Proceedings of the Operational Research Society Simulation Workshop 2012 (SW12)
B.Tjahjono, C. Heavey, S. Onggo, and D-J. van der Zee, eds.
DOI:10.13140/2.1.3260.1924

UNDERSTANDING THE IMPLICATIONS OF SERVICE CONTRACTING IN PRODUCT-SERVICE BUSINESSES

Sarocha Phumbua

Cranfield University
Manufacturing & Materials Department
sarocha.phumbua@cranfield.ac.uk

Dr. Benny Tjahjono

Cranfield University
Manufacturing & Materials Department
b.tjahjono@cranfield.ac.uk

ABSTRACT

Service contracting has been adopted in several industries especially for high value assets with long life time. Such a contract typically specifies asset usage information, availability or capability of the contracted assets required by customers, and the scope of services the manufacturers are obliged to support the assets. Consequently, such a contract imposes major risks to the manufacturers. This paper aims to explore approaches that be used to assist manufacturers to model service contracts in order to understand the risk and reward prior to committing a contract with customer. The work described in the paper involves the development of a simulation model from a case of the ship building industry. The use of the model in aiding contracting decisions is demonstrated through three experiments conducted at the case company. The outcomes have demonstrated the potential of the approaches in practice and contributed to the Product-Service Systems modelling paradigm.

Keywords: Service contract, Product-Service Systems, Simulation

1 INTRODUCTION

Original Equipment Manufacturers (OEMs) in the developed countries are facing ever increasing competition from emerging, low cost economies in Asia and eastern Europe. Competing solely on cost is no longer an option for these OEMs and even rapid development of technology still makes it difficult to sustain competitiveness on product innovation and technological superiority. Along this line, many of the OEMs now shift their business strategies and operations to include services. As delivery of services is somewhat harder to imitate (Oliva and Kallenberg, 2003), integrating services to product offerings is perceived to be a new distinctive, long-lived competitive strategy, and is 'easier to defend' from the lower cost economies (Baines et al, 2009).

Integrated offerings of product and services can be found in many cases and are usually delivered via service contracts, e.g. rental contract, pay-per-use, lease and take back (Lindahl et al, 2009). These cases have reported various success stories whereby OEMs were able to avoid unnecessary expenses through service contracts. For instance, $1.4 billion were saved over the 30 years of F/A-18 contract (Gansler and Lucyshyn, 2006), $53.4 million were saved in the F404 engine PBL agreement (AIA, 2011), and £510 million expenditure was avoided in a 10-year period ATTAC support contract (BAE Systems, 2010).

Such a contract typically specifies asset usage information, availability or capability of the contracted assets, and the scope of services proposed by customers. Based on these customer requirements, the OEMs can determine the contract charges. The OEMS are subsequently obliged to support the assets as soon as the contracts are signed.

Although the integrated offering appears to be an attractive solution, Baines et al (2007) reported that 'inexperience in setting up the pricing structure' is a major pitfall to implementation of service contracts and could lead to a catastrophic failure to the whole business. Furthermore, the OEMs need to absorb the risks which may include early termination of contract, request for contract renegotiation, overuse of asset, excessive demands, market price change and obsolescence, throughout the long-term contract period. Therefore, it is critical that the OEMs are able to assess the impacts prior to committing a service contract. Such a tool that enables the OEMs to understand the risks and rewards from the service contracts is therefore desirable.

This paper proposes a simulation approach that can be used to assist OEMs to model service contracts in order to understand and have a better visibility of the potential risks and rewards prior to committing a contract with their customers. The paper is structured as follows. Following an introduction to the context, Section 2 provides more general information of service contracting in a product-service business. Section 3 takes the ship building industry as a case study and describes service contracts in this context in detail. Section 4 discusses the simulation model followed by the experimentation in Section 5. The paper finally concludes with the discussion and some insights for future work.

2 BACKGROUND

Generally, service contracts in product-service businesses aim to guarantee availability and/or capability of assets to the customers. The assets are typically high-tech, high-value, reliability-critical that require proper maintenance services throughout their long life time. A contract may have different availability (or capability) definitions. The DocuCare service contracts define availability as the percentage of photocopier uptime within contracted hours (Xerox, 2010), whereas the Northern Line underground service contract in the city of London specifies availability as available trains in the morning (Harding and Watts, 2000). The actual level of availability (or capability) is monitored against the agreed level of availability specified in the contract. If the OEMs fail to achieve the agreed level, then the OEMs are subject to a penalty which is also predefined in the contract.

Availability and capability of assets usually depends on the asset health and the OEM's service capability. For example, an asset can be rarely available if it often fails and maintenance service engineers take long time to recover it. OEMs often can estimate the contract price structure based on this information.

In a service contract, *asset usage* or *operating conditions* are usually clearly specified. For instance, an aircraft service contract specifies that the aircrafts can fly up to 140 hours per month (BAE Systems 2010) or a photocopier service contract defines that the photocopiers will be used between 9am - 5pm (Xerox, 2010). Besides the asset usage, the scope of OEM's services must be agreed in the contracts. For example, Pratt & Whitney is responsible for supplying spare parts of CFM56-3 aero-engines to Jet2 (Pratt and Whitney, 2009), while Rolls-Royce provides spare and ground supports to RB199 engines including health monitoring capability for the UK Royal Air Force (Rolls-Royce, 2010).

3 CASE DESCRIPTION

To illustrate how modelling and simulation can be used to better understand the implications of service contracts, a case study was conducted at a ship building company. For confidentiality reason, the case company is referred to as ShipCo hereafter. The figures used and presented in the experimentation section have been normalised. Despite this, being anonymous allows the discussion of the findings to be carried out in a more openly manner without necessarily obliterating the key ideas and accuracy of results.

ShipCo operates its main business in the area of military ship building and provides through-life supports to the customers. There are three types of service contracts offering by ShipCo: *after-sales*, *leasing* and *output-based* contracts. Leasing contracts guarantee availability of ships for a long period contract (25 years), whilst after-sales and output-based contracts incorporate spares, maintenance, and technical supports at the customers' cost, and generally involves 5 years of commitment. The output-based contracts differ from the after-sale contracts as their ships are built specifically for each customer from a given set of requirements whereas those ships in the after-sale type have already been designed and made by ShipCo.

In this study, the model was developed only for the leasing-type service contract. ShipCo initiated leasing contracts approximately five years ago and estimates the risks and rewards based on the failure patterns of individual subsystems using spreadsheet. In the case that the actual cost exceeds the estimation, the company renegotiates with the customers for extra payments. ShipCo leases a fleet of ships to its customers based on an agreed available days in a month and also rents the fleet to commercial customers on a short-term basis. The payment is made on monthly basis and considered from the actual available days of a ship in relation to the agreed level. Operating condition is predefined in the forms of location in which the ships will operate, for example, 80% operating in the UK and 20% outside the UK. However, these numbers as well as the target availability level can be renegotiated during the contract delivery phase. There has been no case of early termination.

A ship is made of several heterogeneous subsystems which influence the maintenance schedule. Once maintenance is required, maintenance service engineers have the flexibility and autonomy to perform the appropriate services. The number of engineers can be adjusted in correspondence with the desired target utilisation of the ship. When the asset utilisation is low, ShipCo may have short-term contracts with commercial customers to increase ship utilisation. In case of excessive demands, the OEM may outsource service activities.

4 THE SIMULATION MODEL

Using the Agent-based Modelling paradigm, a simulation model has been developed to assist ShipCo in understanding implications of a leasing contract in terms of risks and rewards. An agent can be simple, in which its interactions with other agents can lead to different model behaviours, as well as complex where its autonomy and adaptability are embedded in decision rules. The agent-based paradigm was applied in this study due to the following reasons:

- The decision hierarchy and interactions between agents are highlighted in an agent model, which align with a key characteristic of service contracts that the manufacturer and the ships (which imply customers in this model) have their usual tasks that cannot be interfered by the others but the parties can interact on the servicing basis.
- A ship fails as a result of subsystem's condition and these subsystems have significant differences in life time and service cost. Maintenance activities are also triggered by individual subsystems. Agent structure allows these characteristics to be modelled easily.
- Staff productivity is crucial to contract performances and adaptable in this case, where the agent adaptability can potentially describe the situation.
- Composite and simple states in an agent model enable emergent events to interfere in the agent's usual function easily. For instance, a ship operates according to an operating schedule, yet, an accident can interfere in the operation and leads to an unplanned maintenance service.

The structure of the model is shown in Figure 1. In the model, a Ship agent represents asset operation during the leasing period, whilst an OEM agent provides the Ship agent (assets) with service supports. A number of Ship agents can communicate with the OEM agent to enable connections between asset operations and the OEM's maintenance/servicing activities. These two functions are independent from one another and also can co-exist without one another. However, the Ship agent's behaviour depends on its key components (represented as Part agent). Similarly, the OEM's capability to sustain the contracts is influenced by the maintenance engineers.

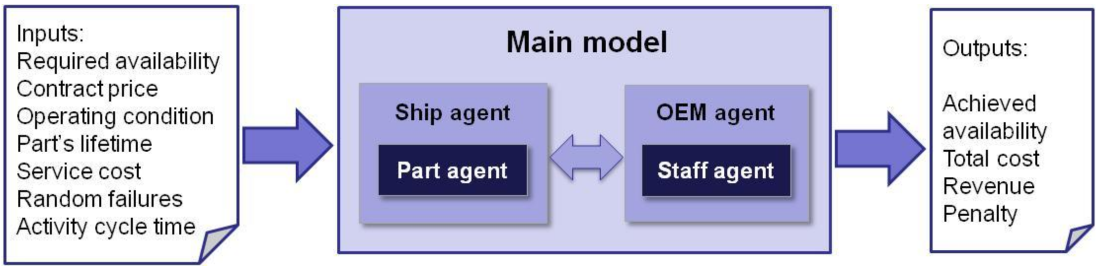


Figure 1 *Model Structure*

The actual agent-based model is implemented using Anylogic®, shown in Figure 2. Anylogic® is a multi-paradigm simulation modelling tool which enables SD, DES, and ABS to be applied simultaneously based on simple drag and drop operations. The time unit in this model is in days. The main model describes an OEM that provides ship leasing contracts. These ships can also be rented out to other customers on a short-term basis if they are not being used by the contracted customers. Users of the model can adjust the rate of occurrence of this short-term demands at any time during the model execution by moving the slider of *ST_Demand* e.g. 5 ships a day.

The ship model presents each ship's state which could be 'not ready' or 'ready' for operations, signalled by its Part agents and OEM agent respectively. Within the *Ready* state, it can be 'in operations' or 'waiting' for an operation, represented by the *Operating* and *Idle* states respectively. The composite state enables emergent events to interfere in the simple states as mention earlier. The operations are signalled by both short-term and contracted demands, hence, the two transitions to the *Operating* state. Once an operation is completed, the ship becomes Idle, triggered by a timeout transition. If not ready, the ship is assumed to be 'under service' by the OEM or subcontractor. The OEM shall outsource maintenance services if the maintenance staff are not available, therefore, the ship is triggered to *WithOther* from *WithOEM* by the OEM agent. The recovery period is estimated and input in the timeout transition inside the *WithOther* state. Upon service completion, a signal is sent from the OEM agent to transfer the ship to the *Ready* state. This model also records monthly performance of each ship in terms of *achieved availability level, cost, revenue* and *penalty,* throughout the contract. Users can interactively change the contract prices/charges, operating condition and agreed available days in a month during model execution (these changes imply contract renegotiation). It is assumed that each ship has three key components (e.g. vessels, controllers, gears), and each component has 3 replications (e.g. 3 vessels).

The spare part model looks into each Part agent's behaviour, dictated by lifetime, failures, and incurred service costs. Users can interactively change these values, implying the design changes of the ship. The ship needs maintenance if one of its components or spare parts has no remaining useful life (governed by *Schedule)* or simply fails randomly (controlled by *NonSchedule*). However, once the ship is under the maintenance service, the OEM may decide whether or not to replace other degrading parts as well. This decision, denoted as *ChangeLikelyhood,* depends on the remaining useful life of the part.

Within the OEM model, risks and rewards from signing the service contracts are monitored in terms of total service cost, revenue, and penalty. The OEM capability can also be evaluated based on the recovery performance (dictated by *Turnaround* time histogram) and the ship's state throughout the contract period. The OEM agent assigns jobs to the maintenance team with the fewest jobs in-hand. It is assumed that all the required jobs can be completed by the team. Users can adjust the number of teams during the model execution using the buttons (implying the capability of the OEMs to adjust its capacity - so called adaptive capacity).

The staff model captures the difference amongst teams of maintenance staff in terms of sequence in performing services and their levels of productivity. For the sake of simplifying the concept, only two maintenance tasks are modelled in this study. Once the team receives a job order from the OEM agent, the job is registered in *Asset*. The team can adapt their levels of productivity depending on this workload, in other words, the team can speed up the job when the baseline level is exceeded (for example, when there are more than two ships in hand). This mechanism can be captured in the timeout transitions from the two activity states, which adjust actual durations from the standard cycle times and the number of jobs in *Asset* in comparison with a baseline level (two jobs in this example). Users can also interactively change the standard activity's cycle time as required. Once completed, the ship is in a 'ready-to-work' state.

The outputs to this model are linked with the risks and rewards in the ship leasing contracts and respond to their requirements. These include monthly ship's availability, revenue, total service costs, total penalty, and recovery period. An analysis of these outputs can provide several benefits, demonstrated in the next section.

Figure 2 *ShipCo Model*

5 EXPERIMENTATION

Having built the model, it was sent to the OEM for validation. The feedback revealed its capability in capturing the issues involved in service contracts and its contribution in designing the contracts. Along with the model, three experiments were conducted and presented to the OEM as part of the validation as well as to demonstrate its practical use.

- **Experiment A** aims to illustrate the pricing provision based on the total service cost of a contract, which can be estimated from the usage requirement in the contract and product functionality. The OEM can use this information to decide appropriate pricing structure of a contract.
- **Experiment B** aims to visualise the impacts from contract renegotiation during the contract period. The OEM can use the model to understand this risk and prepare a contingency plan for it.
- **Experiment C** aims to evaluate the financial benefits of a marketing strategy. The outcome can enable the OEM to decide whether or not to employ the strategy prior to implementation.

5.1 Experiment A

This situation deals with an estimation of the potential maintenance cost of a ship, based on the usage and life information of the critical components. The ship is required to operate 70% in UK and 30% elsewhere at the price of $300000 per month for a 30-years contract term. In this example, the life-time of the three critical components are approximately 500, 800 and 1000 operations, and their associated replacement costs are estimated at $0.5 million, $1 million and $1.5 million per part per replacement respectively. The ship is expected to be available for the military customer 10 days in a month, and its initial production cost is $50 million.

To analyse this, the *OpCon* slider in the ship model was set to 0.43 (i.e. 30/70), the *ReqAvail* slider was moved to 10, the *Life* slider of the *Part1* models was set to around 500 and their *ServCost* sliders were set to around 0.5. The given values were also assigned to the *Part2* and *Part3* models. The result is shown in Figure 3.

After executing the model, the ship can be available for the 10-days availability requirement almost every month. This means the OEM can mostly recover the ship within 20 days. The accumulated cost throughout the contract becomes $12 million. The revenue has an initial negative value to account for the production cost of the ship that the OEM needs to invest under the leasing-type contract. The company starts to gain profit after 15 years and will finally achieve up to $50 million. Based on this result, the monthly contract price may also be further adjusted to obtain a desirable cash flow pattern.

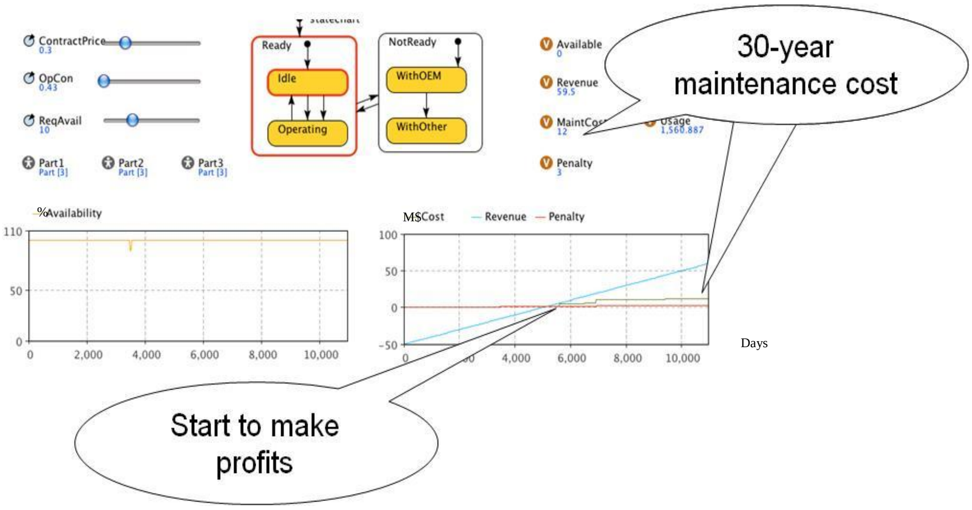


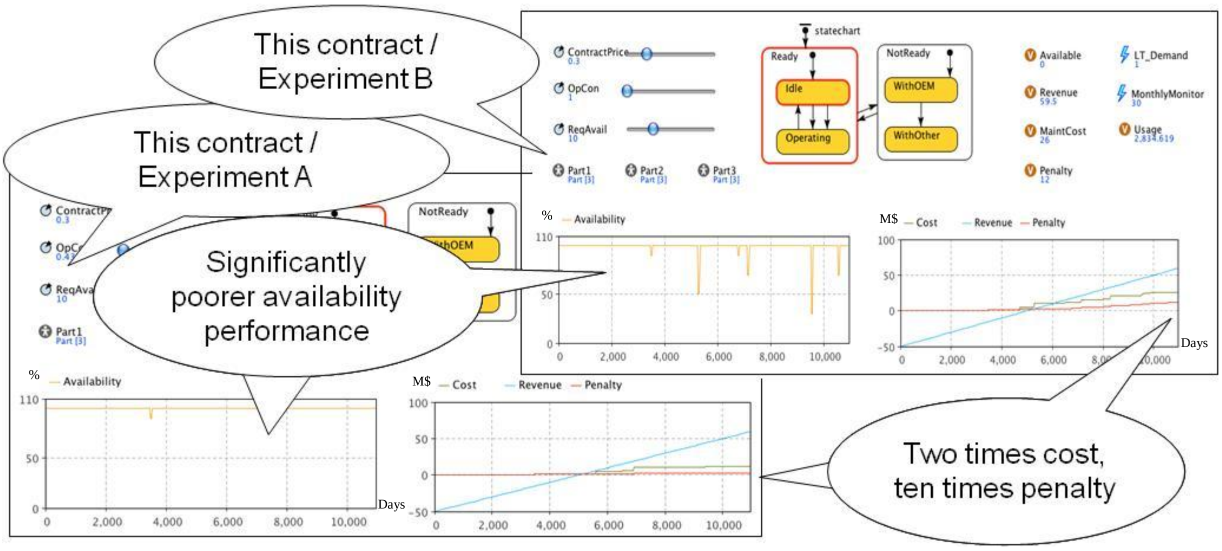
Figure 3 *The Results from Experiment A.*

5.2 Experiment B

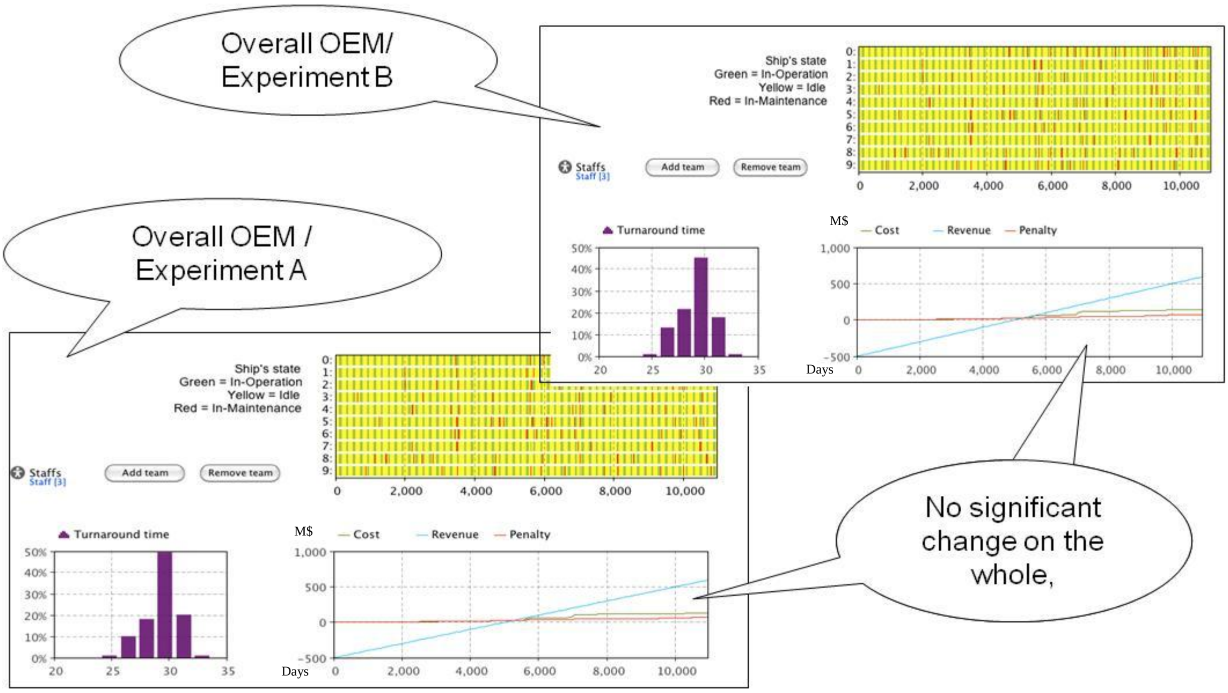
In this experiment, the OEM would like to assess the impacts if the customer will renegotiate the contract from Experiment A, e.g. to operate 50% in UK and 50% outside UK at year 11. Both experiments have 10 contracted ships.

To do this, the model was run until the simulation time reached around 4000 simulation time. Then, the model was paused and the *OpCon* slider in the ship model was changed to 1 (i.e. 50/50). The model was then continued until the end of simulation and the result was contrasted against the normal situation with no condition change (i.e. Experiment A). The outputs are shown in Figure 4.

The outputs reveal that the change can lead to a substantial poorer availability performance of this contract, double the cost and ten-time increase in penalty charge. There would be six occasions that the OEM cannot recover the ship within 20 days period. This means that subsystems are degraded significantly quicker than the original requirement. To improve the ship's availability, the OEM may need to invest in the design and development of subsystem's life so that the time between ship's failures can be extended. Alternatively, the servicing capability may need to be enhanced to shorten recovery period, for example, by recruiting and training new staff. However, the change from this contract has no significant financial impact on the OEM as a whole because the revenue from the total of 10 contracts still surpasses the risk. Therefore, the OEM might handle the renegotiation at no additional cost.



(a) Impact on Contract Performance



(b) Overall Impact on OEM

Figure 4 *The Results from Experiment B*

5.3 Experiment C

In this experiment, the OEM may evaluate if a discount of $0.1 million per month per ship can be offered to the contracted customer on the condition that the ships will be also used by other short-term customers at the rate of 5 ships per day.

To set up this experiment, the *ST_Demand* slider in the main model was set to 5, and the *ContractPrice* slider on all ship models were set to 0.2 (since the default setting is at $0.3 million). The experiment was carried out in comparison to the default setting (i.e. Experiment A) and the outcomes are presented in Figure 5.

According to Figure 5, the graph of ship's state reveals that the ship utilisation increases substantially with the addition of short-term rentals. The time plot of financial status also demonstrates that even if there is no significant revenue change but penalty and maintenance costs are rising as a result of the increase in utilisation. Thus, this offer should not be implemented unless the OEM can offer the short-term rentals at a higher price.

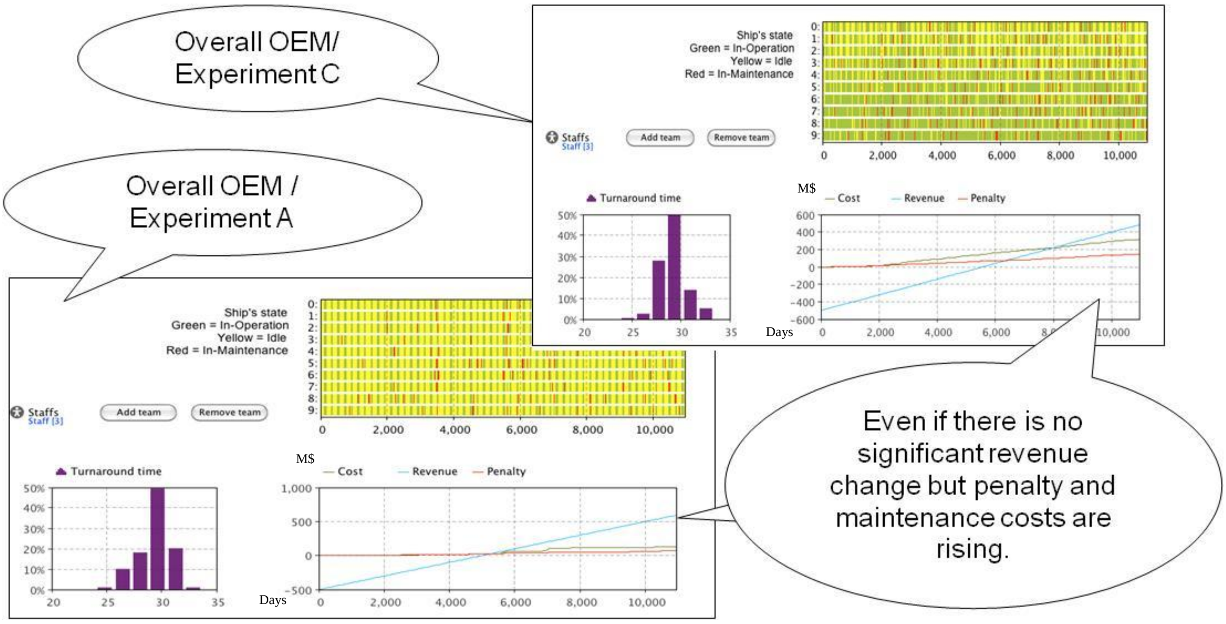


Figure 5 *The Results from Experiment C*

In addition to these examples, users can adjust other inputs which involve the number of maintenance teams, penalty cost, activity's cycle time, number of contracted ships, part's random failures, agreed available days, staff's adaptive capability, chances of opportunity fixing, the number of major components and all the uncertainties subject to these inputs.

6 DISCUSSION AND CONCLUSIONS

The purpose of this paper is to propose a simulation approach that can assist the OEMs to assess and ultimately understand the risks and rewards prior to committing a long term service contract with their customers by using a simulation model. The model is based on Agent-based Simulation and in order to demonstrate the practical implications, a case study of a ship building has been conducted. The model was subsequently built following the business scenarios at the case company.

The model consists of Ship agents, Part agents, OEM agent, and Staff agents. The Ship agents describe in-service states which relate to asset operations and maintenance, dictated by their subsystem's behaviour. The Subsystem agents encapsulate random failures and scheduled maintenance depicted by their individual failure patterns. The OEM agent captures overall contract and service performances as well as job allocation to staff while the Staff agents detail service operations. The agent structure captures OEM-customer relationship during the in-service phase via signalled message between the OEM and Ship agents. Similarly, impacts from subsystems on a ship can be investigated easily by embedding Subsystem agents inside Ship agent. Furthermore, Staff agents enable adaptive productivity, flexible capacity, and decision hierarchy within the OEM to be effectively presented. Finally, the composite state inside Ship agents allows random failures to interfere in their operations conveniently.

Three examples are presented to demonstrate how to use the model for supporting decision making. The experiments revealed the model's capability in estimating the costs based on usage and subsystem information, enabling the contract renegotiation and future provision of marketing strategy. A number of implications can be drawn in terms of the model's capability:

- Impacts of any possible risks or any deviation from the plan during the contract delivery phase can be visualised prior to committing the contractual agreement.
- The input values can be changed at any time during the model runs, thus the model can capture contract modifications as well as market sensitivity and operational changes after the contract is executed.
- Users do not need to repeat several experiments to gain more reliable results as the agents can be replicated to imply multiple experiments. In other words, additional sets of agents in the model can be added to represent different model runs.
- On the other hand, users can change the inputs (for example, availability requirements) in some Ship agents and compare the result with other Ship agents. This enables comparison between contracts to be proceeded.
- Users can visualise performances of both individual contract and the whole system simultaneously in one experiment.

Sensitivity analysis has not been conducted in this paper as the real values of inputs are not publically accessible. This means the analysis would only provide understandings of model behaviour but not contribute to a robust solution for the OEM. Therefore, it is excluded in this study. Future work can be focused on embedding techniques such as cost analysis and optimisation. Overall, the approach has been proven to successfully assist the OEM to better understand the implications of service contracts in product-service businesses.

REFERENCES

AIA (2011). *Performance-Based Logistics Award* [online]. Available from: http://www.aia-dev.org/newsroom/awards/pbl_award/ [Accessed 24th June 2011].

BAE Systems (2010). *Case Study: ATTAC (Availability Transformation: Tornado Aircraft Contract* [Online]. Available from: http://www.sanders.com/WorldwideLocations/UnitedKingdom/UKDefenceIndustrialStrategy/CaseStudies/autoGen_10721411422.html [Accessed 8th November 2010].

Baines T S, Lightfoot H W, Benedettini O and Kay J M (2009). The servitisation of manufacturing: a review of literature and reflection on future challenges. *Journal of Manufacturing Technology Management* **20(5)**: 547-567.

Baines T S, Lightfoot H W, Evans S, Neely A, Greenough R, Peppard J, Roy R, Shehab E, Braganza A, Tiwari A, Alcock J R, Angus J P, Bastl M, Cousens A, Irving P, Johnson M, Kingston J, Lockett H, Martinez V, Michele P, Tranfield D, Walton I M and Wilson H (2000). State-of-the-art in the product-service systems. *Journal of Engineering Manufacture* **221(10)**: 1543-1552.

Gansler, J S and Lucyshyn W (2006). Evaluation of Performance Based Logistics. *Research paper*, Maryland University College Park Centre for Public Policy and Private Enterprise.

Harding, A., Watts, P (2000). The Northern Line train service contract. *Proceedings of the Institute of Mechanical Engineers Part F*, In *Journal of Rail and Rapid Transit* **214(1)**: 55-60.

Lindahl M, Sakao T and Öhrwall-Rönnbäck A (2009). Business Implications of Integrated Product and Service Offerings. *Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference*. Cranfield, UK, pp 165–172.

Oliva R and Kallenberg R (2003). Managing the transition from products to services. *International Journal of Service Industry Management* **14(2)**: 160-172.

Pratt and Whitney (2009). *Pratt & Whitney and Jet2.com Gear Up for Installation of First GMS Life Limited Parts for CFM56-3 Engine* [online]. Available from: http://www.pw.utc.com/media_center/press_releases/2009/04_apr/4-23-2009_10412146.asp [Accessed 26th June 2011].

Rolls-Royce (2010). *Rolls-Royce signs £690 million contract to support UK Tornado fleet* [online]. Available from: http://www.rolls-royce.com/defence/news/2010/100407_contract_support_uk_tornado_fleet.jsp [Accessed 21st June 2011].

Xerox (2010). *Customer Service Agreement Exhibit A* [online]. Available from: www2.dir.state.tx.us/DIR_Contracts/1243454341976.pdf [Accessed 26th June 2011].

AUTHOR BIOGRAPHIES

SAROCHA PHUMBUA received a BEng (Hons) in Mechanical Engineering from Newcastle University in 2007 and an MSc (Hons) in Manufacturing System Engineering from University of Warwick in 2008. She is currently a PhD researcher at the Manufacturing & Materials Department, Cranfield University. Her PhD research concerns with simulation modelling of service contracts within the Product-Service Systems context.

BENNY TJAHJONO is a Senior Lecturer at the Manufacturing & Materials Department, School of Applied Sciences, Cranfield University. He received both MSc and PhD degrees from Cranfield. His overarching research interest is in the area of manufacturing systems modelling and simulation which also includes product and service systems modelling. He has been working closely with global companies such as Rolls-Royce, Airbus and Motorola on a number of industrial projects. He is one of the Associate Editors of the Journal of Simulation and a member of the editorial board of several journals.