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HUMAN RESOURCE MANAGEMENT DIGITALISATION IN MULTIDISCIPLINARY SHIP DESIGN COMPANIES

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ABSTRACT

The digitalisation in the ship design sector is currently applied to the design process itself and is well defined, partially standardised and practically implemented by both independent design companies and the design departments of shipyards. The situation is similar in other sectors of engineering. However, the requirements for the digitalisation of other processes in design and engineering companies have not previously been studied, and the limited financial resources of ship design companies mean that there is a need for research on the digitalisation needs of multidisciplinary ship design companies. The implementation of building information modelling (BIM) solutions is costly for design companies and generates benefits mainly for shipyards and shipowners. The lack of benefits for design companies leads to the hesitation of managers whenever digitalisation is considered; the scope and scale of the digitalisation, as well as the selected software and BIM level, are defined by the shipyard requirements. The participation and support of management in the digitalisation process is one of the key success factors; the expected benefits caused by digitalisation for the organisation will increase the motivation of managers to invest limited resources in digitalisation. There are no data that indicate the processes with a high potential for digitalisation and the scale of expected improvements in ship design companies; therefore, research in this area was performed with a group of project managers from design and engineering companies. The research focused on collecting the opinions and experiences of the managers related to the manual management of resources and comparing the poll results with the conclusions from the enterprise resource planning (ERP) system data analyses. The paper analyses if the digital automation of the resource management process can lead to the substantial improvement of the operations of multi-project, multidisciplinary engineering ship design companies.

Keywords: Ship design human resource management, digital automation, project portfolio, multidisciplinary engineering, ship design, marine engineering

INTRODUCTION

All sectors of engineering are experiencing an intensive digitalisation process [1]; this applies to the marine [2], infrastructure, industrial, plant design, architecture engineering construction (AEC) and mechanical sectors [3]. The implementation of software solutions for design and engineering companies brings numerous benefits [4], and in most cases it leads to substantial efficiency improvements [5]; however, it generates a number of risks [6], especially when the organisation is not ready for implementation [7]. The impact of digitalisation is clearly visible in the design system area and the design of data management systems [8]. Change itself, for engineers, is an integral part of the iteration design process, which is usually turbulent due to the constant modifications [9]. Considering a business point of view, there

should be a justification for a change, and usually there are good economic reasons to make a change [10].

The direct costs of the software, implementation, training and changes are covered by the design and engineering companies, which can be the reason that in the short term, digitalisation can be considered an unfavourable change. Another challenge for the design and engineering sector is the globalisation of services and distributed design networks. There is the possibility of easy cooperation with designers from different time zones and countries with lower cost levels, which is not always is beneficial in terms of quality [11].

The subject of project planning and execution is strongly connected with resource management [12], and for companies facing aggressive competitors from low-cost countries, the possibility of increasing the effectiveness of the organisation and simultaneously reducing management costs by lowering the amount of time required by the management process, which often involves highly experienced and expensive experts [13], [14], might be an interesting area to explore. It is interesting from the scientific point of view to understand the current solutions used by design and engineering companies to manage resources and how much of the project budget, in terms of time and financial resources, is utilised for management [15]. Data-driven analyses could provide answers that could be compared with the managers' individual opinions, which can be collected using a poll.

The conducted review of scholarly publications revealed a lack of studies specifically targeting human resource management processes in marine design firms; however, a prevalent recommendation among researchers in the domain of project portfolio management and its human resource management sub-process is to conduct inquiries within distinct engineering sectors, thereby catalysing research endeavours within the marine design firm sector. A good example of both multidisciplinary and diversified engineering activity is the ship design sector. Based on the matrix organisation structure, design and engineering companies are simultaneously performing several projects, facing a large number of changes [16]. In these circumstances, design and engineering resource management becomes a crucial foundation of competitiveness and the key to business and technical success [17]. High-level digitisation results in an increase in the design process' economic efficiency by improving internal procedures and eliminating manual activities [18]. The implementation of available software solutions allows the top management of engineering design companies to focus on the decision-making process [19]. In Fig. 1, a graphical representation of the scope of the multidisciplinary exhaust gas system conversion project developed by one of the Wayman software users is shown.

Fig. 1. Visualisation of the BIM model of the exhaust gas system of the cargo vessel

The greater the scale of the disturbances generated by changes, the more justified it will be to develop and implement digital solutions that support the process of continuous management [20]. The scale of the problem and the potential for improvement need to be determined [21]. The reduction of the management time and a faster decision-making process can generate benefits in the organisation and leverage the efficiency of the engineering departments. In examining the need for innovative solutions in human resource management for engineering and design projects, especially under conditions of change and uncertainty, the work by Litwin, Piątek, Leśniewski and Marszałkowski on the design and implementation of a hybrid propulsion system in a 50' sail catamaran provides a relevant example [22]. Their approach in effectively balancing multiple design criteria and navigating through complex engineering challenges underlines the importance of adaptive and forward-thinking strategies in project management. This aligns closely with our discussion on the necessity of rapid and flexible planning in human resource allocation, where the goal is to efficiently manage resources in the face of evolving project requirements, much like the multi-dimensional optimization challenges tackled in their yacht design project. Also the innovative approach detailed by Branowski, Zabłocki, Kruczewki and Walczak in their study on the universal design of yachts for people with disabilities demonstrates the necessity of adaptable design solutions that cater to diverse user needs, mirroring our discussion on the need for flexible and responsive human resource planning in engineering projects, where

diverse and changing requirements must be met efficiently and effectively [23].The expected improvements might be a good justification for investments and the implementation of new solutions, and the solution selection process is an interesting subject in itself [24]. Current global trends in design and engineering companies lead to the conclusion that an increase in the subsidiary processes in the organisation and IT tool integration should lead to an increase in efficiency and collaboration; digitalisation is an obvious next step for the construction and shipbuilding industry [20]. As the implementation of the core business-related building information modelling (BIM) software generates the majority of profits for the end customer, the construction company [25], the management personnel of the independent design and engineering companies strive to cut the costs and time consumed by their own work [26]. Fig. 2 shows a visualisation of the complex multidisciplinary scope of the Ro-Pax vessel exhaust gas system developed by one of the Wayman users using the BIM software.

Fig. 2. Visualisation of the scope of a complex multidisciplinary exhaust gas modification for a Ro-Pax vessel

Among the subsidiaries of the core business process, those that require higher time and resource levels should be prioritised, and the available resources should be allocated to the implementation of the most promising solutions from a business point of view [17]. In order to be able to properly define the priorities and the scale of the potential positive impact on the organisation, it is necessary to understand the current state of the art and the resource management activity level [27]. This article describes results from the first iteration of research related to the changes initiated by the continuous resource management process in design and engineering companies. The goal of the enterprise resource planning (ERP) system database analysis, performed in parallel to the questionnaire research, was to collect and analyse the data registered in the ERP used by the design and engineering companies in order to understand how time and resources are consumed in the resource management process. It is expected that project management activities in ship design companies consume around 20% of the project budget, and 70 to 80% of the management budget is consumed by human resource management activities. Moreover, the poll made it possible to understand managers' opinions on the resource management process and the tools used among the various design and engineering sectors.

METHODS

The thesis, which boils down to the statement that the management of design and engineering resources is one of the key areas that needs to be digitised, leading to the need to eliminate manual management activities, has been verified in a selected community of medium-level managers of selected design and engineering companies in Poland. As part of the research, using anonymous questionnaires, information was collected from 1283 design and engineering company employees on how the problem of resource management is perceived, and the content of the databases containing information on the labour intensity of manual management activities was analysed. The analysed databases were not prepared for research and were taken directly from the production IT structure of the 20 engineering companies operating in the ship design, infrastructure, offshore, infrastructure and oil and gas sectors. The environment was not prepared in order to precisely collect data related to manual management.

Due to the standardisation of the nomenclature, the numbering of the activities performed and the possibility of importing data from various software systems, it was achievable to combine data from various design companies operating in various engineering sectors in order to compare and analyse the results. The first research step was to build an anonymous questionnaire that made it possible to obtain information relevant to the analysis of the problem. The link to the research was sent to managers of design companies using one of the most popular ERP systems in Poland used for managing multi-sector engineering companies. Courtesy of the software vendor of our own developed-in-house ERP software, a customer communication channel was used to promote and deliver a request to complete the questionnaire. Due to the need to protect the identities of users, the surveys were anonymous. The accessibility of a large number of design company managers and the serious approach to the research supported by the software vendor, which distributed the survey through official software vendor communication channels, justify the selection of the questionnaires as a research method. The survey research duration was 14 months.

The first group of questions in the survey was used to determine the characteristics of the enterprise in which the surveyed person is employed. Information was collected on the scale of the company, the engineering sector, the types of industries, the applied solutions supporting management and the share of the labour intensity devoted to manual management in the budget for project management and in the overall budget of the project. It is important to underline that budgets were examined in both hourly and financial terms.

In order to initially verify the validity of the thesis, the opinions of the respondents were examined to confirm the problem of a lack of digital resource management and to determine its significance and the possible impact of eliminating manual management. As part of the parallel study, the databases of ERP system users were downloaded and analysed in a way that allowed the results obtained by processing the data reported to the ERP system to be compared with the responses provided by the respondents. The ERP system dedicated to engineering made it possible to define task dictionaries, use a unified numbering of tasks for all projects and assign tasks to appropriate groups, as well as to use any attributes to group and process data and information. Such attributes can distinguish to some extent the hours allocated to manual management activities and other management activities.

The ERP systems used in the design and engineering companies require employees to be assigned to precisely defined roles. Based on this feature, it is possible to identify the users responsible for resource management activities. Typically, management tasks are performed by middle-level management experts (department managers, project managers, discipline leaders, leading engineers) who can be generally classified as the employees who are permanently or temporarily responsible for teams of designers or for tasks performed by a group of people. It is a common practice that each employee is obliged to record the amount of time spent on certain tasks. This makes it possible to collect information about who is doing what, compare the plan and the reality and easily calculate the cost of the work. In spite of the fact that there are local, national and corporation-wide standards for defining the tasks, there is no universal task-defining policy. Therefore, it is important to verify to which object in each analysed database the time consumed by resource management is registered.

RESULTS

Descriptive analyses of the survey results were used for the analysis of the questionnaire responses. Four hundred and thirty (430/1283) of the questionnaire respondents are employed in the ship design sector. Ship design sector representatives are the largest group of respondents in the research, and 1187 respondents confirmed that they are employed by design and engineering companies. This high conversion rate was achieved through cooperation with a dedicated ERP software vendor for the design and engineering sector. In the group mentioned above, 70% (893/1283) of the respondents declared that resource management is performed manually using spreadsheets, and the remaining managers also use the resource load matrix, which is available in popular project planning and management programs. Considering the impact of manual resource management on the consumption of the hourly budget dedicated to management activities, over 86% of respondents (1105/1283) believe that manual management activities consume 75% or more of the available time. According to the respondents, the cost of manual resource management also remains high; 79% of survey participants (1010/1283) believe that on average, more than 75% of the costs allocated to project management go to manual management. This is a value slightly lower (1010 vs 1105) than the number of hours spent on the manual management of the hourly budget, but due to the fact that some activities related to manual management can be delegated to staff with lower competencies, the values declared by the respondents seem to be consistent. The analysis of the results of the study in terms of the impact of manual resource management on the budget of the entire project, in terms of both the hourly and financial budgets, indicates that the majority of respondents define the share of activities related to manual resource management to be at the level of at least 10%, in both hourly and financial terms.

In the case of one company, it was possible to identify the date when the resource planning procedures were migrated from manual management using spreadsheets to a resource matrix in the planning/project management software. The organisation was performing, at the same time, a large amount of exhaust gas conversion multidisciplinary projects that, according to the company's management, were similar in terms of the scope and level of design process disturbances. Before the implementation of the planning procedure, the consumption was 2834 hours (2398 on design and 436 on management); the scope of the work of the referenced project is presented in Fig. 1. After the implementation of the planning procedure, the consumption on a similar project was 2140 hours (1820 for design and 320 on management); the graphical representation of the scope of the work of this project is presented in Fig. 2. The results are shown in Fig. 3.

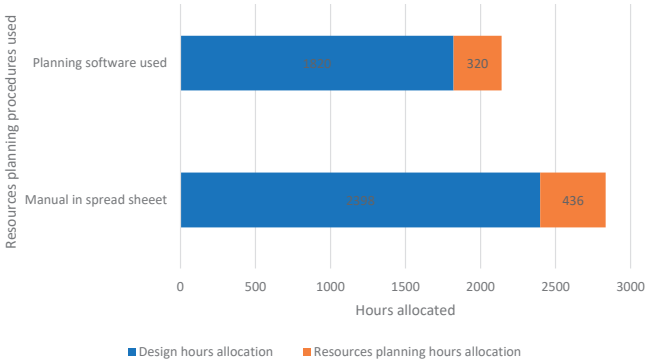

Fig. 3. Comparison of the time consumption (in hours) before and after the implementation of the planning procedure

Most of the respondents (1242/1283, or 93%) define the elimination of manual resource management as an important aspect of improving the efficiency of a design company and state that they develop several variants of future plans as part of manual management, while 75% of all respondents (957/1283) state their interest in a software solution that supports the preparation of future variants to support the resource management process in a design and engineering company. The combined results are presented in Table 1.

Tab 1. ERP software user questionnaire results

1. Can you describe your company as a design and engineering multidisciplinary corporation?			
No.	Answer	Res.	%
1.1.	Yes	1187	93%
1.2.	No	96	7%
2. Please indicate your sector of engineering			
2.1.	Marine (ship design)	430	34%
2.2.	Infrastructure	356	28%
2.3.	AEC	120	9%
2.4.	Plant design	257	20%
2.5.	Airspace	7	1%
2.6.	Energy	113	9%
3. Please indicate the methodology of resources management in your organization			
3.1.	Manual in spreadsheet	893	70%
3.2.	In resources matrix in planning/project management software	387	30%
3.3.	In dedicated automated resources management software	0	0%
3.4.	Other	3	0%
4. How big is the % of the hourly budget for project management consumed on resources management?			
No	Answer	Res.	%
4.1.	<25%	0	0%
4.2.	<50%	178	14%
4.3.	<75%	673	52%
4.4.	Other	432	34%
5. How big is the % of the financial budget for project management consumed on resources management?			
5.1.	<25%	0	0%
5.2.	<50%	273	21%
5.3.	<75%	437	34%
5.4.	Other	573	45%
6. How big is the % of the project hourly budget consumed on resources management?			
6.1.	<5%	767	60%
6.2.	<10%	389	30%
6.3.	<15%	124	10%
6.4.	Other	3	0%
7. How is the % of the project management financial budget consumed on resources management?			
7.1.	<5%	17	1%
7.2.	<10%	697	54%
7.3.	<15%	565	44%
7.4.	Other	4	0%
8. How big is the impact of resources manual management elimination on the efficiency of engineering company?			
8.1.	Critical	671	52%
8.2.	Significant	571	45%
8.3.	Minor	32	2%
8.4.	No impact at all	9	1%
9. Do you prepare several variants of resources management projection?			
9.1.	Always	25	2%
9.2.	When requested and when I feel it is needed	654	51%
9.3.	When requested	595	48%
9.4.	No, never, it is useless	9	1%
10. Would you be willing to use the software tool for automated resources management even if it creates only variants for consideration?			
10.1.	Yes	957	75%
10.2.	No	258	20%
10.3.	I do not know	68	5%

For some companies, manual management is just a part of general department management; it might be registered as a general management task, just like periodical project meetings and even quality control activities. This means that in this first iteration of the research, the assignment of tasks to the appropriate category may be imprecise, due to the fact that the users of the ERP system did not use attributes that clearly define tasks for managers for tasks related to manual management. This caused the need to manually review each stage of the selected projects and each task in order to manually assign the tasks and the hours allocated to each task to the proper group. On the other hand, an unambiguous result is that 18–27% of the financial budget and 22–28% of the hourly budget were used for activities related to the management of project work and resources; this is applicable to virtually all engineering sectors. Considering these numbers in the context of the average margins on design and engineering services should focus the attention of employees responsible for business efficiency on this particular area of the company's operations.

DISCUSSION

The subject of project portfolio selection and management is of scientific interest, and it is gaining momentum when it comes to the number of publications on the topic. Currently, researchers are exploring the area of decision support systems, and the trend is to develop more management-oriented

solutions, as the usefulness of elegant and sophisticated mathematical methods is often questioned [28]. Within the area of ship design and engineering management activities, including engineering resource management, real-life managers, who face a limited amount of available time and an urgent need to make decisions, always prefer the tools that reduce the time required by a decision-making process over the complex methods that require the participation of an expert in order to be useful in real-life cases. The ship design sector tends to migrate from the area where activities are balanced among art, science and handcrafted approaches [29] to less creative approaches, where designers use computational methods and computer-based models.

The same research shows, in its onion model, that currently, research related to project portfolio management is focused on coping with change and uncertainty [28]. Considering the frequency of change in project portfolios, the ability to predict the future is urgently required [30]. In terms of human resource allocation in engineering, predicting the future is naturally impossible, but the concept behind the research presented in this article is the real need for a quickly available list of variants of future human resource allocation created on the basis of parameters that are easy to define for managers. The goal in this respect is not to create the optimal solution as it would lead to the infinitive number of Pareto optimal solutions, but to provide input data for decision maker to make a rational decision about the future plan of resources allocation. In addressing the complexities of human resource allocation in engineering, particularly under the constraints of unpredictability and the need for rapid adaptation, the principles outlined in Pawlusik, Szłapczyński, and Karczewski's study on optimizing rig design for sailing yachts using an evolutionary multi-objective algorithm [31] offer valuable insights. Their approach in handling multiple, often conflicting objectives through multi-objective optimization and multi-criteria decision making provides a pertinent framework for our discussion on managing dynamic project portfolios and resource allocation in engineering firms. Their methodology underscores the importance of balancing various factors, a concept that is integral to our analysis of efficient and flexible human resource planning in the face of change and uncertainty.

The current state of the art related to project portfolio resource management is presented by Hollister and Watkins [32]. They specified seven causes of the resource overload problem: impact blindness, multiplayer effects, political logrolling, unfunded mandates, band-aid initiatives, cost myopia and finally initiative inertia. In the same article, the authors provide a recipe for practically solving the project portfolio resource overload problem, and they share an interesting result of the research related to the scale of the involvement of managers in initiatives that are non-productive and not directly related to business, which reached 30% of the overall time. In the described example, the company implemented a process for the manual review of plans and selected the variant that allowed them to complete the top-priority projects and allocate more time and resources to business-related activities. The organisation described by Hollister and Watkins was a retail company that faced resource overload and the incorrect allocation of resources. For the design and engineering sector, the scale of project portfolio-related turbulence is much higher and turbulence occurs much more frequently compared to the example of the retail company. The available data and the ability to create variants of the future with various assumptions and priorities are obtainable but time-consuming. The scale of the difficulty and the involvement of managers in the resource management process in design and engineering companies has not previously been a subject of research; therefore, our research had the goal of verifying the scale of the involvement based on the available data and the opinions of the managers.

In this study, the results of research from two sources, databases and the subjective opinions of the surveyed managers of design and engineering companies, were compared. Currently, there is no data available from the wider design and engineering sector that could be compared to the results achieved. At the time that this research began, there was no synthetic information in the analysed customer databases that would allow one to determine the actual workload for activities related to manual resource management; however, it was possible to determine the total costs of project management based on hard data, registered working hours and the hourly rates of the reporting persons.

At the same time, the subjective assessments of managers regarding the share of activities related to manual resource management of the overall budget for project management, which oscillated around 70% of the budget, indicate that resource management is an area of interest and probably has the potential for both direct and indirect cost reductions. Considering the justification for this research and the actions leading to the digitalisation of human resource management in maritime engineering design firms, it is vital to focus not just on the benefits generated for the organisation itself, which stem from the anticipated reduction in the amount of time dedicated to human resource management tasks. It is equally crucial to emphasise the broader advantages, which will include enhanced quality, more efficient budget utilisation, the swifter development of value-driven projects and a more effective execution of engineering services.

As the database content does not allow the comparison of data at the same level of detail, it is worth focusing on the results obtained from the surveyed managers. It is remarkable that in design and engineering companies, according to the majority of respondents, 70% of management work is still done manually. This result is naturally surprising, especially when the number of changes and modifications that affect project implementation plans in shipbuilding, and also in other sectors of engineering, is considered. Reducing the amount of time spent on manual management decreases the direct costs of management, and most importantly, assuming that a faster transfer of guidelines to the project team results from the reduced management execution time, increases efficiency by shortening the circulation time of the decision loop.

CONCLUSIONS

The analysis of the results leads to the conclusion that the development of solutions that support the management of human resources in engineering and design companies may address the essential needs of managers and increase the efficiency of a company's work. Shortening the reaction time to changes can lead to the reduction of numerous risk elements, which can increase the company's competitiveness and the efficiency of engineers' work. The effort to minimize the time needed for preparing new project in shipbuilding is widely visible in the actions taken in other areas of ship design and shipbuilding for example application of reverse engineering in part design [33]

The responses of the respondents show the importance of the management topic and the perceived need to spend a large amount of time on management, with a simultaneous careful approach to the topic of preparing many variants of future projections, especially in terms of possible management variants. The great interest of managers in the application for the preparation of management variants also shows that the topic is worth further exploration and is one of the areas of operation of an engineering design company that is probably difficult to learn using classic manual methods.

The results of the research conducted lead to the conclusion that the analysed area has the potential to be improved; the activities related to the management of resources can be classified as problematic for managers, while the currently used methods involve numerous risks and are ineffective.

The opinions of a selected group of managers indicate that further exploration of data collected in ERP systems is justified and may lead to a more reliable and transparent picture of the situation, provided that the collected data are properly prepared. Users should be properly motivated to increase the amount of detail in their reporting to allow a precise understanding of the time spent on management and the preparation of future variants. The binary data that have been analysed so far have not been prepared in a way that allows the proper identification of resource planning-related activities and the separation of the planning budget from other management activities; therefore, in the future, an effort must be made to organise the database structure in order to make it possible to report resource planning hours for separate objects.

The short-term prospect can lead to the wrong conclusions, but competitiveness, or even remaining active on the engineering market, is not possible without modern design tools. Therefore, digitalisation for design and engineering companies is a part of reality that managers have to cope with, face and cover the costs of.

The objective of the research described in this article has been partially achieved. Over a 14-month period of survey research, 1283 responses were obtained; based on the content analysis of databases from ship design companies, these responses confirmed that over 20% of a project's hourly budget is allocated to management-related activities. The survey research further revealed that 86% of the surveyed project company managers believe that 75% of the time dedicated to project management activities is spent on human resource management tasks. However, it was not possible to reliably confirm these assertions, due to the lack of the precise definition of activities belonging to the set of tasks related to human resource management. This implies that in the future, there is a need to assign clear attributes to tasks associated with human resource management. Another significant conclusion is the confirmation of both a reduction in the hourly budget for project work and the budget allocated for project management after the introduction of a system that supported management. This suggests that potential further benefits in this area could be achieved through automation and the use of AI algorithms for human resource management in maritime engineering design firms.

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