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The optimisation of a tendering process in warship refit – a case study

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ABSTRACT

The optimisation of a tendering process for warship refit contracts is presented. The tendering process, also known as the pre-contract award process (PCA), involves all the activities needed to be successfully awarded a refit contract. Process activities and information flows have been modelled using Integrated Definition Language IDEF0 and a Dependency Structure Matrix (DSM) with optimisation performed via a Genetic Algorithm (DSM-GA) search technique. By utilising this approach the process activities were re-sequenced in such an order that the number and size of rework cycles were reduced. The result being a 57% reduction in a criterion indicating 're-work' cycles.

1 INTRODUCTION

Babcock BES designs and refits both naval and commercial vessels, with more than 90% of the work involving one main customer (1). Facing the dilution of future turnover in this competitive sector, due to the reduction of available contracts, the company is responding by accelerating its improvement programme. It is accepted that Babcock BES contains the expertise and knowledge to continue supplying the customer with high quality, leading edge products. The challenge lies in reducing cycle times and costs.

To obtain the necessary performance improvements within the pre-contract award (PCA) process, a strategic business process, it was decided to apply a business process improvement methodology (BPI) that reflects the philosophy of Cook (2) and Ziari (3). The methodology will use techniques to identify key areas for improvement. These improvement areas will be benchmarked and changes in the process's performance monitored, via key performance indicators. Based on early findings, process rework was identified as a target area where performance improvements may be obtained. This paper describes the application of an optimisation technique to the PCA process. The findings of this study led to recommendations that aim to reduce rework cycles and streamline information flows. A qualitative modelling tool was used to formalise the 'As-Is' process. This was then transferred into a quantitative modelling and optimisation tool. The results of which lead to the following recommendations:

- Re-order the 'As-Is' activity sequence to reduce the size and number of rework cycles.
- Greater congruency with 'customer' and 'design' processes.
- Improve activities that have the most positive impact on streamlining overall process flow.

The above recommendations are discussed in more detail, as are the particular strengths and weaknesses of the DSM-GA method. The paper details some cycle time reduction challenges, in an information intensive process, and demonstrates how the DSM-GA method could be applied. Advice is given on technical and social issues that have to be overcome when performing a similar project.

2 DESCRIPTION OF CASE STUDY PROCESS: PRE-CONTRACT AWARD PROCESS (PCA)

Make/Engineer-to-order companies spend a significant amount of time and effort in putting together tenders (4). In Babcock BES this is known as the PCA process and involves all the work activities required to obtain a refit contract. This includes converting the customer requirements into a product specification and executing the design work, through to estimating (material & labour), tendering and contract negotiation. These high level functions were modelled to a level of abstraction that showed 86 work activities and 460 information links. Hence, the size and importance of the PCA process necessitates that its structured and supported to allow the generation of both accurate and timely tender bids and in addition communicate the rationale, upon which the tender is based, to the rest of the business (4).

The selection of the PCA process for improvement was based on an internal Babcock BES study, which explained that a significant degree of company inefficiency, in refitting a ship, lay in the early contract stages (i.e. precisely the activities that are covered by the PCA process). This is a common situation in many companies and is discussed further by O'Grady, et al (5) and Nevins and Whitney (6). This can often be attributed to two generic problems, new/late information being injected into the project and/or activity products failing to meet downstream requirements. Therefore, it is important to understand the PCA process's key characteristic, information transfer between the various departments and the customer. If the information transfers can be formalised and understood, there is an increased probability that changes, aimed at improving the efficiency and effectiveness of the PCA process, will be focused where they would have most positive impact (7).

3 PROCESS MODELLING AND ANALYSIS TECHNIQUES

Practitioners and academics have recognised that the key to process improvement lies in how well the process is understood (8), decomposed and subsequently restructured (9). This realisation has led to many process modelling tools and techniques, each possessing certain strengths and weaknesses. These were evaluated against process characteristics and project objectives, to ensure that an appropriate tool was selected for the study. The PCA process is characterised by a considerable exchange of information, both internally and with the customer. It was important that the tool selected could capture these information requirements and allow the process to be streamlined. It was decided that the tool should have the capability to:

- Illustrate activities and the information flows between them.
- Demonstrate the size and number of iterative cycles.
- Demonstrate the degree of importance of information in relation to each activity.
- Handle large information intensive processes.
- Methodically decompose a process.

IDEF0, Structural Analysis Design Technique SADT, Gantt Charts, DSM-GA and Program Evaluation and Review technique (PERT) were considered, as they are commonly used tools for modelling and managing processes. None of these techniques were uniquely appropriate for this study. Therefore, it was decided to use IDEF0 in tandem with the DSM, in order to fulfil the above modelling requirements. The IDEF0 technique, discussed further in (10), was used to gather the required information and populate the DSM, whilst the DSM-GA was used for process optimisation and analysis in this study.

The DSM is a generic process modelling tool. Developed by Stewart (11), the DSM was developed, primarily to formalise complex information flows and iterative cycles, a process characteristic often overlooked when modelling processes (12). Figure 1 shows a DSM model of the ‘As-Is’ PCA process. The ‘As-Is’ model contains a series of activities in identical order, both along the horizontal and vertical axes. An ‘X’ represents information being passed on from an activity in a column to an activity in a row. An ‘X’ above the leading diagonal represents iterative blocks (see section four for a definition of iterative blocks). The darker ‘X’ signifies more critical information.

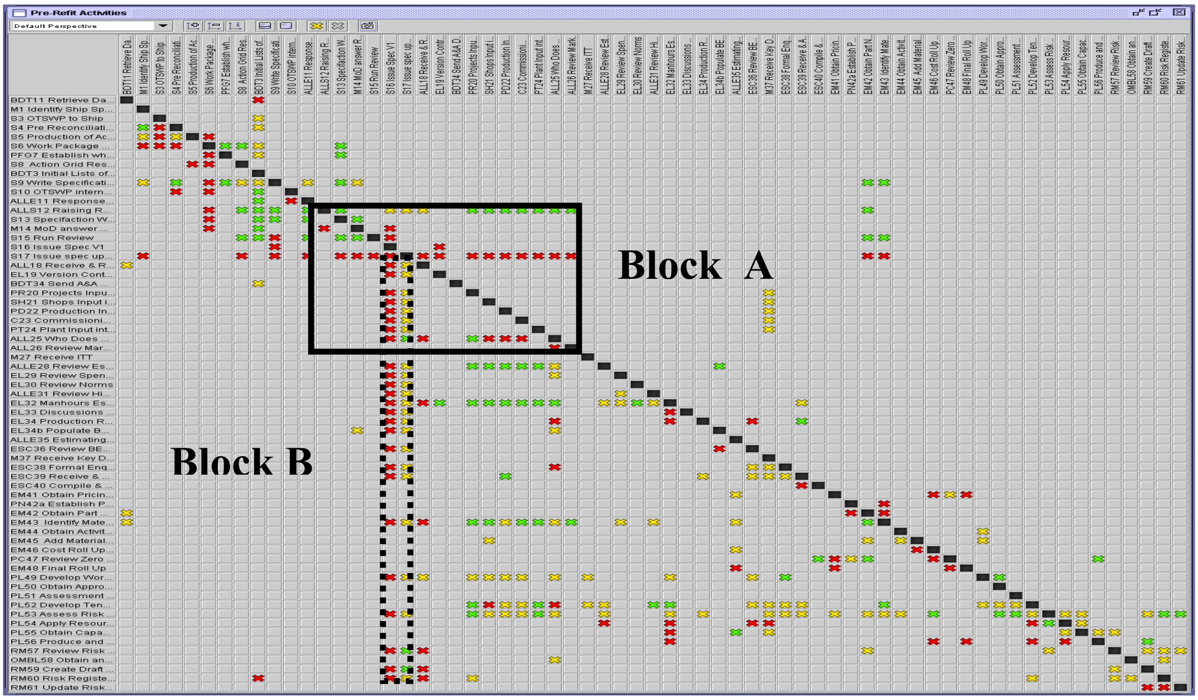

Figure 1 'As Is' Matrix

Whitfield et al (13), built on the strengths of the DSM modelling technique with the introduction of a Genetic Algorithm (GA) optimisation search technique. This technique allows the described process to be quantitatively modified, i.e. computationally re-sequenced. There are currently 6 performance criteria that may be selected to optimise the process. Scott partitioning criterion was selected as its capable of optimising the process sequence, to reduce iterative cycles (7).

The GA works on the basis of searching various combinations of process sequence of which, there are a potential $2.42*10^{130}$ within the PCA process. A sequence is evaluated with respect to the Scott partitioning criterion. At this stage the sequence with the highest performance characteristic is selected for the next generation. Crossover and mutation operators then act on the selected sequence. This increases the probability that the next generation has less iterative cycles. A full description of the GA and its structure can be found in (13).

The number of activities within the process dictates the maximum GA search space and can be calculated by n!, where n is the number of activities. Hence, the computational time increases with the number of activities, however this may be limited by the use of a population size and generation count. Instead of searching through all possible combinations, the search space is limited to a practically reasonable yet effective domain size, as proposed by Whitfield et al (13).

Despite the DSM-GA having had considerable use in a product design, (14) and (15), it has had limited application in projects similar in size and context to the PCA case study, (7). Hence, a number of novel issues are described in the following sections, such as cross-functional optimisation, information validation techniques and the suitability of the DSM-GA for applications outside design.

4 DSM APPLICATION OF PCA PROCESS

For the case study it was decided to adopt three different dependency weightings, represented by coloured crosses within the matrix. The darker crosses represent the most critical information; the interested reader is referred to (10) and (15). The Scott partitioning criterion re-sequences the activities and their associated dependencies, to reduce the effects of untimely information across the process. The aim being to reduce the overall number and size of iterative blocks within the process.

Two workshops were arranged to formalise and verify the 'As-Is' process's activities, information links and their specific weightings. These workshops, each lasting three hours in duration, allowed the key staff within the process to verify that the DSM matrix reflected their current process. The process owner signed off the 'As-Is' process, to confirm its accuracy and completeness. This signified the end of the information gathering and process modelling stage. Important features of this type of model are the iterative blocks, represented by an 'X' above the leading diagonal. This is information that is required by an activity to allow its completion, yet its availability is constrained by the fact that the feeder activity has not occurred and/or the information it provided was incomplete. In such cases the activity owner will often make an intelligent estimate, and at a later time when the required information is available, confirm the accuracy of their estimate. Figure 1 shows an example of an iterative block, driven by product specification updates, marked on the matrix as ‘block A’. These updates are caused by critical activities occurring too late in the PCA process. These activities provide knowledge and experience from previous contracts, customer requirements and engineering drawings. This is even more significant as the product specification is used as the main input to many of the downstream activities, such as material, labour and sub-contract estimating- see block 2, in Figure 1. Each product specification update requires these activities to be reworked according to the new information. This can lead to significant problems for the estimating and planning functions e.g. time constraints and managing changes. Further examination of the matrix in Figure 1 highlights other areas in the process with a high concentration of ‘X’s above the leading diagonal i.e. areas where untimely information is causing rework. The performance criterion, Scott Partitioning, measured the existing rework at 9.29×10^7.

5 OPTIMISED AND VALIDATED PCA PROCESS

The ‘As-Is’ PCA process was optimised using the DSM-GA. A population size and generation count of 3000 was used in tandem with independent position crossover and shift mutation operators. This allowed $9*10^6$ possible solutions to be evaluated over a period of 4 days using a standard personal computer. A 'new' sequence was produced that exhibited a reduction in iteration i.e. there are less information dependencies above the leading diagonal. This reduced the Scott Partitioning performance criterion by 51% to 4.55×10^7. This reduction in Scott Partitioning brought about by computationally optimising the sequence, represents a reduction in the overall process ‘rework’ cycles.

There are factors that may result in an impractical sequence, these include, no specific process heuristics, a limitation in the applicability of the GA, an insufficient search space and/or incorrect dependencies in the matrix. Hence, the optimised sequence was presented to the process operators for validation. This was an important step to gain ‘buy-in’ and prevent the project remaining a paper-based exercise.

A workshop was organised as it provided an appropriate environment to encourage the process operators to interact and participate fully in the validation (17). It allowed the process operators to critique the practicality of the DSM-GA solution and explore & discuss ‘What If’ scenarios. The following points provide insight to how the workshop was performed:

- Firstly, the optimised process, showing a 51% reduction in rework, was projected in front of the group. Each individual was invited to start at the top of the matrix and identify tasks they felt were impractically ordered along with the rationale. As a result, 54 separate changes were made, for example the ‘collate and compile tender’ activity was repositioned before the ‘submit tender’ activity. It is important to note that changes made were only accepted if a further reduction in the Scott Partitioning performance criterion was achieved and/or there was a fundamental requirement for activities to be repositioned elsewhere.

- The DSM-GA is a tool that allows the dynamic manipulation of the matrix sequence. This enabled the user to manually ‘drag’ an activity to a new position, the Scott Partitioning criterion is re-calculated at the same time. A number of ‘What If’ scenarios were performed and the resulting changes to the global impact assessed and discussed. In doing so the process operators built on their existing expertise by learning from each other. The end result was a further 6% reduction in the Scott Partitioning value. (See Figure 2, for optimised and validated process).

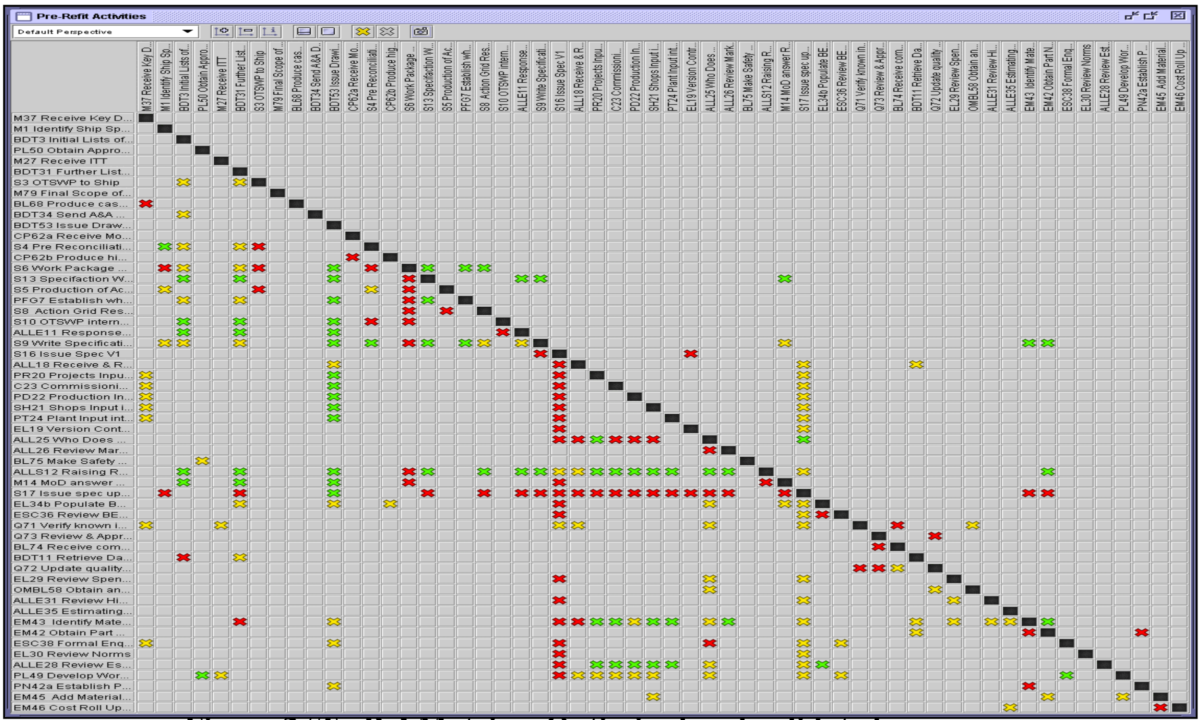

Figure 2 'To Be' Matrix – Optimised and validated process

It has been argued that companies should move from silos of expertise and become more process focused (16). This is not an easy transition for any company, especially those of a traditional nature and working in antiquated industries. The workshop brought together the various representatives, from each department within the process, and raised awareness of information needs and constraints. The new sequence meant that in some instances process operators would now receive information they previously estimated, whilst others would have to estimate information they previously had. It was agreed that some tasks would suffer due to some additional rework, but the overall process would benefit by the global reduction in rework. This was a step towards Babcock BES becoming a more process focused company.

The validated and optimised process reduced the Scott Partitioning criterion, which measures rework due to ineffective activity sequencing, by 57%. However, non-conforming work products and delivery mechanisms can also cause rework. These are issues that should not be ignored as they may have a significant effect on the new process.

6 IMPROVING EFFECTIVENESS OF KEY ACTIVITIES

In addition to improving the sequence of the process this study has identified key areas that need to be improved. These key areas were identified, based on the PCA process' specific characteristics and some analysis of the various matrices. (See Figures 1 & 2)

The PCA process's key characteristic is information transfer, both with the customer and internal departments. Modules of information are used to create the product specification and the company generates additional information, which is in turn exchanged with the customer for approval. In addition to every module exchanged with the customer, many more transfers of information occur within the company. All this information is required to fully prepare the specification and the subsequent tender. These information transfers need to be enhanced from their present state. The following recommendations address some of these issues.

- The information needs to be co-ordinated and transferred more effectively internally within Babcock BES, and externally between the company and customer. This will help reduce the occurrence of late and unreliable information, such as estimators working from different versions of the specification, a possible contributor to rework. Communication with the external customer, who is dispersed geographically, is currently done via traditional communication modes, such us email, phone and post. Improvement areas will involve looking at adopting better transfer media e.g. a shared database could be considered.

- Better integration of the company's design cycle and the customers review cycle should be considered as many of the approvals and associated information are received late. When the company's design cycle has reached its peak the customer is not following in step. In fact the customers peak is closer to when physical refit begins, forcing overlap between the PCA process and refit processes. A recommendation for improved congruency could be achieved by having senior customer engineers onsite and involved in the creation of the product specification.

7 DISCUSSION

The PCA process captures customer requirements and translates them in to a tender bid. It is therefore critical that the process is efficient, in terms of resources it uses, and the products meet the processes high level goals. An improvement area that was identified as a constraint on these elements of performance, is rework. This project looked at the PCA process's information dependencies and the rework caused by the order in which they are performed. The DSM-GA performed a quantitative optimisation on the PCA process that reduced the global effect of rework by 51%. This was reduced by a further 6% during the validation stage. The DSM process models provided a rich source of information on blocks of activities that are dependent on each other. These blocks represent the key areas that should be looked at for improvement. Examples of the future improvements include better communication mechanisms and greater congruency with the supplier processes.

Application of this modelling and optimisation technique, to the PCA process, has unearthed some interesting insights. The final IDEF0 product provided realistic models that represented the activities and information requirements. However at times the process operators found it difficult to comprehend this formalism. This was due to varying levels of process decomposition and the concentration of information flows within each model. If a more structured approach had been utilised to capture the 'As-Is' process then it is believed that less time and effort would have been expended. Future projects that require IDEF0 will follow a more structured procedure. This will include, setting the context for IDEF, identifying the sub-processes and placing them into a main path. The diagram will be detailed using the 80/20 rule, i.e. 80% of information is gathered initially and the remainder at subsequent interviews. Finally the IDEF0 model will be reviewed and validated by process operators.

Verification and validation workshops were designed as control stages, to ensure the ‘As-Is’ model was a true and accurate representation of the PCA process and the optimised process was practical. Although these control points were necessary to get the desired information integrity they were time intensive. To help streamline these stages a glossary of terms and definitions was produced. In future a simple flow diagram will be created to accompany the DSM process model.

The validation workshop allowed the cross-disciplinary staff to view the whole PCA process and observe the information needs and constraints of others. This was important in allowing the company to move toward being more process focussed and allowed a consensus to be gained on what was perceived to be an optimum solution. This solution will be used in the next phase of this project. However, the number of changes made, 54, took away from the main power of the DSM i.e. quantitative optimisation of the process sequence. Future work will involve an investigation of the relationship between project size and search space.

During the validation workshop it was highlighted that some areas of the process still do not receive products or information required. For example procurement do not currently get the specification, tender schedule, quality or risk plan. However, the DSM-GA will not solve these types of issues. Future improvement initiatives will address these types of issues. This could cause a further need to optimise the process.

The next stage of this project will focus on the extraction of the optimised and validated sequence and lead to a new process that has less iteration and planned concurrency. Performance indicators will also be introduced to monitor the current and future performance of the process.

8 CONCLUSION

Information dependencies affect the order in which activities can be performed. Therefore, inappropriate sequences can cause iterative cycles and limit the process performance. This paper demonstrated a DSM-GA technique that resulted in a 57% reduction in the Scott Partitioning criterion, which indicates re-work cycles. In practical terms it is recommended that any optimised sequence be fully validated by process operators before considering implementation. It is suggested that this be done through a series of group workshops. The DSM-GA has proved useful in visualising the information relationships and resultant constraints between activities. This study recommends that process improvement could be achieved through, re-sequencing, greater congruency with the customer and streamlining of key activities.

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