, Noud Gademann, Geert Schouten & Marco Schutten

WP-78
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Roelof van Dijk (rdijk@ortec.nl), ORTEC Consultants (Gouda), The Netherlands;
Noud Gademann (ngademann@ortec.nl), ORTEC Consultants (Gouda) and University of Twente (Enschede), The Netherlands;
Geert Schouten (g.m.schouten@centerline.nl), Center Line (Roosendaal), The Netherlands;
Marco Schutten (mschutten@ortec.nl), ORTEC Consultants (Gouda) and University of Twente (Enschede), The Netherlands;

Abstract

Planning of time and capacity is an important instrument to improve the performance of a shipyard. In practice, however, the opportunities that planning offers are not fully exploited. In this paper, we describe common planning techniques and propose improvements by organizational changes and by support from computer applications. An important observation is that planning and organizational aspects are closely related. In order to exploit the planning opportunities, the planning process must be facilitated by an appropriate organizational structure. The common approach, in which orders are treated as projects, has proven to be successful, but offers new challenges. A shipyard is a multi-project environment, in which projects interfere and usually have a certain degree of uncertainty in the beginning. We discuss organizational aspects of multi-project planning and explain why traditional project management techniques are not always sufficient. Simultaneous management of time, capacity, and costs is required to balance the various interests in the organization and to improve a shipyard's performance. The multi-project level is the best platform for tactical time and capacity planning for engineering, purchasing, and production. Plan integration results in a more effective planning process. Spatial plans require attention as well, because they cause constraining relations for the production and assembly plan. We discuss several trade-offs for a planner in the planning process. Planning support can contribute to plan optimization and is required to fully use the potential of planning. We describe the possibilities and the demands for planning support. Also, we describe the ongoing implementation of a decision support system at a Dutch shiprepair yard. Although the planning processes for shipbuilding and shiprepair are different, the same principles can be applied.
Introduction

Dutch shipyards build and repair ships, often with a high technical content, in cooperation with subcontractors and suppliers. Pre-outfit, concurrent engineering, and the integration of engineering, purchasing, and production are important aspects for the planning at a shipyard. Each shipyard works on several ships simultaneously and has only a finite amount of resources available. Customers have bargaining power and demand a high quality, short delivery dates, and a high delivery reliability. To meet these demands, a shipyard must focus on short project lead times and high efficiency. Planning is an important tool for achieving these objectives. However, the opportunities that planning offers are not fully exploited in practice (see Andritsos [1], Van Dijk [5]).

Similar planning principles can be applied to both shiprepair and shipbuilding. There are both important differences and similarities between these environments. To start with the differences, the shiprepair market is more dynamic. Also, there is more uncertainty in the order and activity information. Moreover, at a shiprepair yard, the functional organization is more dominant than the project organization, in comparison with a shipbuilding environment. Finally, engineering is less important in shiprepair. There are also important similarities. A modern shipyard is a multi-project environment, in which projects require the same set of resources and interfere. In both shiprepair and shipbuilding, as well as in other multi-project environments, projects have a certain degree of uncertainty in the beginning. Also, in both environments, it is crucial to have a continuously high utilization rate and a balanced workload within the organization. Moreover, a stable demand for temporary labor is preferred for continuity at the work floor. Another aspect is that in both environments the overall capacity is flexible, within a certain range, because of the use of temporary labor. Furthermore, the availability of spatial resources, such as a quay or a dock, is crucial in planning. Also, conflicts can occur between projects whenever the total demand for a resource exceeds the available capacity. Finally, constraining precedence relations may exist between activities of different projects.

Organizational aspects

Business processes

The main business processes at a shipyard, both for shiprepair and for shipbuilding, take place at three levels. At the top level, the order acceptance takes place and the project portfolio is managed. At the medium level, activities are scheduled and assigned to resources, such as departments or space. At the lowest level, tasks are assigned to individual persons. The planning structure and the organization of planning should be designed in a way that facilitates management of these processes. In the following sections, we discuss the traditional planning organization and propose an alternative.
**Traditional organization**

Organization and planning are closely related. The organizational structure should facilitate an effective and efficient planning process. Therefore, organizational aspects of planning must be addressed in order to improve the planning process at a shipyard (see Van Dijk [5]). Most shipyards approach an order as a project. In a matrix structure, which is common in shipbuilding, the project organization is responsible for reaching the project’s goals. The departments deliver the resources for executing the work. The general management of a shipyard is mainly occupied with acquisition and facilitating and managing organizational processes. Within this organizational structure, conflicting interests between the functional (production) organization and the project organization are likely to occur. In the production organization, the management decisions are focused on preventing underutilization and minimizing the use of extra capacity. In the project organization, the management decisions are focused on completing projects in time and within budget. In a multi-project situation, conflicts occur more frequent and become more complex. In some cases, project and resource managers try to manipulate the situation to achieve personal objectives (see Figure 1). Platje [9] states that frequently the informal communication circuit, such as ‘private chats’, is used for this. A coordinating mechanism that covers all projects and all resources is frequently missing. This hinders in particular an effective and efficient capacity management.

**Portfolio management**

The *project portfolio* is defined as the bundle of projects that are in process in the organization. In order to cope with the recurring conflicting interests in the multi-project situation at a shipyard, *portfolio management* can be used (see Platje [9]). Portfolio management brings the project and functional organization together: All project and resource managers should meet regularly to discuss issues of project and resource management (see Figure 2). The chairman of the portfolio management meeting is the *portfolio director* and should be a representative of the general management, such as a sales or production director. Portfolio management results in better decisions for the whole organization and creates commitment among its members (Platje [10]). The portfolio management should discuss issues such as the acceptance of new orders, the utilization rate, and the allocation of resources to projects. Also, the meeting should discuss the performance of the project portfolio and the potential trade-offs in the organization. Moreover, the portfolio management should discuss all multi-project plans, such as the acquisition plan and the tactical capacity plan. The portfolio management meeting should be
Planning aspects

Demands

The demands that a plan must meet are both coming directly from customers and from the internal organization. The customer demands a high delivery reliability, short project lead times, and competitive prices. Also, a customer may ask a shipyard to prove that it can meet the contract requirements. Planning is an important instrument to realize these goals (see Andritsos [1]). Internally, the utilization rate is an important performance indicator for a shipyard. Planning must ensure that this rate remains high enough. The planning process should be designed for a multi-project situation and reliable plans should be the outcome of the process. In practice, plans frequently lack reliability. Also, plans should be optimized, because cost optimization is important in a competitive market with low margins. Moreover, a plan should be ready to use for coordination of the internal organization, suppliers, and subcontractors. Furthermore, the planning process should be ready to cope with other issues, such as concurrent engineering, the integration of engineering and production, and spatial planning. Finally, the planning should have a top down structure in order to cope with uncertainty and aggregate information.

Plan structure

A benchmarking study (see NSRP ASE [8]) by the American Shipbuilding Research Program in 2001 among European yards concludes that “high performing yards have de-centralized multi-level planning”. In order to support the business processes as previously described, a hierarchical top-down approach to planning with at least three levels is required. At the highest level, strategic or tactical decisions should be made. Medium-term to long-term capacity management must be performed in order to match capacity requirements from the expected or operational project portfolio to the available capacity. In that way, reliable due dates and cost estimations can be obtained to support the order acceptance process.
Also, at this level, important milestones for projects must be set. Moreover, capacity must be rearranged in case of major changes in the project portfolio. Note that, for instance, order acceptance takes place under a condition of information uncertainty. Detailed information about the project work breakdown is not always available. This means that capacity planning must be partly based on large work packages and aggregate capacity requirement estimations. At the medium level, based on more detailed process planning, work packages are divided into activities. These activities are then scheduled, meaning that both their timing and their assignments to departments and other resources are determined. At the bottom level, the department planning is performed. Activities may be further divided into tasks. Individual laborers should be assigned to tasks and work instructions should be made. The implementation of the three levels may depend on the specific environment and the project sizes. In any environment, however, capacity planning, activity scheduling, and department scheduling must be performed.

Note that the suggested organizational structure with portfolio management facilitates this top-down planning much better than the traditional organization structure. The portfolio management team plays a central role. It supports the management by performing the capacity planning. The portfolio management team receives the project plans from the project managers and the actual department schedules from department managers. Based on this information, the team determines the project schedules (timing of activities) and the allocation of resources to activities over the entire project portfolio. The department planning is performed in the departments within the constraints that are set by the activity scheduling.

Planning of the purchasing, engineering, production (fabrication), and assembly processes at a shipyard each require a different approach. There are different plans for all of these processes and in general different people are responsible for each of these plans. A multi-project plan is used for acquisition purposes and for tactical and strategical management. There are also separate production, engineering, and purchasing plans. Moreover, a spatial plan is used for management of the building dock and the floor space for production, assembly, and storage. Each of these plans has its own characteristics. Generally, the engineering plan must be detailed because engineering work is usually specialized work. For the planning of the production and assembly organization a rougher plan can be used that is transformed later into detailed work plans. The purchasing plan should be deduced from the production, engineering, and assembly plan.

**Integration**

Plan integration is a crucial step in the planning process. Integration is necessary to get a complete overview of ongoing and planned activities and of the resource usage (such as labor, facilities, materials, and space) at a shipyard. This overview is required to improve the performance of a shipyard by means of planning. The plans at a shipyard are usually integrated by making project milestones correspond. Milestones can be changed by mutual agreements. In practice, when internal milestones are negotiated between project and resource managers, capacity constraints are usually not taken into account. Also, planners are not warned when
a feasible milestone becomes infeasible after updating a plan with realization and progress data. An integrated approach to the plans at a shipyard is preferable and leads to better results. We illustrate this with two examples. First, to optimize a plan for pre-outfit activities, it is required that a planner has both insights into the engineering and the production activities. Second, in practice, the initial purchasing and production plan usually correspond with each other. In most cases, however, the purchasing plan is not updated when the production plan changes.

Plan integration should be achieved in several ways. First of all, decisions must be taken at the right planning level. This means for example that decisions that significantly affect several projects and departments should not be taken via bilateral discussions but in the portfolio management team. Second, the information in different types of plans, such as an engineering plan and a production plan, should correspond. A central database or interfaces between different information systems should be used for that. Third, when determining project milestones, used for integrating plans, planners should take both time and capacity into account. Fourth, relations between plans and planning levels should be monitored.

Plan reliability

Introduction

In practice, plans at a shipyard are frequently not reliable enough (see Guyt [7], Van Dijk [5]). This has a negative effect on both the shipyard’s performance and on the commitment among employees in the organization. There are several reasons for the lack of plan reliability, which we describe in the following sections.

Management of time and capacity

Figure 3 shows the common planning process at a shipyard. With professional experience and well developed rules-of-thumbs, planners can make reliable estimations of the work content of projects and activities. The activity lead time is determined on the basis of the estimated work content. In the current planning process, time and capacity are managed independently and often sequentially. This means that a planner focuses on meeting the project milestones, such as the delivery date. In a next step, he performs a capacity check. The management of capacity is secondary and the planner does not optimize the use of capacity.
Independent and sequential management of time and capacity does not give reliable and cost effective results, especially in a multi-project environment. In practice, planners focus and base their decisions in the first place on the time performance of a plan. By not constantly taking constraints into account, such as capacity constraints, a shipyard faces the risk that a plan can only be realized at the expense of high costs. We illustrate the possible unexpected consequences of time-driven planning by the following example. In practice, planners often use the Critical Path Method (CPM) as a technique for activity scheduling and project planning. This technique has a major flaw: It does not take the finite capacity of resources into account and does therefore not give reliable results in a situation with finite capacity. We illustrate this with an example concerning the assembly of a steel block (block 1-2) that consists of two subassemblies. Table 1 gives an overview of the activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity description</th>
<th>Duration (days)</th>
<th>Work content (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Assembling subassembly 1</td>
<td>3</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Assembling subassembly 2</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>Transporting subassembly 1 to block assembly site</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Transporting subassembly 2 to block assembly site</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Assembling block 1-2</td>
<td>3</td>
<td>150</td>
</tr>
</tbody>
</table>

*Table 1: Description of the activity network.*

In Figure 4, the activity network is represented by an activity-on-node (AON) model. The start and finish of the network are indicated with S and F. The estimated activity duration is shown above the activity nodes. The assembly department performs the activities. This department consists of 8 persons, who each work 8 hours a day. Because of the lunch break, the available total capacity is only 60 hours a day. As can be seen in the activity network, activities 1 and 2 can both start immediately, if we assume infinite capacity.

In practice, the CPM is often used to calculate the minimum project duration. The planner estimates the activity lead times, required for the CPM, and introduces a margin (time buffer or fixed lead time) to take the finite capacity into account. For example, activity 2 has a work content of 250 hours. The calculated lead time would be 250/60 = 4.2 days. The estimated activity duration, however, is 5 days. Activities 2, 4, and 5 form the critical path of the activity network for the assembly department. The critical path dictates a minimum project duration of 5+1+3= 9 days.
If the planner takes the finite capacity into account, it appears that the lead time of the activity network for the assembly department, the time elapsed between S and F, is longer than the critical path. Figure 5 shows an optimal schedule for the assembly department. The total lead time is 11 days, which is 2 days longer than the critical path. This means that even in a single-project situation (the activity network for the assembly department can be defined as a single project), the CPM does not give a reliable estimation of the project completion date (F). In practice, planners introduce time buffers and slack in the original activity network to get better results. In our example, this has turned out to be insufficient. A multi-project situation, in which different projects require the same set of resources, is much more complex. In that situation, the CPM gives even less reliable results.

![Figure 5: Department schedule taking finite capacity into account.](image)

Time and capacity should be managed simultaneously, especially in a multi-project situation. Simultaneous management of time and capacity is more efficient than independent management and results in more reliable and cost effective plans, which will have a positive effect on the attitude of both management and employees towards a plan. Also, a direct trade-off becomes possible in the planning process between longer lead times (or even activities being late) and using extra capacity. A direct trade-off results in better decisions, because there is a better insight into the situation and a good basis for analysis.

**Common planning techniques**

Planners, and most project planning systems, usually follow the traditional approach for project planning that is time-driven: It focuses mainly on time planning of single projects. In this approach, capacity requirements are merely a consequence of project plans, instead of being the result of simultaneously managing time, capacity, and costs. In the example above, we have illustrated that this can have unexpected consequences. Many tricks have been suggested to overcome nasty surprises of time-driven planning for capacity requirements. We mention the introduction of time buffers in time plans, and the application of fixed lead times that are (much) longer than the work content justifies. Such methods try to deal with the consequences of finite capacity in time-driven planning. Another popular method is leveling that has the following procedure. First, time-driven planning is performed. If this results in an undesirable peak demand for capacity, this peak is flattened by slightly modifying the schedule. Leveling is based on time first and then capacity. This rule is its main flaw: it only optimizes locally which, again, results in sub-optimization. If time and capacity would be managed simultaneously, what would be left to level?
Capacity planning

Capacity of relevant resources should be planned to increase the reliability of plans and to truly optimize a plan. Also, management of a shipyard benefits from a reliable tactical capacity plan by using it to anticipate required capacity changes. A tactical capacity plan can be used to make long-term agreements with temporary labor agencies and gives a shipyard more bargaining power in these agreements.

There are different variants of capacity planning. An example is Rough Cut Capacity Planning that can be used for tactical capacity planning. In this technique, the planner cuts the total demand for capacity of a work package in pieces and assigns each piece to a period in time, taking the feasible time windows and precedence relations with other activities into account. In capacity planning, a work package may have a capacity profile that describes its demand for capacity according to resource over time. A capacity profile limits the freedom of a planner to plan resources, but is very realistic in shipbuilding. The planner is not totally free in cutting the demand in pieces but is constrained by the prescribed capacity profile. It is also possible that there are demands on the minimum and maximum progress of a work package in time. In that case, the planner can plan capacity freely, as long as the demands on activity progress are met.

Relations between plans

In order to make reliable plans, relations between plans should be monitored and taken into account in the planning process. Otherwise, plans may be infeasible or do not represent reality very well. For example, production can only start when sufficient engineering information is available and when the required materials have been delivered. Spatial planning is another aspect in shipbuilding that causes relations with other plans.

Spatial planning

By means of spatial planning, the limited space should be managed as well as possible. The building site plan describes the availability of the building site over time and is mainly used for bidding and tactical planning. A floor plan is used to manage limited floor space and is important because ship sections are often transported through the hall and the material flow is usually high. Floor space is required to store and handle materials and sections. The floor plan is usually an operational plan.

Currently, a floor plan is usually constructed independently, even though there are all kinds of relations with other plans. If, for example, a floor plan changes, the production plan can be affected because some processes can only be performed on certain locations. Also, the production may be interrupted because of the required transportation time. Moreover, if a planned location of a section changes in the floor plan, the operational work instructions must be changed. Moreover, updates on the realization and progress of activities impact a floor plan. Integration of spatial plans with other plans provides opportunities to increase the effectiveness and efficiency of the planning process.
Quality of information

Reliable planning is only possible with reliable and up-to-date information. In practice, insufficient measurement of realization and progress data frequently leads to plans that do not represent reality anymore. Observations show that collection of reliable information is not well organized and therefore timeconsuming. As a result, sometimes people are already happy if they have some sort of plan. As long as the plan looks nice, it is easy to continue and to just take it for reliable.

Optimization

Control factors

Project milestones are usually not flexible, because there is hardly room for change without harming the due date performance. In general, there are two control factors that a planner can use to optimize a plan. He can propose to change the available (labor) capacity or he can propose different work methods. An effective infrastructure exists of subcontractors, suppliers, and temporary labor (see Bruce [3]).

Flexible labor capacity

Production work can usually be partly performed by temporary laborers. These can often be arranged on a fairly short notice and in the right quantities. This applies much less to specialized engineering work, which can usually only be performed by regular employees. Also, it is more difficult to hire specialists in a flexible way. In most cases, there is the possibility to subcontract work. A planner should have the possibility to change the available production labor capacity. He can use several methods to temporarily increase the capacity. First, hiring temporary production laborers with the help of temporary work agencies. Second, exchanging workforce between departments. Third, working overtime increases capacity for a short period of time. Finally, working in shifts increases the available capacity significantly.

Multiple execution modes

Usually there are multiple execution modes for performing an activity: it can be performed by different sets of resources. The choice of the resource set influences the duration of an activity. De Boer [2] mentions two trade-offs: The first is between an activity being late and using extra capacity and the second is between resources and resources. The latter is skill related: Normally, the use of another resource set than the usual results in longer activity duration. He considers multiple execution modes an important practical extension to the standard resource constrained project scheduling problem (see for example Demeulemeester and Hersselen [4]). In practice, planners use rules-of-thumbs for dealing with these trade-offs.

Optimization criterions

Project lateness is usually not accepted in shipbuilding. Plans can be optimized on criterions such as costs, workload, and capacity. We discuss two optimization
criterions for tactical capacity management: minimization of the demand for extra capacity and minimization of fluctuations in the demand for extra capacity. An optimal plan in practice is not optimized on each of these criterions. By working interactively with a planner, a planning system should support a planner to use these criterions as instruments to improve a plan. The value of the first criterion is obvious: minimization of the demand for extra capacity leads to cost reductions as long as all orders are completed in time. The second criterion gives a shipyard more bargaining power in the negotiations with temporary labor agencies, because it can make medium term agreements on the basis of a reliable capacity plan. Temporary laborers that work at the shipyard only for a short period first must adapt to the local procedures, culture, and habits. In the adaptation period, the productivity and quality of work is usually lower. An optimized medium term capacity plan ensures that workers stay at the shipyard for a period long enough to become fully productive and against lower costs.

**Trade-offs**

The management at shipyards makes several trade-offs in the planning process. For making these trade-offs, in practice, manual data processing is usually necessary to calculate and compare alternatives. As a result, the management has to decide on the basis of limited and sometimes inadequate information. Decision support for making these trade-offs speeds up and improves the decision making process. A computer application could, for example, automatically calculate the consequences of a change in a plan on the total costs of the plan. Also, it can compare plans, using pre-defined criterions. We describe the main trade-offs. The first trade-off is between a project being late and using extra labor capacity. Using extra capacity may prevent project lateness. This trade-off exists on all planning levels. The second trade-off is between different types of extra labor capacity. The main criterion for this trade-off is the cost of the extra capacity. However, other aspects are important as well, such as labor agreements and the availability of flexible labor. The third trade-off is between making and buying. The planner should be able to assign costs to subcontracting to make it easier to compare alternative plans on a cost basis. The fourth trade-off is between different scenarios. A scenario represents the environment for a plan and consists of constraints, external demands, and input data. A plan should be tested and evaluated for different scenarios in order to reduce risks and optimize the performance. On the multi-project level, a project bid results in a new scenario for the project portfolio, in which the new project is added to the portfolio. By analysis, a multi-project plan can be evaluated on the effects of lateness or on a changing demand for capacity of a project. On the project level, a planner could test a plan on the effects of changed project milestones or on the late delivery of the engine of the ship. On the department level, a planner could test a plan on the effects of changing due dates for activities. In general, a planner should be able to make and save different plans for each scenario, in which he can change the available capacity. The eventual decision on the allocated capacity is the responsibility of a resource manager.
Planning support

Planning support is required to achieve performance improvements by means of planning. A planning system can be an important element of that (see Goldan [6]). A planning system must be able to cope with specific planning issues at a shipyard to be of significant added value to a shipyard. When using standard planning systems, such as current project management systems, it is usually not easy to deal with those issues. We have already mentioned several important aspects that a planning system should be based on. A recent short survey (see Van Dijk [5]) concluded that there are several demands for a supporting planning system for shipyards. We summarize the demands that a planning system should meet, organized by category. In the category planning techniques, a system should be designed for a multi-project situation and should support hierarchical planning. Also, it should be based on the simultaneous management of time and capacity. Moreover, it should integrate different plans at a shipyard and should be able to cope with specific planning issues such as spatial planning. In the category business processes, a system should support the acquisition and the order intake process. Also, it should offer decision support to optimize plans and to support a planner in making important trade-offs. Moreover, it should support capacity planning for tactical management and to optimize resource usage. In the category interfaces, a system should be easy to use, support manual planning, and communicate interactively with the user. Also, it should have interfaces with various other systems at the shipyard, such as a logistic system for material coordination, to ensure that data corresponds and is reliable. Moreover, it should use realization and progress data of activities for making plans. Furthermore, it should be ready for use by different users, among which a portfolio management team, that each have individual demands and require specific information.

A decision support system

In this section, we discuss PROMPT, a decision support system for multi-project planning and describe in what way PROMPT follows the principles promoted in this article. We sketch the background of the system and the system itself and discuss implementation aspects at the Royal Netherlands Navy Dockyard.

Background of PROMPT

The Royal Netherlands Navy Dockyard (RNND) is responsible for the maintenance, repair, and modifications of the Dutch naval vessels, including frigates and mine counter vessels. The RNND and the University of Twente have cooperated in a large research project on production control (see De Boer [2] and De Waard [11]), with the objective to improve the delivery and cost performance of the shipyard.

As part of the conclusion, it was proposed to re-engineer the RNND's functional organizational structure because it was not adequate anymore (see De Waard [11]). In a functional organization, the work is divided according to the required skills in the departments. Since there are a large number of skills, a huge amount of activities were defined with a lot of dependencies between them. The available
coordination mechanisms at the RNND were not able to handle this properly. De Waard [11] concludes that re-engineering of the organization was necessary. He advises that the organization should have a matrix structure, combining the advantages of a functional organization and a project organization. Also, a portfolio management team (see Section “Organizational aspects”) should be introduced that decides upon order acceptance and prioritizing projects in case of problems. Finally, multi-functional teams should perform the work and the activities should be defined such that each activity is about one week of work for a team.

The new organization structure requires new tools to support the portfolio management team (see De Boer [2]). The operations of the RNND involve a high amount of uncertainty about the work to be done. De Boer suggests to use a top-down approach to handle this uncertainty (see also Section “Planning Aspects”). First, a multi-project rough-cut capacity plan should be made to support order acceptance in which agreements have to be made about delivery dates and costs. The input to this capacity plan consists of estimations of the work contents of large work packages. The goal of capacity planning is to make a good trade-off between projects being late and using extra capacity. Later, in the detailed process planning, the work packages are divided into activities of which detailed information is available. These activities are then scheduled in which the objective is to meet the agreed delivery dates.

De Boer concludes that no commercially available system was able to support the portfolio management team adequately. An important reason is that such systems do not support the top-down approach in a suitable way. Also, those systems are not truly multi-project systems and are not able to properly deal with the finite capacity of resources, especially of spatial resources. Therefore, the University of Twente has developed a prototype of a decision support system to support the portfolio management team. The RNND has tested this prototype and decided that it wanted to use such a system. On the basis of the prototype decision support system, ORTEC has developed PROMPT.

**PROMPT**

PROMPT is a commercially available tool to support decision making at the portfolio management level. It supports true multi-project planning and scheduling, taking into account the limited capacity of the resources. For rough-cut capacity planning, PROMPT can automatically generate solutions. Figure 6 shows an automatically generated capacity plan in which all desired delivery dates must be met. This may imply that extra capacity is needed besides the regularly available capacity. The goal is then to minimize the use of this extra capacity. In this example, PROMPT proposes to use about 136 hours of extra fitter capacity in week 10. In another planning mode, PROMPT minimizes lateness without using any extra capacity. This may imply that it is not possible to meet all delivery dates. The objective of the system is then to meet those delivery dates as good as possible, i.e., to minimize project lateness. Using both planning options in an interactive way, PROMPT supports making agreements with customers about delivery dates and costs.
After the acceptance of a project, detailed process planning is performed. This detailed process planning means that the large work packages, which are planned in the rough-cut capacity planning, are divided into activities. In PROMPT, these activities can be scheduled automatically. The objective is then to meet the agreed delivery dates as good as possible, given the limited capacity of the resources.

On both the rough-cut capacity planning level and the scheduling level, PROMPT allows the user to define multiple scenarios and plans, with which he can perform ‘what-if’ analysis.

**Ongoing implementation**

At this moment, ORTEC is implementing PROMPT at the RNND. Figure 7 shows how PROMPT is embedded in the existing information structure of the dockyard.

The Business Planning System (BPS) is a kind of ERP system that the RNND uses. The Shop Floor Control System (SFCS) is a system that the RNND uses to dispatch work to the work floor. Note that the SFCS is used for department planning (‘bottom level’ in Section “Planning aspects”). PROMPT is used for capacity planning and project scheduling (‘highest level’ and ‘medium level’).

The BPS is an older system in which it is very hard to upload data automatically. The SFCS is more recent application that contains all information of the BPS that is relevant for PROMPT. The data in the SFCS is synchronized with the BPS once a day. Since data transfer with the SFCS is much easier than with the BPS, we chose to use the SFCS for data transfer from the BPS to PROMPT. The BPS, however, does not contain all information necessary for PROMPT. For example, information with respect to which activities must be performed in one of a ship’s
The docking period is not stored in the BPS. Therefore, we need the Central PROMPT Database (CPD).

The CPD stores all information relevant to PROMPT. The Order Specification Module (OSM) is a multi-user application specifically designed for specifying all project data. Projects (or parts of projects) can be saved as a template in a library. This speeds up the process planning of future similar projects. While the users enter data, the OSM performs all kinds of checks. For example, it checks whether the available time windows for activities are large enough, taking into account the precedence relations with other activities and their minimal durations. Since automatic uploading of data to the BPS is very hard, the OSM generates a report with the data that should be entered manually in the BPS.

Data in the CPD can be downloaded to PROMPT, which has its own local database. As a preparation for the portfolio management meeting, PROMPT users can make their own scenarios and plans that can be uploaded to the CPD. At the portfolio management meeting, these scenarios are discussed and, possibly, new scenarios are defined and evaluated. The result of the meeting should be an agreed scenario, according to which the work will be performed. This agreed scenario is then uploaded to the CPD and the data of this scenario that is relevant for the SFCS is then uploaded to this system. This data concerns, for example, planned starting and completion times and chosen execution modes of activities.

**Conclusions and future developments**

The current technology offers possibilities to increase the efficiency and effectiveness of planning techniques. Computer applications should not only focus on planning techniques, but also on efficient data input. In combination with better organization this will bring shipyards another step forward. At present, the opportunities that planning offers are not fully exploited. Both traditional organizational structures and traditional project planning are not suited for simultaneous management of time and capacity. This is crucial for multi-project environments like shipyards. In order to pursue improvements in the planning process, planning support and different work methods should be introduced. Expertise from planners, consultants, and software developers is required. Their expertise alone, however, is not enough to achieve these goals. Collaboration between experts from all fields is necessary in order to improve planning significantly. In cooperation with the University of Twente, maritime and management consultants, and, last but not least, Dutch shipyards, ORTEC is extending the decision support system PROMPT to create a planning system that meets shipyard requirements.
References


