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Improve Ship Design Success by Utilising Proactive Elicitation to Enhance Communication Among Diverse Stakeholders

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ABSTRACT

Ships serve as crucial tools for maritime transportation and account for over 80% of global trade. However, the boundary between naval architecture and the maritime industry has existed for 150 years since the first Industrial Revolution. Despite the current ship design processes ensuring compliance with standards, a significant gap exists in effectively communicating and incorporating diverse stakeholders' expectations and desires during the ship design process. This communication gap may lead to a potential risk for incidents and compromise safety. To tackle this issue, this paper proposes to use proactive elicitation as a means to enhance the communication between various stakeholders and naval architects. To verify the impact of proactive elicitation on ship design success, discrete event models were developed in the study to simulate the ship design process. The simulation results demonstrated that the earlier the proactive elicitation is applied to ship design, the higher the level of design success can be achieved. In the short term, this approach can assist shipyards in the timely delivery of ships, while in the long term, it fosters improved compatibility between stakeholders and ships, enabling effective adaptation to future complex design conditions.

KEY WORDS

Ship design; Conceptual design; Tender phase; Elicitation; and Whole ship design

INTRODUCTION

In the current ship design practice, Ships are often tailor-made and designed to meet the specific expectations of the stakeholders. So, the design brief is provided by stakeholders at the beginning of the ship design process. Then naval architects utilise their knowledge and engineering expertise to plan, formulate and design the ship according to the stakeholders' design brief. According to the statistics of the ship design flaws observed from 1545 to 2006 (Andrews, 2020), misunderstanding, poor communication, and overconfidence are the primary causes of ship design flaws in the commercial shipping sector. To minimise these flaws, international organisations established standards and regulations for design criteria that stakeholders and naval architects should adhere to. However, eliminating ship design flaws has not been entirely achieved today, which poses a potential risk of operational accidents.

Long-term marine accident investigation data reveals that approximately 80% of accidents are attributed to human error, with 30% specifically resulting from human failure to take evasive action (Baker & Seah, 2004). The remaining 70% of accidents happened when no one was aware that something was happening (Bafang & Chen, 2021). Nevertheless, the majority of reports persistently attribute human error as the primary cause of accidents, thereby placing a disproportionate burden on seafarers.

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However, among the maritime incidents widely cited as being caused by human error, it is worth noting that 80% of them lack substantial supporting evidence (Wróbel, 2021). One potential contributing factor to these accidents is flaws resulting from a ‘communication gap’ between various stakeholders during the ship design process.

In the current era of highly advanced information and communication technology, the ‘communication gap’ between diverse stakeholders arises mainly from the assumption on each side that the other will actively familiarise themselves with their respective knowledge rather than a lack of willingness to communicate. For example, sailing, navigation, and naval architecture are all interconnected with ships. However, they represent distinct fields. Seafarers may assume that naval architects will naturally incorporate user-friendly features into ship designs, while naval architects may assume that seafarers will provide explicit guidance on the need for such features. If seafarers did not provide clear requirements for these features, naval architects may assume that these features are not necessary. On the other hand, management personnel focus more on integrating the entire ship design plan, providing comprehensive solutions, and demonstrating and communicating the overall ship design concept and capabilities to customers during the early ship system design (ESSD) (Andrews, 2018). Consequently, these differing understandings among the parties naturally lead to discrepancies.

In the past, some efforts have been made to address the barriers within the maritime and shipbuilding industry. For instance, the Nautical Institute (1998) conducted a study examining the relationship between ship design and operation, especially focusing on incorporating the input of seafarers. In the study, the institute distributed a survey questionnaire to seafarers, generating 185 comments. The study concluded that enhancing naval architects' understanding of nautical knowledge is crucial for improving communication with stakeholders and ensuring that the design meets stakeholders' needs. Hughes (1989) categorised operational problems into ten topics, with dedicated sections on equipment and management. The study advocated for the use of precise standards as guidelines for naval architects to facilitate communication with stakeholders during ship design. Those studies highlight the importance of communication between naval architects and stakeholders in ship design. Additionally, several studies have highlighted the significance of incorporating stakeholders' requirements across various aspects of ship design, particularly during the conceptual stage. For instance, Heather (1993) and Graham (1996) emphasised the aspect of 'Requirement' Andrews (1985) and Tibbitts et al. (1993) focused on 'Functional Requirement' Andrews (1985) and Burcher & Rydill (1995) considered 'Operational requirements' Rawson (1986) explored 'Reliability, Maintainability, availability, and logistics' Andrews (1985) delved into 'Systems operating and upkeep philosophies' Andrew (1985) considered the aspect of 'Performing need analysis' and Andrew & Dicks (1997) considered the aspect of 'Functional hierarchical decomposition', and so on. However, how to implement such a recognition in the actual ship design process remains an issue today. Moreover, as the issue evolves and the range of stakeholders may expand under increasingly complex design conditions, incorporating diverse stakeholders’ requirements and desires into ship design becomes more challenging. This motivates the research of this paper, which aims to improve ship design success by utilising proactive elicitation as a means to bridge the ‘communication gap’ among diverse stakeholders.

STUDY FOR GAINING INSIGHTS INTO THE ‘COMMUNICATION GAP’

To facilitate the study, a preliminary survey was conducted, and the stakeholders’ backgrounds covered ship owners, ship managers, equipment suppliers, shipyard naval architects, ship design firm naval architects, seafarers, and academics. A total of 20 people participated in this survey. The first part of this survey was conducted to gain insights into the ‘communication gap’ between stakeholders and naval architects. A questionnaire was thoughtfully designed based on 12 keywords. The survey results are illustrated in Fig.1. During the survey, the 12 keywords were classified into two distinct groups: i.e. ‘concrete’ and ‘cogitation’. The former, indicated by the colour orange, signifies data and standards. Meanwhile, the latter, indicated by the colour blue, highlights the need for exploration and research. In each group, subcategories are distinguished using different shades of the colours. Lighter shades represent aspects that have already been integrated into existing ship design practices, while darker shades indicate areas that require improvement in the future. The degree of concern indicates the areas within ship design to which three distinct stakeholder groups attach importance.

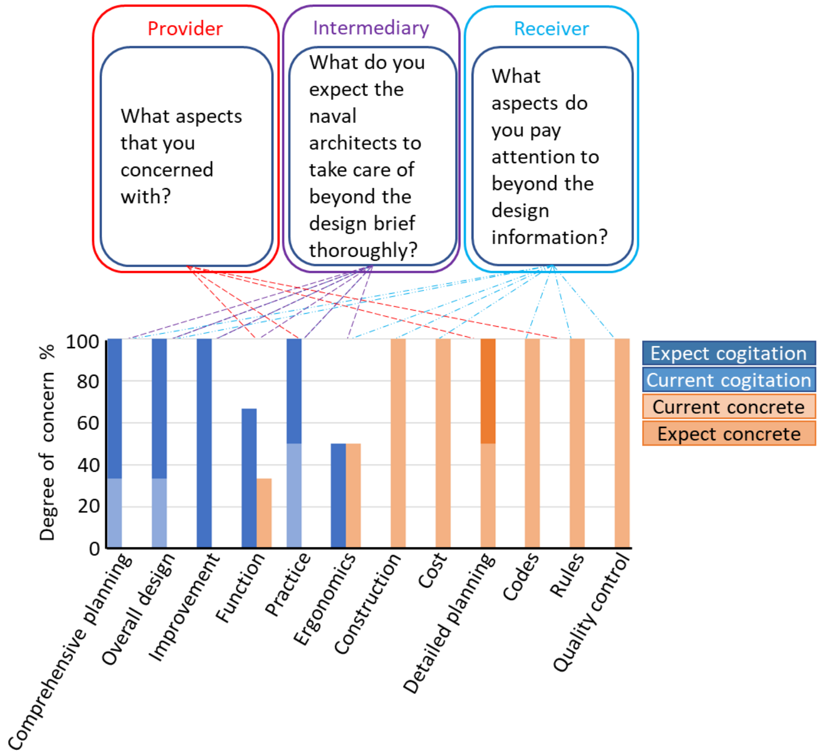


Figure 1 Results of the preliminary survey

Based on the insights depicted in Figure 1, the elements along the horizontal axis are arranged chronologically from the comprehensive planning to the quality control of the shipbuilding production process. It is evident that information providers exhibit greater concerns before the "construction" stage. They prioritise the integration and enhancement of their ideas with lofty expectations. By contrast, information recipients, primarily naval architects, express concerns at every stage and tend to emphasise practical considerations over abstract thinking. This disparity between stakeholders and naval architects highlights the need for additional sources to complement the information provided, as stakeholders' expectations might not be explicitly outlined in the design brief.

Subsequently, a further survey was conducted to investigate the additional sources the naval architects tend to favour. These information sources are categorised into primary (first-hand) and secondary (second-hand), and the findings of the survey are presented in Figure 2. In the figure, the primary sources are depicted on the left side, while the secondary sources are shown on the right. The vertical axis of the chart displays the degree of preference. The results in Figure 2 highlight that naval architects predominantly rely on secondary sources to supplement the design information, with a higher proportion leaning towards indirect means. This observation suggests that naval architects demonstrate a preference for sources that acquire information through intermediaries or administrative procedures, thereby aiding in the reduction of design risks.

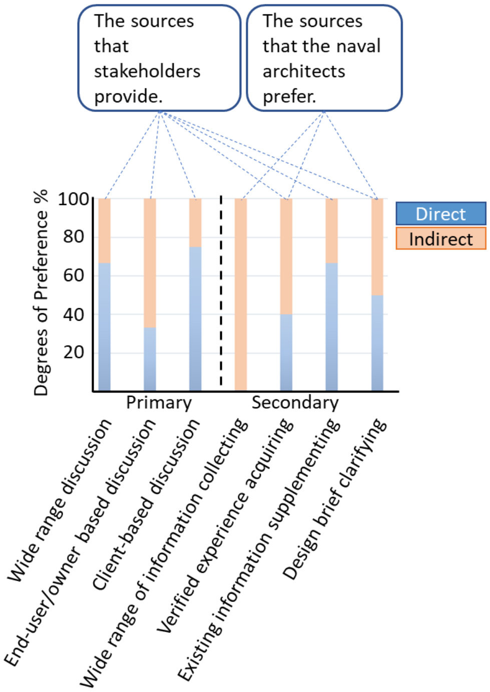


Figure 2: Survey results of information sources.

IMPACT OF COMMUNICATION ON SHIPBUILDING PROJECTS

From 2017 to 2020, a shipyard implemented an experimental policy aimed at successfully delivering 11 shipbuilding projects, as outlined in Table 1. It was discovered that proactive engagement with stakeholders and the broadening of design information sources by naval architects, coupled with an active approach to integrating diverse requirements during the concept design stage, led to a notable enhancement in design success. To assess the implications of this policy, an on-site investigation was conducted at the shipyard, employing a readily understandable market indicator known as the 'on-time delivery rate' of ships. This indicator signifies the ratio between the scheduled and actual building time, offering insights into the efficiency of project management within the organisation. The on-time delivery rate contributes to the effective utilisation of resources, including manpower, materials, and time, while also aiding in waste reduction. Moreover, the 'on-time delivery rate' serves as a measure of the cognitive gap between stakeholders and naval architects throughout the entire project execution process. This cognitive gap represents the additional time required to explore solutions. By successfully completing a project on time, it can be inferred that the surplus time spent on the project is relatively minimised. Thus, the on-time delivery rate serves as a tangible representation of the effectiveness of the experimental policy.

Table 1. Ship projects are being observed.

Project No.	Size and function	Hull type
1	16m Patrol Boat	Monohull
2	17m Attack boat	Monohull
3	18.5m Rapid Response boat	Monohull
4	19m Patrol Boat	Monohull
5	41m Utility craft	Monohull
6	28m Missile boat	Catamaran
7	35m Firefighting boat	Catamaran
8	65m Patrol craft	Catamaran
9	25m Crew Transfer Vessel	SWATH
10	25m Hydrographic vessel	SWATH
11	25m Crew Transfer Vessel	SWATH

In 2018, the shipyard faced two significant challenges that had notable impacts on its operations. Firstly, during the bi-annual audit inspection for ISO 9001 compliance, the International Standard Organization (ISO) identified deficiencies in the shipyard's handling of comment replies, particularly regarding the ISO 9001 8.2.1 Customer Satisfaction standard. Secondly, clients raised complaints asserting that comments on drawings or inspections were not adequately addressed, leading to delays in delivery. These incidents directly affected the shipyard's production quality and design management. To address these issues, the shipyard issued the following directives to all naval architects:

(1) All naval architects and marine engineers must comprehensively understand the requirements and criteria before initiating any schematic drawings.

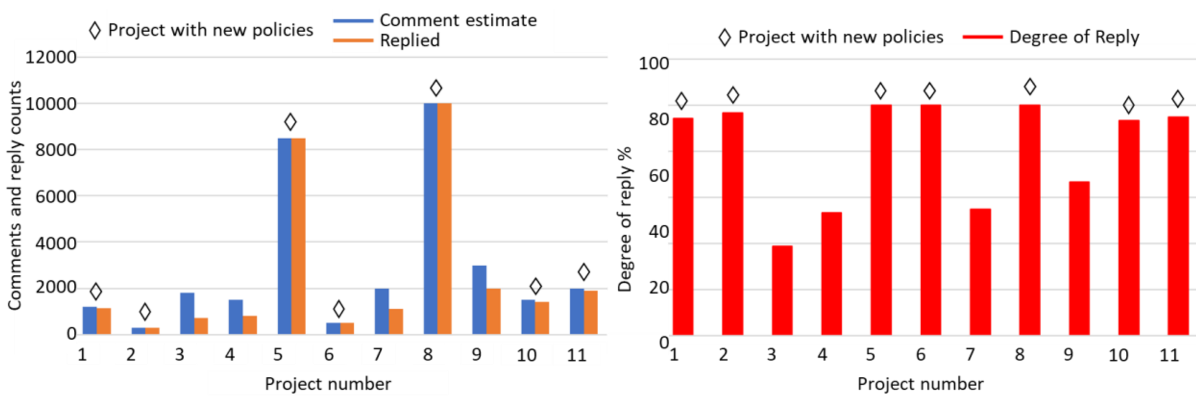
(2) Issues, comments, and conflicts should be resolved through consensus and approved by both parties prior to considering them as completed.

(3) When explicit instructions are unavailable from the client, it is advisable to seek guidance from individuals possessing relevant expertise. If required, contractual adjustments should be considered.

(4) Should a proposed solution deviate from established rules, regulations, practical engineering handbooks, previous references, or contractual documents, it is imperative to initiate immediate discussions. Design work should not commence without a viable solution.

(5) All outstanding issues must be resolved prior to the commencement of production.

The objective of this observation is to assess the number and percentage of comments that have been formally addressed and accepted, as well as to compare the on-time delivery rates across various ship projects. Figure 3a provides an overview of the approximate number of comments received (indicated by the blue bar) and replied comments (indicated by the orange bar) for 11 projects. Figure 3b illustrates the degree of reply. In both charts, the diamond shape stands for the project that is applied to the new policies.



(a) Comments and reply counts estimate **(b) Rate of reply degree**

Figure 3. Comments and replies count corresponding to the Rate of reply degree.

The bar chart in Figure 3b shows a significant increase in the number of comment replies within projects that have been applied with the new policies. This observation highlights a noticeable shift in the behaviour of naval architects, who previously prioritised substantive design tasks (Andrews, 2015) over administrative paperwork. Prior to the enforcement of the new policy, naval architects may have viewed the process of addressing comments as burdensome, potentially hindering the progress of design work and causing distractions and disruptions. Imposing a mere requirement of a 100% response rate to comments may result in counterproductive outcomes resembling a checkbox approach. Such an approach fails to address the fundamental issue of precision in ship design. Consequently, three different approaches have been revealed between conventional design philosophy and new policies. These disparities serve to underline critical areas for improvement, and these two aspects are related to the idea of elicitation:

(1) Under the new policies, the project places a strong emphasis on completing the design phase to ensure alignment among stakeholders and the shipyard, even if it results in a delay to the construction schedule.

(2) In situations where the contract, specifications, and design brief are not adequately defined, the shipyard engages in collaborative efforts with stakeholders to enhance and augment these elements, identifying potential solutions that effectively align with the established criteria.

Figure 4 illustrates the on-time delivery of each project, represented by the blue dimonds or circle, along with their respective reply rates, indicated by the red dimonds or circles. Notably, projects 1 and 2 remain on schedule despite a lower reply rate. Nevertheless, the overall trend demonstrates that the implementation of new policies has played a significant role in ensuring adherence to the established project schedule. In the figure, two additional bars are also presented, i.e. ‘Eliciting from client’ represented by the grey bar and 'Eliciting beyond client' represented by the yellow bar. These bars reflect the efforts of naval architects in expanding their search for additional sources of information, which has contributed to the timely delivery of ships.

Figure 4. Comments replied corresponding to on-time delivered rate and elicitation source.

In Figure 4, projects 1 and 2 stand out as exceptions to the general trend due to their status as repeat projects. Many of the challenges faced in these projects have already been addressed based on feedback from previous batches, resulting in a consensus between the shipyard and clients. Consequently, most potential conflicts have already been anticipated, and corresponding solutions are readily available.

THE CONCEPT OF PROACTIVE ELICITATION

The aforementioned study unearths a notion of 'elicitation', which emphasises proactive information-seeking and problem-solving approaches (Delicado, 2019). 'Elicitation' extends its focus beyond the customer and includes a wide range of stakeholders, placing a strong emphasis on establishing comprehensive requirements through a rigorous and independent process. It is worth noting that elicitation is not limited by design briefs. Since elicitation focuses on capturing the essence of diverse stakeholders' desires, it can be used as a means to gather information for decision-making and bridge the gap between stakeholders and the 'real design' (Andrews, 2021).

In this study, proactive elicitation endeavours to gather comprehensive information during the initial or concept stage of ship design. Conflicts between stakeholders' expectations and the design brief can be resolved by proactively seeking additional information beyond design briefs. The timing of applying proactive elicitation can significantly impact its effectiveness in improving ship design accuracy. To facilitate understanding, Figure 5 illustrates an area between the curves of Commitment Technology (represented by the orange curve) and System-Specific Knowledge (represented by the red curve). This area between the two curves is referred to as 'design freedom'.

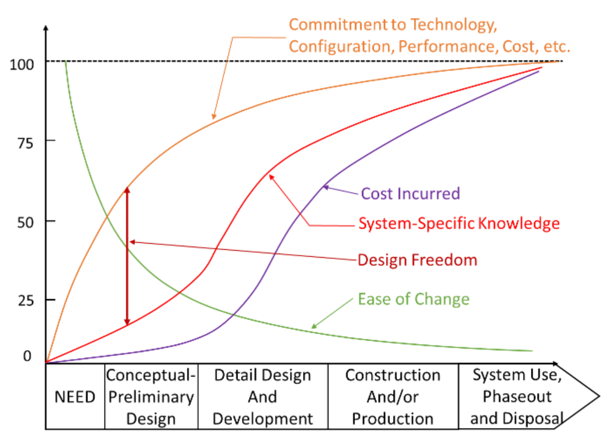


Figure 5. Illustration of project phases and design freedom (Malmgren & Ulfvarson, 2006).

During the conceptual design phase, naval architects will explore various design options in a variety of ways, with the goal of minimising 'design freedom' while meeting the stakeholder's requirements. To fully harness the advantages of proactive elicitation, it is imperative to establish it as a systematic workflow. Therefore, an extensive survey, called the full survey in this paper, was conducted, encompassing stakeholders at various management levels in the shipbuilding industry. The aim was to investigate the essential tasks involved in this workflow. In the survey, the stakeholders were divided into two groups. The first group are stakeholders who contribute design information or standards to naval architects. They responded favourably when questioned about their capacity to integrate their requirements and actively identify potential needs. This signifies that they recognise and appreciate the willingness of naval architects to enhance the design of their products. Another group of stakeholders consists of naval architects responsible for driving the ship design process and overseeing it at a supervisory level. They also expressed a positive inclination towards proactively considering potential requirements beyond the initial design brief. This underscores the naval architects' awareness of their pivotal role in shaping ship design and the significance of adopting a proactive approach to overcome constraints. The keywords adopted in the open-end questionnaires are categorised into 12 stages throughout the design process, concrete and cogitation aspects and current/expectation concepts. The survey results are shown in Figure 6. The degree of concern indicates the areas within ship design to which two distinct stakeholder groups attach importance.

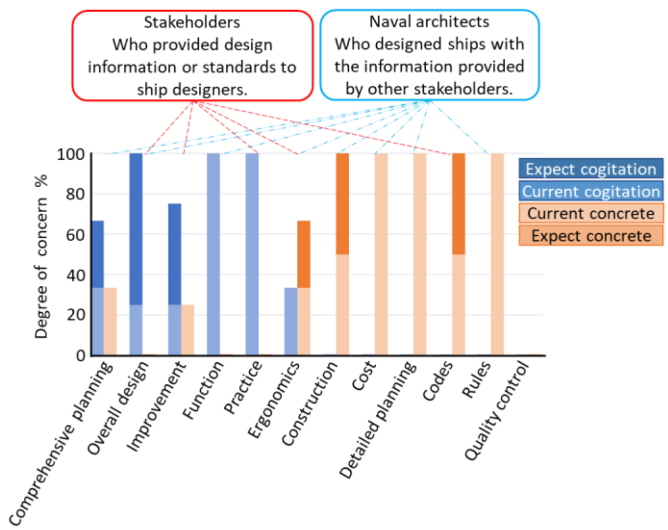


Figure 6. Results of the full survey.

Figure 6 indicates a significant emphasis by both groups of stakeholders on the cogitative and expectation aspects of the design process, particularly in the pre-construction phase. The survey results suggest that all stakeholders hold high expectations and demonstrate a strong desire to explore the design's potential. However, as the design progresses towards the detailed and construction plan stage, both groups of stakeholders tend to prioritise preserving a particular style while solidifying their ideas, aiming to minimise potential risks. This approach is justifiable as it ensures that the design plan is well-defined and carries minimal risk upon completion. Additionally, the survey results also suggest that stakeholders require additional information to meet their design expectations during the ESSD stage. It is evident that stakeholders' concerns encompass two distinct aspects: concrete and cogitation. To establish proactive elicitation as a self-contained process and seamlessly integrate it into the current ship design process, a potential implementation approach is depicted in Figure 7.

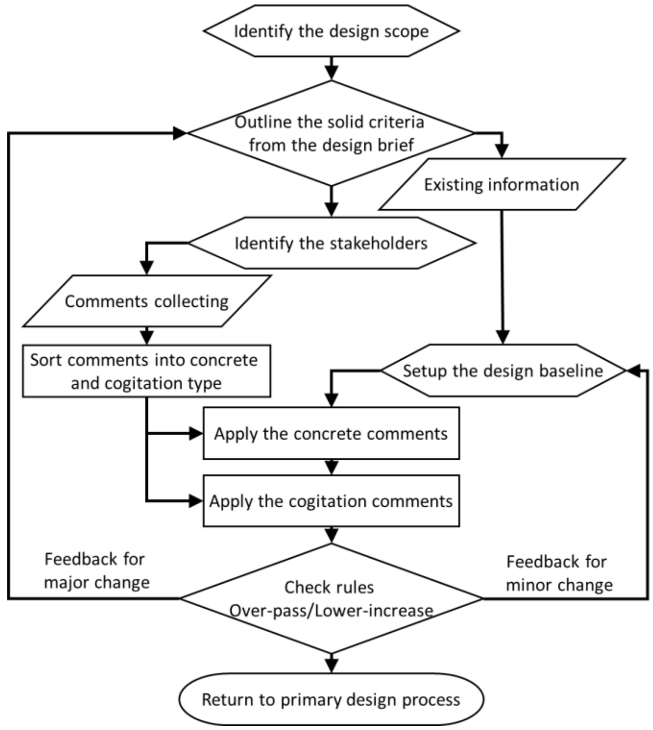


Figure 7. Implementation approach of proactive elicitation.

The proactive elicitation implementation approach depicted in Figure 7 originates from numerous shipbuilding projects. Through extensive trial and error, it has been observed that design issues can generally be classified into two principal categories: concrete issues, which can be resolved through specific information such as rules, regulations, or quantitative analysis, and cogitation aspects, which necessitate thoughtful deliberation or brainstorming for resolution. This approach can be incorporated at any stage of ship design to acquire additional information. To be specific, at the initial stage of ship design, there is a lot of room for design freedom, which needs to be decreased in subsequent stages. The process commences by utilising existing information to establish a design baseline, serving as a reference point. Subsequently, stakeholders are identified, and their concrete and cognitive comments are extracted for application. The final stage involves evaluating the design against concrete criteria, such as industry rules and regulations. If the design meets the specified criteria, it can proceed. Otherwise, adjustments are made to ensure compliance, or it may be sent back to the appropriate stage for reevaluation.

Development of discrete event models

To assess the efficacy of proactive elicitation in improving the success of ship design, two discrete event models were constructed in Simulink in the following. The agent-based discrete event model is appropriate for tracing the agent that travels through the model to study the interactions between agents and events. The agent-based model is built with a series of events as a loop according to individual agents (stands for accuracy and elicitation accuracy in this paper) assigned certain attributes and could be processed by each event. These models were designed to simulate real bureaucratic systems, aiming to provide a realistic representation of the workflow of ship design. The first model serves as a generic bureaucratic system model, simulating design-related tasks, while the second model is specifically tailored to implement and incorporate proactive elicitation in the ship design process.

The general bureaucratic system model for design work was derived from an on-site investigation and transformed into a series of discrete events. These events are scheduled over time, with sequential processing events representing the progress of the design tasks. This event-driven simulated model effectively captures the characteristics commonly found in bureaucratic systems. However, it should be noted that each design team have its own unique bureaucratic culture. This discrete event model cannot fully represent a specific design team or serve as a standard process for the overall design system. Nonetheless, the model serves as a valuable testing platform, allowing the simulation of specific work nodes within the design process. Simulation enables the examination of the impact and effectiveness of these nodes. The proactive elicitation model is built upon the proactive elicitation process depicted in Figure 7. It comprises a series of events aligned with the specific tasks outlined in the flowchart. This model serves as a modular component that can be seamlessly integrated at any stage within the generic bureaucratic system model. When simulating real-world systems using these two discrete event models, certain assumptions must be made, and relevant variables need to be accounted for. The assumptions considered in this study are outlined below, and the variables are listed in Table 2.

- The 'agent' is named as the accuracy for the general bureaucratic system model and elicitation accuracy for the proactive elicitation model. Both stand for the level of the design that could reflect the stakeholders' expectations and desires. Both units are in %.
- The agent going through the design/feedback node will decrease by multiplying the design performance when going through the split node, which results in the split rate. This stands for the agent portion going to feedback or sharing. The agent from feedback or sharing will add to the agent in the mainstream.
- In the model, the term 'Time' represents a specific phase in the design process. It does not refer to the duration or length of time.
- The 'model' represents the entire design process, which means the process is complete once the agent reaches the last node.

Table 2. Variables.

Types	Variables
Explanatory Variables	1. Design parameters. 2. Split parameters. 3. Sharing parameters. 4. Criteria for the design check.
Controlled Variable	1. Total design time. 2. Feedback time. 3. Information exchange time. 4. 'Dream' represents 100% accuracy.
Dependent Variable	Accuracy (%)

Figure 8 depicts the generic bureaucratic system model, which serves to simulate the activities carried out by a single team at each event node. In the figure, the nodes are represented by black font, while the activities are indicated using red font.

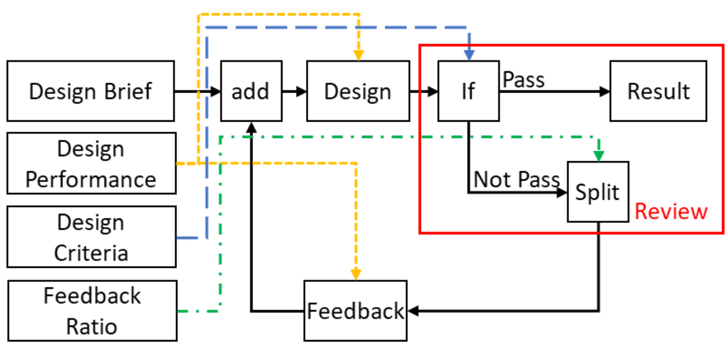


Figure 8. Generic bureaucratic system model for simulating the activities of a single team.

In Figure 8, the term "Design Performance" refers to how well the design team interprets the Design Brief throughout the design process. A higher value indicates a stronger alignment between the design outcomes and the expectations outlined in the Design Brief. On the other hand, "Design Criteria" represents the set of standards utilised to assess the design outcomes during the review process. If the outcomes meet these criteria, they are considered satisfactory; otherwise, feedback is provided to the design team for improvement. The "Feedback Ratio" illustrates the proportion of outcomes that require feedback and subsequent redesign. All these values are expressed in percentages (%), and their specific values depend on the particular design environments being considered. Regarding the "Design Brief," it is also expressed as a percentage (%), with its value indicating the accuracy of the Design Brief in conveying stakeholders' requirements and expectations. A value of 100% signifies a Design Brief that perfectly and completely reflects the needs of the stakeholders. It is important to note that the accuracy of this parameter depends on the initial stage of the design process. If the design process starts with direct stakeholder engagement, the accuracy of the Design Brief may be close to 100%. However, during the Concept Design phase, the Design Brief might be derived from contractual documents, resulting in a lower accuracy level (e.g., 80%). As listed in Table 3, all the aforementioned parameters will be assigned fixed values in subsequent simulations to ensure consistent simulation conditions.

Table 3. Values of model parameters.

Parameters	Value	Remark
Design Brief	80%	Design Brief at the ESSD represents stakeholders' expectations and requirements with 80%.
Design Performance	70%	The design team has comprehension of up to 70%.
Design Criteria	70%	The approval criteria of the Review is 70%.
Feedback Ratio	20%	Assuming that 20% of the design needs to be rechecked when the design is not approved.

The model depicted in Figure 8 can be easily extended to incorporate the activities of multiple design teams, thus enhancing its flexibility and applicability. In order to provide a clearer representation, Figure 9 presents an illustration of the model specifically tailored to simulate the activities of two design teams.

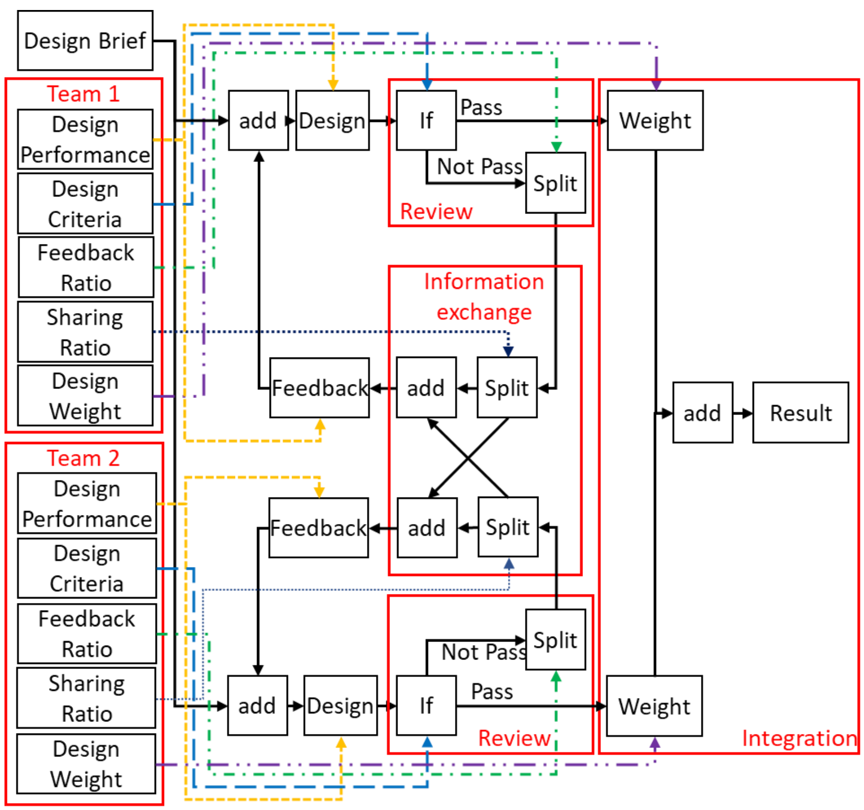


Figure 9. Generic bureaucratic system model for simulating the activities of two teams.

From Figure 9, it is seen that the model has been expanded to include additional event nodes, facilitating the exchange of information between different design teams and enabling the integration of design outcomes. The 'Sharing Ratio' parameter has been introduced to account for the cross-team collaboration within a specific team. Furthermore, individual design teams are assigned different design weights, which capture their specific characteristics and account for the variations arising from their respective design responsibilities within the overall design process.

In the simulations conducted for this study, the focus was on a scenario involving two design teams. While maintaining the unified simulation conditions with Design Brief and Design Criteria set respectively at 80% and 70%, the remaining parameter values are provided in Table 4. It is necessary to note that these parameter designs were based on the relationship between a Structure Design Team (Team 1) and a Propulsion Design Team (Team 2) in a real ship design office. However, different ship design offices may have their own unique cultures and systems in place. Therefore, this particular case serves as only a reference for parameter configuration and should not be considered an absolute standard.

Table 4. Model parameter values for a two-team model.

Team 1 (Structure)		Team 2 (Propulsion)		Remark
Parameters	**Value**	**Parameters**	**Value**	
Design Performance	70%	Design Performance	40%	Team 1 has more personnel than Team 2, with higher performance.
Feedback Ratio	10%	Feedback Ratio	50%	The structure is concrete knowledge, so the propulsion is more flexible with a higher value.
Sharing Ratio	10%	Sharing Ratio	50%	Team 1's sharing range is the engineering section, but Team 2 needs to share all information to help Team 1.
Design Weight	70%	Design Weight	30%	The range of Team 1 in the design is more than that of Team 2.

Overall, these two models serve as testing platforms to validate the effectiveness of the proactive elicitation model. The single-team model is suitable for representing a comprehensive organisation, such as a shipyard, design firm, or similar entity, where the precise breakdown of work information may not be available. In such cases, the single-team model can be utilised, with each node in the model representing the overall performance of similar teams. On the other hand, the multi-team model allows for the incorporation of efficiency parameters specific to individual teams within the organisation. This enables a more in-depth analysis of team efficiency and provides a more detailed understanding of organisational performance. The functionality of this model accurately reflects the operational performance of a particular organisational structure, offering insights into how different teams interact and contribute to the overall success of the organisation. The proactive elicitation model is depicted in Figure 10, which is developed based on the flowchart illustrated in Figure 7. The agent of this model is referred to as 'elicitation accuracy'. It is independent of the accuracy of the design process.

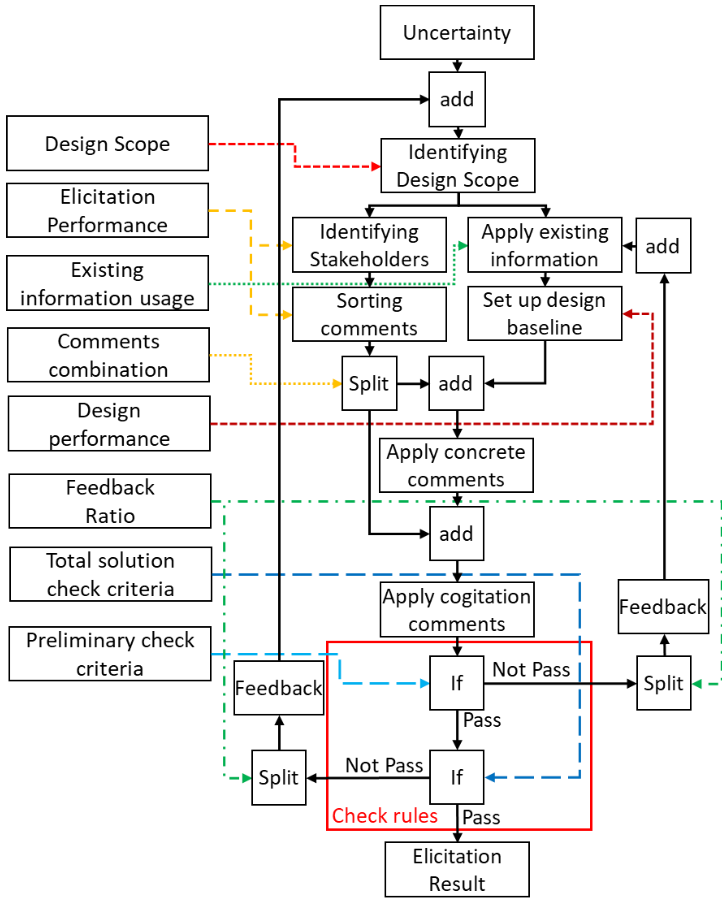


Figure 10. Proactive elicitation model.

In this proactive elicitation model, a total of eight parameters are configured based on the simulation conditions. They are explained in Table 5. In Figure 10, the term 'Uncertainty' represents the flexibility of proactive elicitation in addressing issues during the design process. Generally, as the design progresses and achieves higher completion, the value of Uncertainty tends to decrease. The term 'Design Scope' indicates the design freedom in the design process. A higher value indicates greater design freedom, and it is typically higher at the initial stages of the design process, gradually decreasing as the design progresses.

Table 5. Parameter values in the proactive elicitation model.

Parameters	Value	Remark
Elicitation performance	80%	This team has 80% performance in identifying the stakeholders and understanding their comments.
Existing information usage	40%	The design brief could provide information with 40% accuracy.
Design performance	80%	This design team has comprehension of up to 80%.
Comments combination	80%	This design team has 80% accuracy in sorting the comments into correct categories.
Feedback ratio	50%	50% of the information must be reviewed if it does not meet the criteria.
Preliminary check criteria	20%	The criteria of the preliminary check are 20% accuracy.
Total solution check criteria	50%	The criteria of the Total solution check is 20% accuracy.

CASE STUDY

The case study in this section comprises simulations involving both single-team and multiple-team scenarios, focusing on investigating the influence of the intervention stage of proactive elicitation. The objective is to find which stage at which the implementation of proactive elicitation can yield the highest effectiveness. Figures 11 and 12 show the nodes that represent the three different intervention points of proactive elicitation in the simulations of each model. Table 6 presents the values of Uncertainty and Design Scope when proactive elicitation is incorporated in different stages of ship design. In the table, Case 0 is designated as the control group, where no proactive elicitation intervention is applied. This case serves as a baseline for comparison with the other three cases that incorporate proactive elicitation.

Table 6. Uncertainty and Design scope in different cases.

Parameters	Case 0	Case 1	Case 2	Case 3
	control group	Before the design stage	During the design stage	After the design stage
Uncertainty	0	100%	75%	50%
Design scope	0	80%	60%	40%

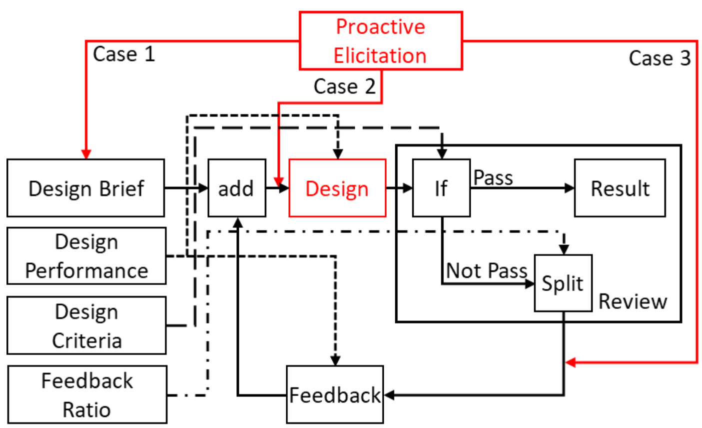


Figure 11. Intervention on the single-team generic bureaucratic system model.

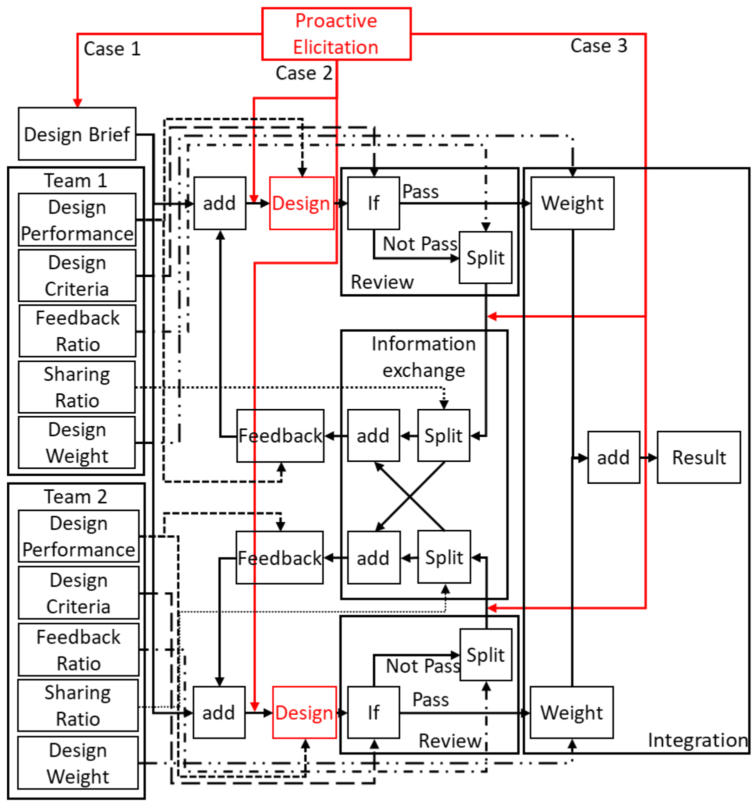
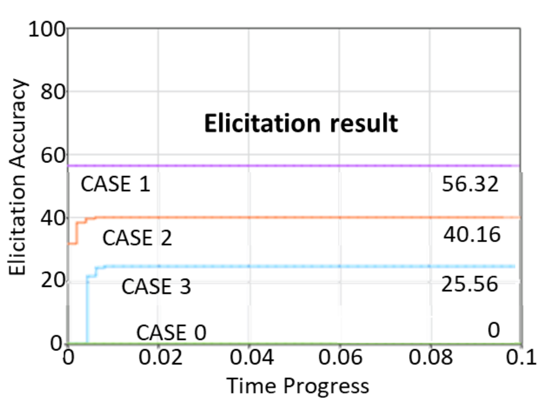
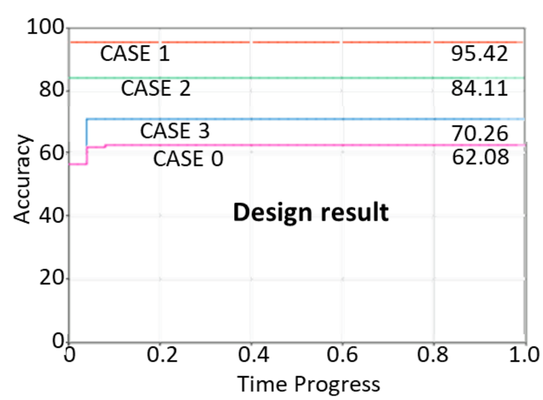


Figure 12. Intervention on two-team generic bureaucratic system model.

The simulation results for the single-team generic bureaucratic system are presented in Figure 13. Figure 13a depicts the proactive elicitation to assess the level of understanding through elicitation accuracy. In the four different cases, CASE 0 serves as the control group, where the elicitation accuracy is 0. On the other hand, CASE 1-3 presents the elicitation accuracy levels of proactive elicitation under varying conditions of different stages. Similarly, Figure 13b illustrates the accuracy of the design result, which serves as an indicator of the level of understanding in the design brief through the design process of a single-team generic bureaucratic system. CASE 0 represents the control group without proactive elicitation intervention, thus reflecting the design result accuracy achievable under the design brief. CASE 1-3 demonstrate the design result accuracy achieved by incorporating proactive elicitation at different intervention points and considering the associated elicitation accuracy. The simulation results for the two-team generic bureaucratic system are presented in Figure 14. As shown in Table 4, different parameters are assigned to each team in the simulation to highlight the differences between the two teams. In Figure 14, the curve indicated by 'total' represents the overall design outcome.



(a) Accuracy of elicitation result



(b) Accuracy of design result

Figure 13. Impact of proactive elicitation on a single-team generic bureaucratic system.

From Figure 13b, it is seen that in Case 0, the design information enters the design process through the design brief. However, due to imperfect understanding, the comprehension of the design brief is not flawless, leading to a result that the efficiency of understanding is not as high as 100%. For this reason, the efficiency of understanding will decline gradually over time in the simulation. However, by employing the ‘review process’, any components of the agent that fail to meet the design criteria will be fed back to the design stage. They are then redesigned and incorporated into the original design, resulting in an iterative process. Consequently, the overall trajectory of the process remains upward. Nevertheless, as the design accuracy improves, the instances where design outcomes fail to meet the criteria and are returned to the design stage will progressively diminish. As a result, the rate at which the process is increasing will continuously decelerate until it eventually approaches zero and stabilises at a certain level.

In contrast to the outcomes observed in Case 0, which does not incorporate proactive elicitation, the results obtained in Cases 1, 2, and 3 show the impact of employing proactive elicitation at different stages of ship design. These results reveal that proactive elicitation indeed enhances design effectiveness, regardless of when it is implemented. The underlying rationale behind this phenomenon can be attributed to the design process itself. When supplementary information is provided, the agent's 'accuracy' achieved through proactive elicitation is integrated with the existing accuracy. This process mirrors real-world scenarios, where the inclusion of new information enriches the comprehensiveness of design outcomes. In other words, by considering additional information through proactive elicitation, the design process becomes more comprehensive, thereby leading to improved design effectiveness. However, the effectiveness of proactive elicitation varies across the three intervention points, with Case 1 demonstrating the highest impact, followed by Case 2 and Case 3. This implies that the earlier the proactive elicitation is introduced, the greater benefits will be yielded.

In Figure 14, in addition to the intervention of proactive elicitation prior to the design stage, which resembles the operations in the single-team model, the two teams also engage in proactive elicitation during and after the design stage. As a result, the information presented in Figure 14 is more abundant compared to the results shown in Figure 13. From Figure 14, it is noticed that the outcomes of Case 1 and Case 2 show an 'accuracy' exceeding 100%. In real-world terms, this situation can be interpreted as heightened stakeholder involvement and the incorporation of a broader range of information, which can lead to designs that surpass the expectations outlined in the design brief. This phenomenon can also be understood as the generation of superior alternative solutions based on the design brief.

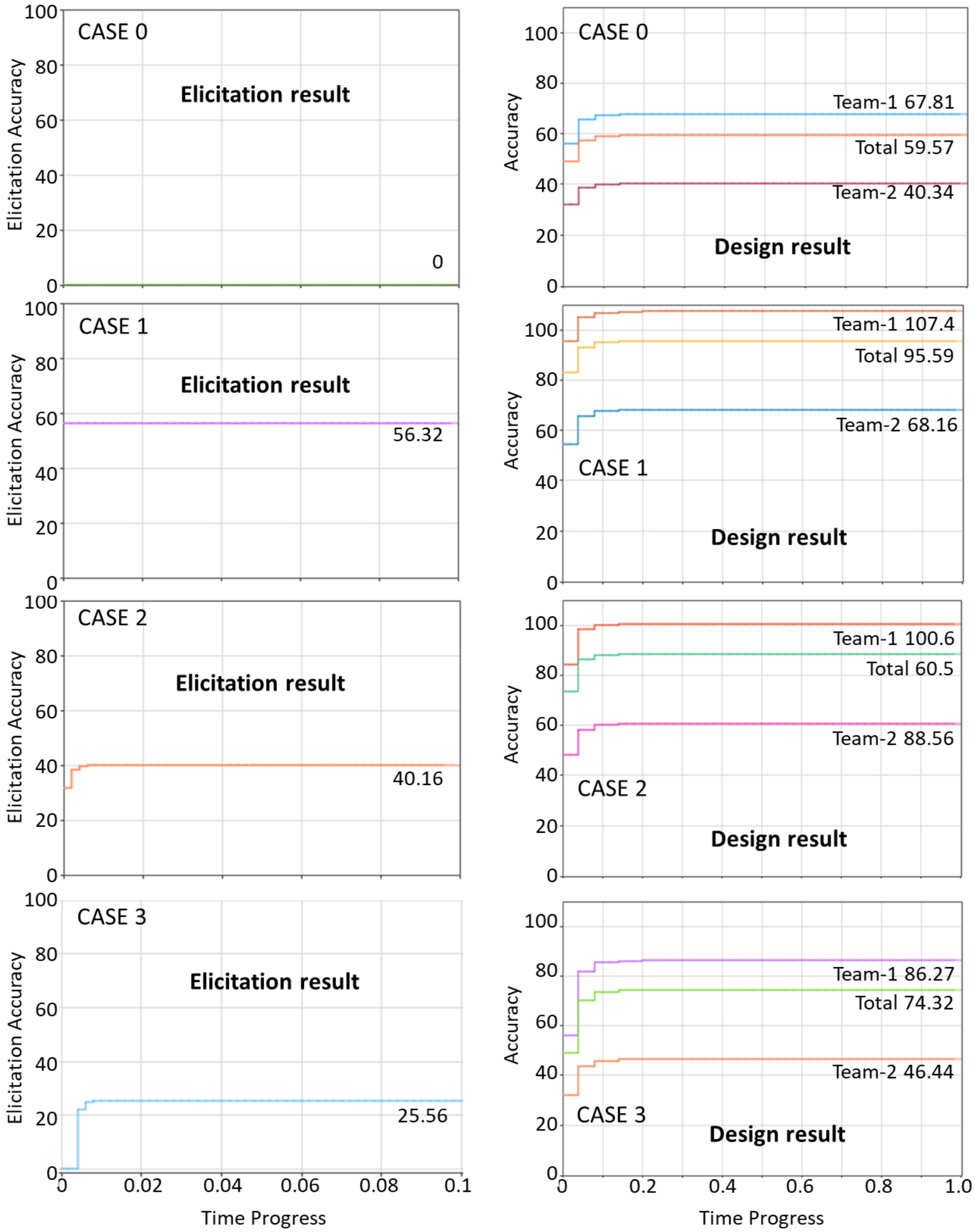


Figure 14. Impact of proactive elicitation on a two-team generic bureaucratic system.

By summarising the simulation results depicted in Figures 13 and 14, it can be inferred that:

- Proactive elicitation functions as a self-contained module unaffected by the quality of the design brief. The information generated through this independent process is directly incorporated into the "accuracy" of specific stages within the design process, leading to an additive effect. Consequently, irrespective of the accuracy of the design process or proactive elicitation, any enhancement in accuracy contributes to an overall improvement in the success of the design results.
- It is evident that proactive elicitation yields the greatest benefits when applied 'before the design stage'. This particular stage presents a direct opportunity to enhance the quality of the design brief. Moreover, during this stage, proactive elicitation exhibits the widest ranges in terms of 'uncertainty' and 'design scope'. These aspects indicate that the initial design stage offers the most significant potential for exploring improved design solutions. However, as the design progresses towards

completion, the scope for modifications diminishes. That will limit the effectiveness of proactive elicitation within the constraints of the existing design.

CONCLUDING REMARK

This paper focuses on studying proactive elicitation and its effectiveness in enhancing ship design success. It is important to reiterate that proactive elicitation transforms naval architects from passive information receivers into active information seekers. It is not a management tool or organisational standard. Instead, it represents an attitude and philosophy towards design embraced by naval architects. Therefore, implementing proactive elicitation involves training personnel in this mindset or utilising policies to encourage naval architects to strengthen their collaboration and communication with stakeholders.
The simulation results demonstrate that the timing of applying proactive elicitation has an impact on the attainment of design success (higher design accuracy in the model). This suggests that individual factors can also contribute to enhancing the design process. Therefore, enhancing the design process or proactive elicitation is meaningful.

Future research on proactive elicitation will emphasise interdisciplinary integration and its influence on education and training for naval architects. This study advocates for naval architects to proactively explore design information. However, it raises the question of whether naval architects possess the ability to understand and effectively apply such information. Observations suggest naval architects rely on accumulated experience but lack comprehensive understanding and application of design information. Therefore, adjustments to education and training are needed to cultivate naval architects who can effectively apply proactive elicitation during the initial design phase.

CONTRIBUTION STATEMENT

Cheng Feng Ou Conceptualised the study and chose the Methodology. Cheng Feng Ou performed Data curation, Investigation, Formal analysis, and original draft and manuscript Writing. David Trodden and Serkan Turkmen contributed to Supervision, Resource provision, Reviewing the draft, and Editing the manuscript.

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