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Computer-aided activity planning (CAAP) in large-scale projects with an application in the yachting industry

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ABSTRACT

The present paper provides the schema for an innovative and modular computer-based approach to the planning of activities in large-scale projects. Such projects are characterized by tens of thousands of tasks, which are consequently burdensome and difficult to plan manually. This is true to the point that in many shipyards only a low level of detail is used and poor planning is generally performed. The proposed approach is called computer-aided activity planning (CAAP), and an application in the yachting industry is shown to demonstrate its effectiveness. In particular, the so-called outfitting planning problem is faced. The CAAP system, taking into account the available shipyard resources and the knowledge on the building rules is able to automatically define, sequence, and schedule the activities of the whole outfitting process acting as a “planning configurator”. Moreover, it allows the industry-specific knowledge to be stored, maintained and shared within the (extended) organization. Owing to these “building blocks”, plans can be defined accurately and in a shorter time starting from pre-defined templates, with particular impact on lead times whenever variations to complex projects are needed. Finally, to verify the actual capabilities of the approach, the CAAP was implemented within a prototypical software called NautiCAAP.

1. Introduction

The consideration of project management as “a method” for solving complex organizational problems [1] can be thought as one of the main reasons that contribute to the wide adoption of project structures within several organizations [2–4]. This trend is also motivated by ever increasing market pressures and technological changes leading to a substantial uncertainty, which requires firms to be flexible. Project management practice helps businesses in this purpose [2,5]. In addition, the value of project management is particularly recognized in novel and/or complex projects handling [6,7], where *ad-hoc* project-oriented organizations are created [8,9]. Examples of such projects belongs to the One-of-a-Kind Production (OKP) domain, *e.g.*, the shipbuilding and construction industries [10–12].

This paper aims to offer a contribution to the literature concerned with the planning of projects in the shipbuilding industry and, in particular, it deals with the outfitting (the whole set of non-structural activities involved in the mounting of ships and yachts) planning and scheduling, with an application in an Italian luxury yachts manufacturer.

To highlight the complexity of such activity, it is worthwhile to provide some remarks on this sector distinctiveness. In accordance to the classification provided by Wortmann [10], shipbuilding companies are Engineer-to-Order organizations exploiting product-oriented systems. In order to reduce heavy investments on permanents manufacturing sites (*i.e.*, shipyards) they are shifting toward the Virtual Enterprise model [13–15]. The intrinsic characteristics of their products require ever higher customization, quality levels and faster deliveries. Consequently, the product has to be developed rapidly and in accordance to severe quality requirements and cost constraints [16]. Finally, in such a virtual environment information and knowledge management are key profit drivers [17–21]. A review concerning the shipbuilding sector and its features is given by Andritsos and Perez-Prat [22], and Müller [23].

In detail, the shipbuilding industry is fundamentally characterized by the peculiarities that countersign its production process. More precisely, the main challenge lies in planning, organizing and executing the tens of thousands of operations leading to the accomplishment of a ship order. Indeed, in the current highly competitive international shipbuilding market, success requires a

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significant reduction of costs and effective time to market [24]. Optimized planning is a key factor to succeed in this critical objective [25]. In the last years several authors have stressed the importance of modularity [26,27] with the aim of improving the overall project efficiency. Modularity "involves the subdivision of larger systems into smaller self-sufficient components that can be recombined in several ways to form new architectures". In the shipbuilding industry these concepts had already been hypothesized by Jolliff [28] when dealing with pre-packaging, that may be seen as the precursor of the outfitting process. This definition refers to "the division of the ship into blocks, sections and modules" with the aim of enhancing the production process. Modularity has been considered so important that there exists a large body of research, starting from the studies of Simon [29,30] on complexity within artificial systems to the more recent works [31] where the most important principles of the modularity concept are identified and codified. Also, modularization is related to product platforms. By "adding, removing, replacing or scaling modules", the product platform can address peculiar customer requirements. Research includes the search of efficient strategies and methods for determining the sub-division into modules, the number of variants, the recombination into product families [32]. The possibility of designing larger standard modules and shifting the outfitting process to external workshops is currently under discussion [33]. Meanwhile, modularity and standardization at unit level are regularly adopted at world class shipyards. The typical example is constituted by modular cabins and bathroom modules [34].

It is noteworthy that modularity concepts can be applied to planning as well, as long as building blocks can be associated to appropriate "planning blocks" that represent, as ready-to-use templates, the standard planning of the blocks themselves. Several researches were carried out to highlight the importance of the outfitting planning and the difficulties in its implementation [23,35–39]. Apart from the intrinsic challenges related to the organization of numerous and highly constrained activities, where the full exploration of the alternatives is generally hard, the outfitting planning task is affected by many questions directly linked to the peculiarities of the shipbuilding industry. A first issue is related to the heavy adoption of outsourcing and subcontracting (it is worth to mention the works of Leufkens and Noorderhaven [40] and Levering et al. [41], which examine the question of the collaboration in interorganizational projects, with particular reference to the Dutch shipbuilding industry). In fact, shipyards generally hold the role of project coordinators, proving the subcontractors with an approximate time frame for the outfitting activities. On the basis of this plan, each subcontractor defines its own work in detail independently from other executers. Therefore, the outfitting process may show interferences leading to conflicts, reworks and considerable delays. A second problem is referred to the loss of industry-specific knowledge and skills. As a matter of fact, the outfitting planning activity is mainly carried out "manually" by the human planner, on the basis of the experience and knowledge gained in years of practice. Thus, the need to make expertise explicit by means of codified information, so that it can be stored and easily transferred to less skilled employees and to all the actors within the Virtual Enterprise, is a key issue. Moreover, contrarily to the structural components manufacturing and assembly processes, which can be considered substantially standardized, the outfitting is strictly related to the specific ship order considered (especially in the yachting industry, where each order is, evidently, largely different from the others). This represents a significant limit to the overall productivity improvement, since it reduces the ability of labor to learn through repetition (*i.e.*, exploiting the learning curve effect), making unjustifiable the use of mass production/process concepts.

The outfitting process criticality is reflected in the whole ship order costs and completion lead time. In fact, according to Andritsos and Perez-Prat [22], outfitting work can represent up to 80% of the total work in a modern passenger cruise vessel. Moreover, Diesslin [37] states that it generally represents more than 50% of the total work and one-third of the total labor costs of production. Consequently, any improvement in the outfitting planning would lead to significant benefits.

The above mentioned points highlight that the outfitting planning task is a great project management challenge, and, in particular, the need for computer-based approaches aiming to boost its effectiveness is thus evident. Although numerous researches related to the computer-aided generation of steel structures assembly sequences exist [42–46], very few works present solutions to support the outfitting planning activity. This is evidently due to the fact that it is a highly problematic task (for the reasons discussed above) and, hence, hardly manageable by means of computerized systems. However, it is possible to cite the following valuable contributions to the outfitting planning sustainment. Graves and McGinnis [47] propose a decision support system (DSS), modeled as an operational research problem, applicable in the zone outfitting method. The approach is subdivided into two phases: in the first one a set of activities is selected to maximize the benefit for on-block outfitting, considering the available time and the total labor constraints, then, in the second phase, a resource feasible schedule is determined. This model allows to take decisions regarding the activities sequencing and scheduling, but it is characterized by a difficult practical implementation, since it needs a detailed and production oriented database to support the solution procedure. Roh et al. [48] present a method for the rapid generation of the 3D CAD model of the pipes, within the pre-generated hull structural model. König et al. [49] present a constraint-based simulation framework to define outfitting tasks and to assist their planning and scheduling. Park et al. [50] build an enterprise ontology for representing enterprise-specific knowledge, which can be used to improve the whole shipbuilding process, and hence the outfitting planning task. Lee et al. [51] present an enterprise Bill of Material which addresses the hierarchy of parts and assembly, product structure and product information of outfitting equipment in marine vessel design. Though, up to now and in authors opinion, the most interesting paper dealing with the outfitting activities planning problem is the one written by Wei and Nienhuis [52]. In their work, they present an automatic sequence generation system of outfitting activities. The model is able to generate the interference-free assembly sequences and to estimate the reasonable mounting time. However, it does not take into account the outfitting activities scheduling and the resources leveling.

The present paper is aimed at enriching the existing literature on the planning of large-scale projects, in general, and on the outfitting planning problem, in particular. This work, endorsing the observation raised by Ahlemann et al. [53], which point out that project management has to be conceived as an action-oriented discipline, provides the schema for an innovative and modular computer-based approach, called computer-aided activity Planning (CAAP), which is fundamentally able (1) to support (drastically reducing his efforts in the process) the human planner throughout the whole outfitting planning process, and (2) to store, maintain and share, within the (extended) organization, the industry-specific knowledge. The CAAP approach, looking at the ship order technical documents, exploiting both a knowledge- and rules-base (both databases define the so-called shipyard *Build Philosophy*), and taking into account the shipyard resources, aims to automatically define, sequence, and schedule the activities of the whole outfitting process. It is noteworthy that, as far as known to the authors, no other similar tool is available at present.