A methodology for analyzing shipyard supply chains and supplier selection

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Abstract

Purpose – The purpose of this paper is to focus on shipyard supply chains in order to identify the processes that take place and evaluate the risks associated with suppliers.

Design/methodology/approach – For this analysis two methodologies are applied. The first is the understand, document, simplify, optimize, where the first two steps are used for analysing the processes and the documentation of the best practices, which take place in the daily operations. The second tool is Kraljic's matrix, which is applied for the identification of supplier selection and associated risks.

Findings – The analysis shows that strategic co-operations between shipyards suppliers are essential for improved supply chain performance since supplier improvement in terms of lead times and product quality are achieved. It is also seen that the shipyard supply chain performance can be improved by adjusting the best practices to the needs dictated each time by the project's specifications.

Practical implications – The findings provide valuable insights for practitioners, as well as academicians, policy makers and also integrate supplier selection under the supply chain. Managers can acquire reliable information about those suppliers who exhibit best practice.

Originality/value – A number of key processes and best practices have been identified, which are essential for the upstream and downstream coordination of the shipyard supply chain. The present work is an approach to evaluating the risks associated with the shipyard's suppliers and assists in benchmarking their risk profile.

Keywords Supply chain, Suppliers, Best practices, Shipyard

Paper type Research paper

1. Introduction

Supplier relationships have been extensively studied in the literature focusing on different, problems, approaches, models and applications (Anfindsen *et al.*, 2012; Lockamy, 2011). Application of supply chain management methods and strategies in the modern business world could not leave the shipyard industry indifferent. The high levels of complexity present in the manufacturing and assembly processes require respective levels of synchronization not only between the suppliers and the shipyards

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but also in the processes that take place within the shipyard itself. Studies have shown that shipyards have begun to realize that their competitiveness is dependent on the improvement of the coordination between shipyards and their suppliers (Fleischer *et al.*, 1999; Chryssolouris *et al.*, 2004) and customers (Celik *et al.*, 2009; Guneri *et al.*, 2009). Characteristic is the case of the American shipyards, which have realized the importance of application of enhanced supply chain management techniques in the improvement of their productivity (US Department of Commerce, 2001) since the early 1990s significant productivity problems had been spotted (Carson and Lamp, 1990).

Among the numerous strategies of supply chain management a significant number focus on the more specific strategies relating to supplier management. In order to achieve an effective management of suppliers, planning practices required by companies include:

- Core competencies: the company must examine whether it is capable to offer a specific product or service efficiently itself. In case someone else can manufacture more effectively and cheaper than the specific task is better to be outsourced (Lamp, 1992; Platts *et al.*, 2002).
- Identification of supplier responsibilities: suppliers' role in manufacturing has increased significantly during the last decades. The fact that more and more parts of a specific product are outsourced it is essential for suppliers to know exactly their responsibilities upon delivery (Dyer, 1996; Hines *et al.*, 1999; Marksberry, 2012). Characteristic examples in the shipyard industry are those of AVONDALE (www.northropgrumman.com) and NASSCO (www.nassco.com) companies, which use HOPEMAN BROTHERS MARINE INTERIORS (www.hopemanbrothers.com) as their main suppliers for internal decoration (Fleischer *et al.*, 1999). Another example is that of CEGELEC (www.cegelec.com) supplying shipyards with full propulsion systems, which works closely with its customers having to fulfil specific instructions (Goldan, 2001).
- Outsourcing rationalization: this practice refers to the identification of the processes that actually need to be outsourced since the rational that whatever can be outsourced should be outsourced is not effective from a management point of view. In many cases when it comes to supplier selection benchmarking is used (Anfindsen *et al.*, 2012; Lockamy, 2011). Depending on the nature of the product and the production stage, outsourcing decisions vary. FINCANTIERI (www.fincantieri.it) and NASSCO shipyards are two such examples, with the former having three main supplier categories depending on the level of contribution to their profits and the risk related to supplier delivery reliability, and the latter having two main suppliers for wood and insulation (Stable, 1993).
- Long-term strategic alliances with suppliers: long-term relationships refer to periods of at least three years in the case of shipyards. This type of alliance is created between manufacturers and suppliers when the latter provide key components of a product, as is the case of NASSCO shipyards with HOPEMAN BROTHERS MARINE INTERIORS. A number of risk assessment and other collaboration methodologies are present in the literature to address similar type of problems across industries (Ramanathan *et al.*, 2011; Ganguly and Guin, 2013).

The aim of this paper is twofold. First to understand and document the supply chain processes that take place within the shipyard industry, which is achieved via the understand, document, simplify, optimize (UDSO) methodology (Watson, 1994) and,

second, to identify supplier selection and associated risks, which is achieved with the assistance of Kraljic's (1983) matrix. According to Kraljic (1983) supplier selection should be based on the importance of purchasing profit impact and complexity of supply market (supply risk) in order to avoid materials disruptions (Gelderman and Van Weele, 2003).

In order to understand the nature and operations of the shipyard industry a series of unstructured interviews took place during the last quarter of 2008 and the first quarter of 2009 with three managers having higher management positions from each of the two biggest Greek shipyards. In these in depth interviews the mapping of the processes (presented in Section 2) and best supply chain practices (illustrated in Section 3) have been discussed and analysed followed by an effort to make a risk assessment of the latter. In order to achieve supplier risk evaluation Kraljic's (1983) matrix is used in Section 4 where the different supply chain practices are categorized. Finally, conclusions and recommendations for further research are made.

2. Understanding and documenting the shipyard supply chain processes

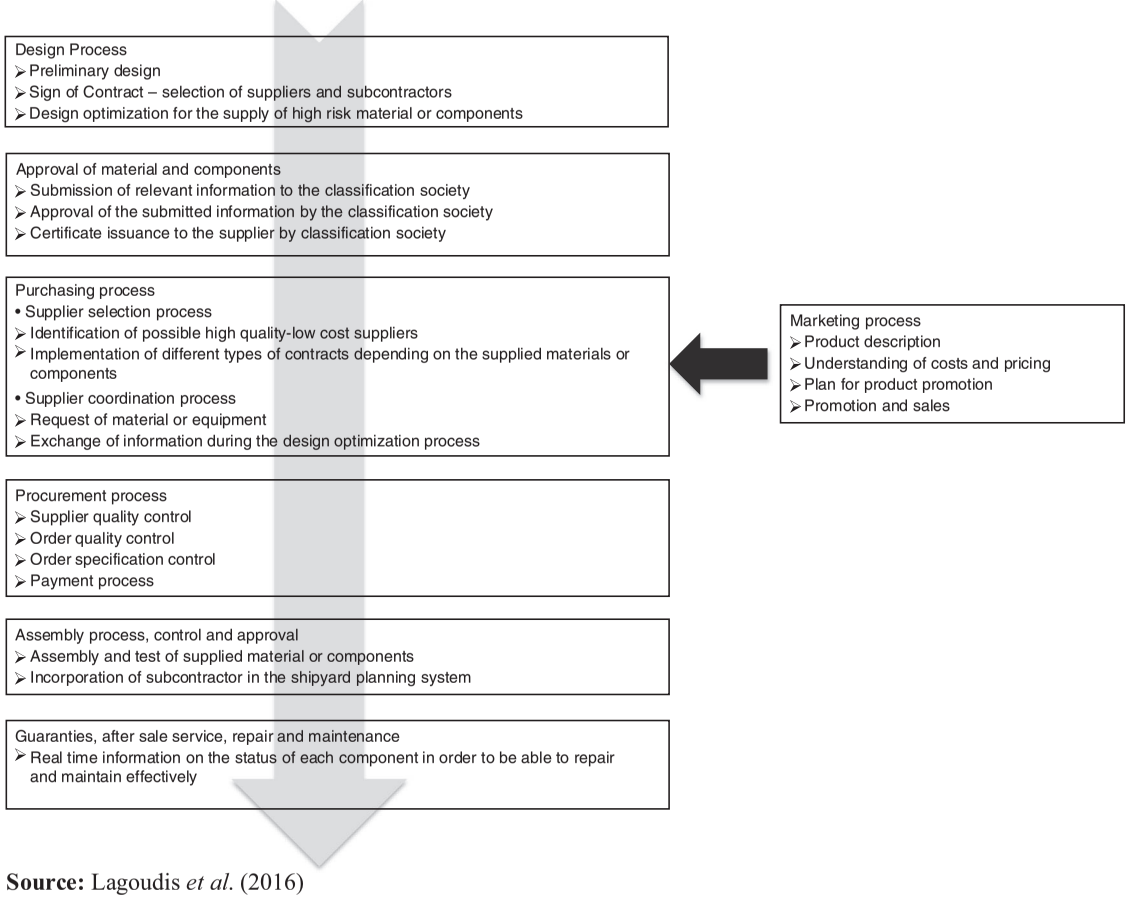
An overview of the main processes that take place in a shipyard supply chain is presented in Figure 1, based on the interviews with the higher management of the two Greek shipyards. As seen, the first step is the preliminary design of the vessel, which takes place upon request by a shipping management company. At this stage the vessel specifications are described and an initial estimate on the construction cost is provided based on at the time available information on steel and other basic material and equipment prices.

Once the contract has been signed between the shipyard and the shipping management company the purchase process follows. This includes the selection of the required material and equipment, suppliers and subcontractors necessary for the project. Orders are placed once the final specifications have been determined. Suppliers needs customize these types of supplies to the shipyard's needs, as they must meet specific customer requirements. This implies that design refinement is needed. The design refinement process begins once the first specifications are sent to the subcontractor and it ends upon the delivery of the project to the shipping management company.

Moving onto the material and equipment approval, it is seen that the role of the classification society is significant. Initially the supplier officially informs the classification society on the material and equipment it is planning to use during the manufacturing process. Once the classification society examines the relevant documents it approves or not the relevant information along with the processes that need to be followed during construction. Finally, a certificate is issued to the supplier after all possible amendments or changes to the initially proposed processes are approved, which is valid for five years. The classification society enlists the specific product in the qualified products list and then the suppliers can proceed to its production.

Purchasing is linked to two very important processes; supplier selection and supplier coordination. The former process takes place prior to the ordering of any material or components whereas the latter takes place during the product development stages. Supplier selection is not an easy task since shipyards must be as certain as possible that their suppliers and subcontractors meet their standards. It must be mentioned here that marketing is essential for suppliers who develop new products or improve existing ones. As seen in Figure 1, among the key processes that take place and are essential for their success are product description, costing and pricing, planning product promotion and finally promotion and sales.

Figure 1.
Shipyard supply chain processes



Source: Lagoudis *et al.* (2016)

Depending on the importance of the component, suppliers in most cases are categorized in high and low risk. Low-risk supplies are mainly those for which long-term relationships are established and orders are placed over the phone. In the case of high-risk supplies better coordination is required since tailor made products are supplied and thus in many cases benchmarking between different suppliers and subcontractors takes place.

It is worth pointing out here that the need for better coordination which leads to greater supply chain efficiency leads to market consolidation which is its turn is a significant threat to suppliers. Coordination is achieved much easier in cases where the needed material or components are standardized (low risk) and more hideous in the case of customized solutions (high risk). In the former case KANBAN systems can be used supported by EDI application, as is the case in the car industry (Womack and Jones, 1996a). In the latter case standardized processes are not applicable since novel projects are developed where the exchange of ideas is continuous and processes have to be specified, especially at the early stages of the development. Once a maturity level has been achieved then more standardized communication and coordination tools can be used.

Procurement processes are related to the quality standards that shipyards impose to their suppliers. Shipyards upon delivery of the ordered materials or components test and control the quality of the received items. A number of available technologies, where feasible, are used in order to make these processes easier and more efficient, such as bar code and EDI. Once the quality process is completed then the payment of the supplier may proceed.

Assembly is a process that takes place less and less at the shipyards. Today shipyards order bigger components of a project from their suppliers, which are delivered preassembled at the final assembly location, the shipyard. The subcontractors are responsible for the initial quality control of the ordered component, which requires a better coordination and higher levels of integration of the supplier in the supply chain. This integration can be achieved via common integrated product teams between the shipyard and the subcontractor.

Finally, the guaranties provided and the after sales service, are essential processes for shipyard supply chains. It is pointed out that, when real time information on the status of the different components of a vessel exists, maintenance costs decrease significantly (Wurst *et al.*, 2002).

3. Documenting the shipyard supply chain best practices

Many different broad supply chain strategies are available in the supply chain management literature (Naylor *et al.*, 1999; Fisher, 1997). Here a more focused to the supplier selection approach is taken differentiating from the literature. From the discussions with the higher management of the two biggest shipyards in Greece the nine most commonly used practices related to supplier selection and cooperation are presented here (see also Table I). These are:

- product standardization;
- integrated product teams;
- lowest total cost;
- supplier training;
- supplier improvement;

Best practice	Description	Expected value
Product standardization	Aims at the highest possible level of standardization on supplied material and components in order to minimize the number of suppliers and orders	Low operating cost due to economies of scale achieved
Integrated product teams	Aims at the best coordination between the shipyard and suppliers for waste minimization	Improvement of product quality and cost minimization due to the significant decrease in defect orders
Lowest total cost	Aims at the selection of the cheapest supplier based on the overall supply chain performance and not on the best market price	Long-term cooperation with suppliers offering high quality and low cost
Supplier training	Aims at the long-life training of suppliers to achieve higher product performance	Better understanding of the processes followed for all parties involved
Supplier improvement	Aims at the creation of long-term contracts where long-term plans and improvement goals are set	Continuous improvement of product and service quality along with price decrease
New supplier development	Focuses on the creation of new supportive businesses by the shipyard or jointly with suppliers	Customer satisfaction via the use of low-cost – high-quality suppliers
Supplier inventory management	The goal is to keep inventory at the suppliers' site	Inventory cost minimization
Turnkey suppliers	The supplier assembles a component on behalf of the shipyards	Better synchronization between shipyard and supplier
Supplier integration	The supplier is informed on the production process having access to the shipyard data	Low inventory levels and inventory cost minimization

Source: Lagoudis *et al.* (2016)

Table I.
Description of shipyard supply chain best practices

- new supplier development;
- supplier inventory management;
- turnkey suppliers; and
- supplier integration.

As seen in Table I there is an expected value out of each of these best practices identified by the interviewed experts. It must be pointed out here that the nine best practices along with the respective expected value of each of these practices has been the outcome of consensus among the higher management staff of the two participating shipyards. The same stands for the results discussed in the text that follows along with those presented in Table II.

Product standardization

With shipyard market cooperation in recent years high levels of standardization are achieved enabling economies of scale and low production costs. As seen in Table II, this best practice is enabled by the guaranties provided by the suppliers making the customer-supplier relationships stronger since long-term relationships are enabled. Characteristic is the example of European Share International Purchasing, where four European shipyards participate, namely, AESA (Spain), CDA (France), HDW (Germany) and FINCANTIERI (Italy), aiming at the exchange of ideas in different production and marker issues (Stable, 1993).

Processes best practice	Approval of material and components	Supplier selection	Supplier coordination	Procurement	Assembly, control, approval	Guaranties, after sale service, repair and maintenance
Product standardization			☑			☑
Integrated product teams	☑	☑			☑	
Lowest total cost			☑			
Supplier training	☑	☑			☑	
Supplier improvement		☑	☑		☑	
New supplier development		☑		☑	☑	
Supplier inventory management			☑	☑		
Turnkey suppliers		☑		☑		
Supplier integration				☑		

Source: Lagoudis *et al.* (2016)

Table II.
Relationship between supply chain processes and best practices

Integrated product teams

These groups are formed from employees originating from both the shipyard and the suppliers, aiming at process and production optimization and the minimization of defective items, which usually cause delays. The close cooperation between the two facilitates the selection of the most appropriate material for the project and of course of the supplier who can deliver the requested product (see Table II). Characteristic example is the case of AVONDALE shipyards, which working together with suppliers such as INTERGRAPH (www.intergraph.com), BATH IRON WORKS (www.gdbiw.com) and HUGHES (www.hughes.com), produced the LPD17 project based on requirements and specifications dictated by the US navy.

Lowest total cost

Total cost refers to the materials, components and processes involved in a specific supply chain. Thus companies select their suppliers not on the basis of lowest market price but on the basis of lowest supply chain cost. Within these costs, apart from the manufacturing cost, other costs are included which stem from delays, excess inventories, defects, etc. The elimination of such wastes is achieved via the continuous coordination with the suppliers, as presented in Table II, where the processes are designed and evaluated at frequent time intervals. HOPEMAN BROTHERS MARINE INTERIORS and CEGELEC have adopted the above philosophy offering the lowest possible total cost to their customers.

Supplier training

The continuous training many companies offer to their suppliers strengthens supplier service improvement, which relates to product quality and service time.

As seen in Table II among the processes that are assisted with the specific best practice are supplier selection since suppliers are continuously evaluated, material and component approval, supplier selection and approval and control of assembly. This training encapsulates a range of issues depending on the nature of the product and the industry. In the shipyard industry the example of FINCANTIERI shipyards offering free training on the CAD software package to its suppliers is among the most characteristic one. Another example is the case of ODENSE shipyards (www.oss.dk), which train their supplier in a number of processes ranging from design to product development.

Supplier improvement

This practice involves the continuous improvement of suppliers in terms of product quality, lead times and costs dictated by manufacturing companies. Customers with whom suppliers are obliged to comply with usually set these targets. Nevertheless as we move towards supply chain integration these targets are discussed, set and adjusted by both customers and suppliers aiming at meeting overall supply chain efficiency and effectiveness goals. In this case the processes of supplier selection, coordination and assembly control and approval are included (Table II). Such examples are not broadly present in the shipyard industry, since the majority of the projects are unique and mass production practices present in other industries, such as the car industry (Womack and Jones, 1996b), are not met.

New supplier development

In cases where suppliers are not responsive enough or offer services of poor quality, companies are forced to find alternative solutions, which are either the replacement with a new supplier or the creation of new suppliers. As seen in Table II, apart from supplier selection, procurement processes are also taken into account under this best practice. In the shipyard industry, FINCANTIERI has managed to merge the efforts of two suppliers, each one focusing on the construction of different parts of the accommodations, into one. Additional examples are NASSCO shipyards, which manage to preassemble 75 per cent of the components via its subsidiary ILLINOIS MARINE TOWING (www.imtowing.com) and ODENSE shipyards, which have created a new supplier base via subsidiaries in countries where production costs are lower such as the Baltic area.

Supplier inventory management

One of the modern practices adopted by many supply chains is inventory postponement. Players in a supply chain aim at positioning inventory at strategic locations in the supply chain depending on the nature of the product (Pagh and Cooper, 1998). Shipbuilding belongs to the buy-to-order supply chain category (Hoekstra and Romme, 1992), since it refers to customized mainly projects, with low standardization levels inventory being kept at the supplier side close to the shipyards. Supplier inventory management is achieved via continuous cooperation with the shipyard enabling higher levels of coordination and improved procurement performances (Table II).

Turnkey suppliers

This type of suppliers work closely with their customers supporting in reality the daily operations since they supply components which are ready for assembly when arriving at the factory. High levels of coordination and well-designed procurement processes are

needed here in order to avoid delays in the assembly process (Table II). Such relationships are widely present in the car industry (Fredriksson, 2002). In the shipyard industry, FINCANTIERI shipyards use turkey suppliers in many cruise ship components such as kitchen appliances and even theatres hulls.

Supplier integration

Supplier integration is essential in supply chain efficiency thus companies that adopt that philosophy aim at synchronizing as many parts of the chain as possible. This is achieved either by direct control (vertical integration) or indirectly, via closer cooperation with suppliers and customers. Procurement is highly facilitated and optimized when suppliers are integrated at high levels (Table II). NASSCO shipyards adopt this philosophy having close cooperation with HOPEMAN BROTHERS MARINE INTERIORS and DSEC, a subsidiary of Daewoo Shipbuilding and Marine Engineering, to the extent that these two suppliers are part of the company since NASSCO shipyards organize the total of the production. FINCANTIERI shipyards also adopt the same philosophy at the late stages of production of cruise ships.

In order to obtain a more complete overview of how best practices are applied in the different processes in the shipyard industry, as identified in this paper, Table II matches these processes followed with the best practices adopted. As seen, best practices can be used in more than one process, as are the cases of integrated product teams, supplier training and others.

4. Supplier selection and associated risk analysis

Moving forward from the documentation of the business processes and the best practices used in the shipyard industry, the next step is the examination of the supplier selection processes used and the evaluation of suppliers based on the associated risks. As already mentioned, for the purposes of this paper Kraljic's (1983) matrix is used for this analysis (Table III). Prior to the analysis, a brief presentation of Kraljic's methodology is given.

Kraljic (1983) defines four main categories via the relation of profit impact with supply risk:

(1) High-profit material: refers to standardized components, which are provided by suppliers at low cost and are of high quality (i.e. diesel generator sets, deck cranes). These components are not so critical to the products' quality since they are of standard format and quality. The high levels of standardization are enabled by the limited need of specialized know-how enabling order optimization.

Profit impact	High	High-profit material	Strategic material
		Low-cost material	High-cost material
		Many suppliers	Few suppliers
		Order optimization	Accurate forecasting
			Long-term supplier agreements
	Low	Non-critical material	Low-cost – high-risk material
		Low-cost material	High-cost material
		Few suppliers	Few suppliers
		Order standardization	
		Low	High
		Supply risk	

Sources: Kraljic (1983), Gelderman and Van Weele (2003)

Table III.
Kraljic's matrix

(2) Strategic material: these are usually turnkey systems such as main engines and bridge components. These are materials or components, which offer significant degree of diversification to the final product since they are customized based on the needs of the customers. They are characterized by high production costs, there are few suppliers and affect significantly the overall product quality. On-time delivery is imperative, thus long-term relations are essential.

(3) Non-critical material: these are products of mass production used in all types of vessels such as water pumps. The high degree of standardization dictates for limited number of suppliers who can supply standard quality and on-time delivery.

(4) Low-cost – high-risk material: in this category suppliers related to materials or components that are of low cost but associated with high risk due to their importance in the product's operation/performance. Such an example is the propeller, the inefficient management of which in the production process could increase the manufacturing cost and the delay of delivery to the customer.

Having in mind the analysis of the best practices in the shipyard industry and Karljic's methodology, these are categorized with the assistance of the experts from the two Greek shipyards, as presented in Table IV. Material and component categorization can assist in the creation of value for the shipyard industry since it enables the identification of value adding activities (best practices) associated with the risks involved stemming from delivery times.

As seen, product standardization fits to the three out of four of Karljic's categories; high-profit material, non-critical material and low-cost – high-risk material. The type, and quality of the product along with the supplier's service characteristics determine the box where the specific best practice lies each time. Integrated product teams best practice in used to minimize the supplier delivery risk. Thus it falls in the strategic and high-risk material boxes as any delays can have significant associated costs. Lowest total cost is applicable in all cases with the exception of non-critical material where there are no significant implications from inconsistent suppliers. Supplier training, new supplier development and turnkey suppliers are practices of most strategic importance for the shipyard, as according to the interviewees are those that can lead to significantly improved performance of the shipyard. Supplier improvement is also of significant importance to the shipyard as according to the experts is positioned in the

Profit impact	High	High-profit material Product standardization Lowest total cost Supplier inventory management Supplier integration	Strategic material Integrated product teams Lowest total cost Supplier training Supplier improvement New supplier development Turnkey suppliers
	Low	Non-critical material Product standardization Supplier inventory management Supplier integration	Low-cost – high-risk material Product standardization Integrated product teams Lowest total cost Supplier improvement
		Low Supply risk	High

Table IV.
Categorization of best practices based on Karljic's matrix

strategic and high-risk categories. As mentioned in the previous sections the continuous supplier improvement is achieved via the periodical evaluation of processes and procedures in product development and delivery, which is made via the close cooperation with the shipyard. Finally, supplier inventory management and supplier integration are applied in low supply risk cases but can have either high- or low-profit impact according to the experts. In both cases of supplier inventory management and supplier integration, it is the characteristics of the supplied products that mainly determine the profit impact. They consider that both practices are important for the shipyard and in cases where the profit impact is higher the coordination between the shipyard and the suppliers needs to be closer.

In general, the analysis shows that even though some supply chain best practices are more appropriate for certain types of materials and components (i.e. supplier training, turnkey suppliers and new supplier development), many of those fit in more than one categories of Karljic's matrix. This leads to the conclusion that shipyard supply chains need to be adaptive and respond to market and customer needs depending on the project assigned.

5. Conclusions

The shipyard industry is characterized by the complexity of operations and processes that take place, which makes the need for close cooperation, both upstream and downstream the supply chain, imperative in order to meet the needs of different customers. This paper tackles the problem of shipyard supply chain management aiming at the identification of the processes and best practices, which take place at the shipyard industry and are essential for the upstream and downstream coordination of the shipyard supply chain.

This has been achieved via the analysis and documentation of the process and the identification of best practices, with the assistance of the first two steps of the UDSO methodology and their categorization in terms of associated risk with the assistance of Kraljic's (1983) matrix. Two parameters are used for this evaluation, profit impact and supply risk.

The shipyard industry is characterized by the complexity of operations and processes that take place, which makes the need for close cooperation, both upstream and downstream the supply chain, imperative in order to meet the needs of different customers. A number of key processes and best practices have been identified, which are essential for the upstream and downstream coordination of the shipyard supply chain. In the former case the processes of: approval of material and components; marketing; supplier selection; supplier coordination; procurement; assembly, control, approval; and guaranties, after sale service, repair and maintenance have been identified, whereas in the latter case the best practices of: product standardization; integrated product teams; lowest total cost; supplier training; supplier improvement; new supplier development; supplier inventory management; turnkey suppliers; and supplier integration have been documented.

The analysis of both the processes and best practices has shown that strategic co-operations between shipyards' suppliers and customers are essential for improved supply chain performance since supplier improvement in terms of lead times and product quality are achieved. Based on material categorization conceptualized with the assistance of Kraljic's (1983) matrix, it is seen that the shipyard supply chain performance can be improved by adjusting the best practices to the needs dictated each time by the project's specifications. Despite the fact that some practices are more

appropriate for certain types of materials and components (i.e. supplier training, turnkey suppliers and new supplier development), many of those fit in more than one categories of the matrix used here.

Future research may focus on more in depth evaluation of the processes documented in this study and examine the value these add to the entire supply chain. Such an evaluation can be achieved via business process re-engineering, which may enable a more detailed mapping of those processes and practices that add value to the chain and those that are considered as waste. Such an approach can assist in the complete application of the UDSO methodology since the simplification and optimization stages will be implemented leading to the improvement of shipyard supply chains.

References

Anfindsen, O.J., Løvoll, G. and Mestl, T. (2012), "Benchmarking of marine bunker fuel suppliers: the good, the bad, the ugly", *Benchmarking: An International Journal*, Vol. 19 No. 1, pp. 109-125.

Carson, J.P. and Lamp, B. (1990), "US commercial shipbuilding in the 1990s: the global context", *Marine Technology*, Vol. 27 No. 6, pp. 387-400.

Celik, M., Kahraman, C., Cebi, S. and Er, I.D. (2009), "Fuzzy axiomatic design-based performance evaluation model for docking facilities in shipbuilding industry: the case of Turkish shipyards", *Expert Systems with Applications*, Vol. 36 No. 1, pp. 599-615.

Chryssolouris, G., Makris, S., Xanthakis, V. and Mourtzis, D. (2004), "Towards the internet-based supply chain management for the ship repair industry", *International Journal of Computer Integrated Manufacturing*, Vol. 17 No. 1, pp. 45-57.

Dyer, J.H. (1996), "How Chrysler created an American Keiretsu", *Harvard Business Review*, Vol. 74 No. 4, pp. 42-56.

Fisher, M. (1997), "What is the right supply chain for your product?", *Harvard Business Review*, Vol. 75 No. 2, pp. 105-116.

Fleischer, M., Kohler, R., Lamb, T. and Bongiorni, H.B. (1999), "Marine supply chain management", *Journal of Ship Production*, Vol. 15 No. 4, pp. 233-252.

Fredriksson, P. (2002), "Modular assembly in the car industry – an analysis of organizational forms' influence on performance", *European Journal of Purchasing & Supply Management*, Vol. 8 No. 4, pp. 221-233.

Ganguly, K.K. and Guin, K.K. (2013), "A fuzzy AHP approach for inbound supply risk assessment", *Benchmarking: An International Journal*, Vol. 20 No. 1, pp. 129-146.

Gelderman, C.J. and Van Weele, A.J. (2003), "Handling measurement issues and strategic directions in Kraljic's purchasing portfolio model", *Journal of Purchasing & Supply Management*, Vol. 9 Nos 5/6, pp. 207-216.

Goldan, M. (2001), "European maritime research: objectives, organization, content, and parallels with the NSRP programs", *Journal of Ship Production*, Vol. 17 No. 3, pp. 119-129.

Guneri, A.F., Cengiz, M. and Seker, S. (2009), "A fuzzy ANP approach to shipyard location selection", *Expert Systems with Applications*, Vol. 36 No. 4, pp. 7992-7999.

Hines, P., Rich, N. and Esain, A. (1999), "Value stream mapping: a distribution industry application", *Benchmarking: An International Journal*, Vol. 6 No. 1, pp. 60-77.

Hoekstra, S. and Romme, J. (1992), *Integral Logistics Structure*, McGraw-Hill, London.

Kraljic, P. (1983), "Purchasing must become supply management", *Harvard Business Review*, Vol. 61 No. 5, pp. 109-117.

Lagoudis, I.N., Vlachakis, N., Mihiotis, A. and Pappis, C.P. (2016), "A methodology for analyzing shipyard supply chains and supplier selection", *Benchmarking: An International Journal*, Vol. 23 No. 2, pp. 1-14.

Lamp, T. (1992), "Organization theory and shipbuilding: a brief overview", *Marine Technology*, Vol. 29 No. 2, pp. 71-83.

Lockamy, A. III (2011), "Benchmarking supplier risks using Bayesian networks", *Benchmarking: An International Journal*, Vol. 18 No. 3, pp. 409-427.

Marksberry, P. (2012), "Investigating 'the way' for Toyota suppliers: a quantitative outlook on Toyota's replicating efforts for supplier development", *Benchmarking: An International Journal*, Vol. 19 No. 2, pp. 277-298.

Naylor, J.B., Naim, M.M. and Berry, D. (1999), "Leagility: interfacing the lean and agile manufacturing paradigms in the total supply chain", *International Journal of Production Economics*, Vol. 62 Nos 1/2, pp. 107-118.

Pagh, D.P. and Cooper, M.C. (1998), "Supply chain postponement and speculation strategies: how to choose the right strategy", *Journal of Business Logistics*, Vol. 19 No. 2, pp. 13-33.

Platts, K.W., Probert, D.R. and Cáñez, L. (2002), "Make vs buy decisions: a process incorporating multi-attribute decision-making", *International Journal of Production Economics*, Vol. 77 No. 3, pp. 247-257.

Ramanathan, U., Gunasekaran, A. and Subramanian, N. (2011), "Supply chain collaboration performance metrics: a conceptual framework", *Benchmarking: An International Journal*, Vol. 18 No. 6, pp. 856-872.

Stable, S.D. (1993), "Shipbuilding's supplier base: outlook for the 90's and beyond", *Marine Technology*, Vol. 30 No. 3, pp. 148-152.

US Department of Commerce (2001), "National Security Assessment of the US Shipbuilding and Repair Industry", Study, available at: www.bis.doc.gov/defenseindustrialbaseprograms/osies/defmarketresearchrpts/shipbuilding_and_repair.pdf (accessed 20 September 2012).

Watson, G.H. (1994), *Business Systems Engineering: Managing Breakthrough Changes for Productivity and Profit*, John Wiley & Sons, New York, NY.

Womack, J.P. and Jones, D.T. (1996a), *Lean Thinking*, Simon and Schuster, New York, NY.

Womack, J.P. and Jones, D.T. (1996b), "Beyond Toyota: how to root out waste and pursue perfection", *Harvard Business Review*, Vol. 74 No. 5, pp. 140-158.

Wurst, S., Brodda, J., Pradillion, J.-Y. and Wheeler, R. (2002), "Shipbuilding Information Society Technology (IST) review I", WONDERMAR II project report.

Further reading

Bemelmans, J., Voordijk, H. and Vos, B. (2013), "Designing a tool for an effective assessment of purchasing maturity in construction", *Benchmarking: An International Journal*, Vol. 20 No. 3, pp. 342-361.

Punniyamoorty, M., Mathiyalagan, P. and Lakshmi, G. (2012), "A combined application of structural equation modeling (SEM) and analytic hierarchy process (AHP) in supplier selection", *Benchmarking: An International Journal*, Vol. 19 No. 1, pp. 70-92.

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