A hybrid systems approach to determine effective factors on the growth of marine industries in developing countries

Shahdad Eshaghpour,
Seyed Hossein Hosseini* and
Seyed Amir Aghaei

Model-Based Management Systems Engineering Institute (SAMAM),
Tehran, Iran
Email: sh.eshaghpour@samamsystem.com
Email: s.h.hosseini@samamsystem.com
Email: s.a.aghaei@samamsystem.com
*Corresponding author

Mohammad Saeed Seif

Marine Engineering Research Center,
Faculty of Mechanical Engineering,
Sharif University of Technology,
Tehran, Iran
Email: seif@sharif.edu

Abstract: Marine industries have always been provided power and development for countries both militarily and economically. Due to the lack of essential economic, industrial, and technological infrastructure in developing countries, the development of marine industries has been facing serious obstacles. As a developing country, Iran has been tackling similar barriers. This paper aims at developing a conceptual model, to examine this complex problem, using a systems approach by which subsystems and casual loop diagrams have been created. Afterward, DEMATEL technique has been used, revealing the most effective variables. The research can remarkably help practitioners in appropriate recognition and investigation of marine industry development challenges. The results show that 'domestic supply chain development', 'special rights and benefits for employees', 'increase in manpower efficiency', 'domestic demand absorption', 'low-interest loans with suitable guaranties', and 'effective and integrated management' are the key factors and main issues in marine industry progress in developing countries.

Keywords: systems approach; marine industries; technology; DEMATEL; casual loops diagram; developing countries.

Reference to this paper should be made as follows: Eshaghpour, S., Hosseini, S.H., Aghaei, S.A. and Seif, M.S. (2021) 'A hybrid systems approach to determine effective factors on the growth of marine industries in developing countries', *Int. J. Business and Systems Research*, Vol. 15, No. 1, pp.124–142.

Biographical notes: Shahdad Eshaghpour received his MSc in Industrial Engineering from the Islamic Azad University, Tehran, Iran. His research interests are in system dynamics modelling, strategic planning, and marine industry development.

Seyed Hossein Hosseini received his PhD in Industrial Engineering in Socio-Economic Systems from the School of Industrial and Systems Engineering, University of Tehran (UT), Tehran, Iran. He is currently the CEO of Model-based Management Systems Engineering Institute (SAMAM) which focuses on research (and business consulting) and training by system dynamics modelling. His research interests are in system dynamics modelling, socio-economic systems engineering, strategic planning and policy research, and model-based policy research.

Seyed Amir Aghaei received his MSc in Control Engineering from the Amirkabir University of Technology, Tehran, Iran. His research interests are in strategic planning, and public policy research.

Mohammad Saeed Seif is an Associate Professor of the Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran. He is now the Head of the Marine Engineering Research Center. His research interests are in mechanical engineering, marine engineering, marine industry development, and strategic analysis of marine industries.

1 Introduction

Nowadays, the marine industry has decisive rule for the countries in which water way is available. Due to the large amount of required investment in this industry and high level of rate of return on investment, marine industry is known as one of strategic industries and its development will results in commercial and even military superiority (Bax et al., 2003).

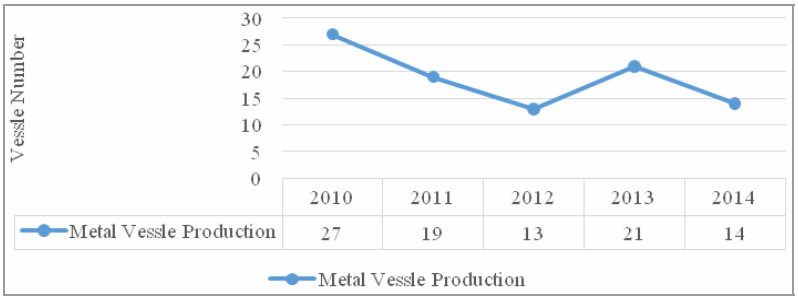
The marine industry in developed countries has strategic and action plans, so appropriate results are achieved up to now. For example, marine industry in China, performing its 11th five year strategic plan, during the recent ten years has had remarkable growth. The applied containers in China ports in 2011 reached to more than one hundred million units and also have 26% container operations of the world. Throughput of cargo and shipping in China during the five years before 2012 with an annual growth rate of 35% is ranked as the first in the world (Xiang, 2010). Data released by the British shipbuilding analysis agency (Clarkson Research Services) shows that in 2017, China took the first place in three indexes measuring the development and capacity of a country's shipbuilding industry: the completion of ships, new orders, and volume of holding orders (China Leads in Shipbuilding, 2018). But new research predict that China will lose advantage in the global market (Hwang and Park, 2018).

However, some developing countries, despite having considerable experience in marine industry and qualified geographical position, have not had acceptable performance. For example, Iran has sufficient experience in marine industry. This country started the completion race with the ones which are among the best in this scope

such as South Korea, but analysing the performance of Iran in marine industry implies serious problems. Whereas the other similar countries could reach a significant position in the global market.

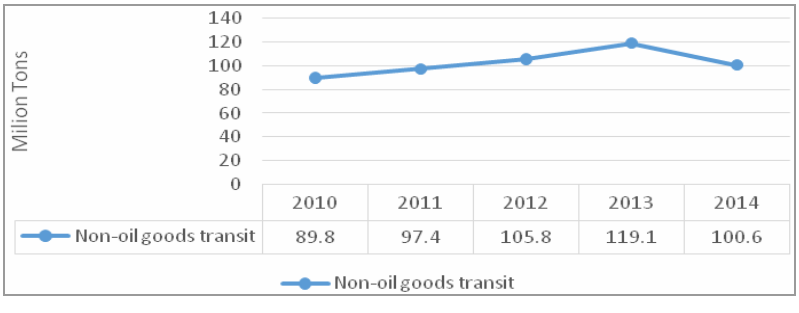
According to Figure 1, total number of metal vessel is decreasing; in contrast, based on Figure 2, the amount of non-oil goods is increasing simultaneously.

Figure 1 Iran's metal vessels production (see online version for colours)



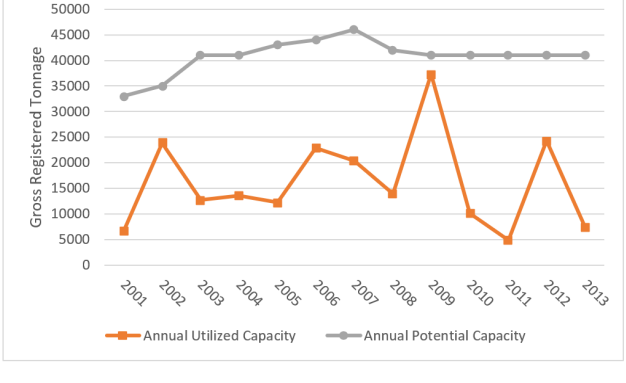
Source: Safargholi et al. (2017)

Figure 2 Iran's non-oil goods transit (see online version for colours)



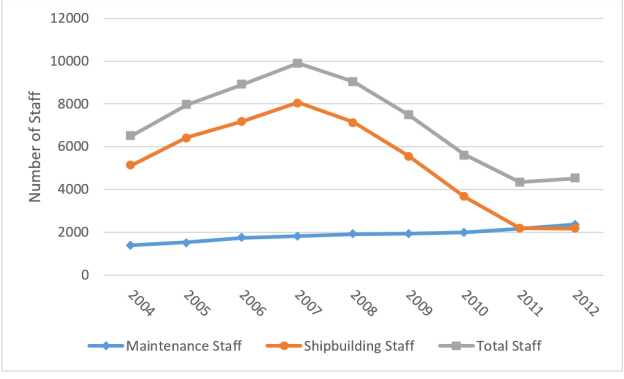
Source: Safargholi et al. (2017)

Figure 3 The total gross tonnage of vessels with an average size in recent years (see online version for colours)



Source: Overview of the Shipbuilding and Maintenance in Iran (2014)

Figure 4 Shipbuilding and ship repair industry's annual staff (see online version for colours)



Source: Safargholi et al. (2017)

However, according to Figure 3, despite the potential of the shipbuilding, the actual utilised capacity is much smaller and has been declining in recent years (Overview of the Shipbuilding and Maintenance in Iran, 2014).

Due to lack of domestic order, shipbuilding supply chain has not developed also, and shipbuilding has a lot of problems. Existing delivery delays caused domestic orders to leave to foreign shipbuilder and so income is decreasing. As Figure 4, the number of manpower in the shipbuilding sector has been declining in recent years and some of them turned their jobs to other and some of them leaved shipbuilding and entered maintenance.

One of the most similar country to Iran, according to infrastructure, population, etc., is Turkey. In this country, shipbuilding is one of classic activities. Turkish shipbuilding, due to competition with global markets, experienced a multiplied increase in shipbuilding, export capacity, and remarkable diversity in products. Turkey is among the first ten countries in the world in terms of deadweight production and also this country is among the top five countries in terms of number of ships (Stopford, 2017).

According to above, the Iran marine industry performance, in spite of its good market potential, domestic demand, and capacity, has serious problems.

Here, the challenging question is that why marine industry in some developing countries (i.e., Iran) has not developed considerably while the industry in other prior competitors (i.e., Turkey) has developed such that they have one of the first ten top shipbuilding industries.

The paper is organised as follows. In Section 2 the literature is reviewed briefly and then the steps and method of research are described in Section 3. Subsystems of marine industry development and the relations are discussed and casual loops are explained and effective variables in any of the loops are explained. Finally, effective factors are ranked by DEMATEL and related policy option is reviewed for important factors in developing countries in Section 6. The last section concludes the paper.

2 Literature review

A few articles has been applied the systems approach in investigating marine industries; especially in the macro policy layer (which is the purpose of this paper) there exists

limited literatures although the approach has been used to investigate complex problems in various field like production and manufacturing systems (Rafiei et al., 2014; Dutta and Ashtekar, 2017), social issues (Saleck Pay et al., 2013; Lashgarian Azad et al., 2010), oil and gas sector in global and national level (Hosseini and Shakouri, 2016; Hosseini et al., 2014), maintenance system (Esmaeili et al., 2019), wind power development (Hosseini et al., 2012), business ecosystem (Marakhimov et al., 2018), etc.

Cakravastia and Diawati (1999) developed a system dynamics model of developing logistic efficiency of marine industry in Indonesia. In the paper, financial flow and supply of materials and equipment are modelled, and mentioning the effective loops, the bottlenecks to improve the profitability of the industry and reduce the delivery time are reviewed and identified. In this paper, financing and information flow are considered as two important factors in the marine industry.

In another investigation, shipbuilding industry analysis is performed in which military project management is emphasised (McCue, 1997). Also, some scenarios for modifying the quality and the time of delivery are presented in which the components are analysed. The author, identified project management and timing as the most important factors in marine industry performance.

In another research proposed in 2009 about South Korea marine industry, classical strategy analysis by SWOT matrices is applied and the competitive advantages are studied as casual loops. The author of the paper, regarded competitive strategies, increase of market share, investment, and entering into new technologies such as wind energy as important factors of compensating the decrease in shipbuilding orders (Samuel et al., 2010).

In another study, a plan is proposed to simulate marine industry of Croatia by system dynamics methodology in which documentation and procedure of shipbuilding are reviewed. The author of the article identifies the documentation processes of building stages as important factors in shipbuilding projects (Munitic et al., 2003).

Another research studied the situation of competitiveness in non-EU countries in Europe and considered main effective subsystems as demand, ship owners, shipbuilding, regulatory system, training and investigation, innovation infrastructure and political issues [Transport Research Market Uptake (Market-up), 2015].

3 Research methodology

Due to complexity of the issue, in this paper the systems approach is used. The most important goal of systems modelling is to achieve a common understanding about the relationships affecting a problem so as to be able to verify the possible policies to be applied for improving the system's situation. This perception is only achieved by way of studying all parts and the relations between them as an integrated system. As an effective methodology to conduct a study by systems approach, system dynamics is developed by a group of investigators of MIT in the late 1950s leaded by Forrester (1961).

Furthermore, because of the multiplicity of factors (which depicted here as a causal loop diagram), DEMATEL[1] technique is used to rank and analyse the effective factors, so that the main factors could be recognised for policy formulation.

In this paper, the systems approach is utilised to analyse system components and main variables in the context of casual relations as causal loops. Casual loop diagram could

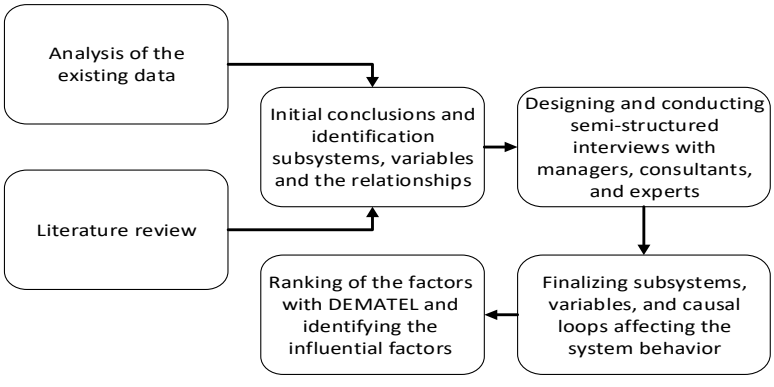
briefly give a good understanding of the main effective factors on the studied problem and the relations among the factors (Sterman, 2000).

Casual loops make the user simply communicate with main hypothesis and feedback structure (Sushil, 1993); causal loops are repeatedly used in academic studies to (Sterman, 2000):

- quickly take the hypothesis about the dynamics of a system
- deduce and take subjective models of individuals or teams
- link the effective separate loops.

According to Figure 5, which shows the steps of this study, after reviewing the systems models in the literature and studying the global facts and figures, considering the principles of systems approach, causal loops and subsystem diagrams are depicted after the primary summary in the next stage, some semi-structured interviews with managers, experts, and advisers in marine industry, casual loops and the effective subsystems in each problem are finalised. In the final step the effective factors are ranked via DEMATEL technique, using expert opinion and related strategies are presented. In this research, we used 12 experts including, politicians, government authorities, shipbuilding owners and managers, representatives from non-governmental organisation, etc.

Figure 5 Flow chart of research process



As mentioned before, casual loop diagram shows the relationships between variables, but it is necessary to use a method, which can determine quantitatively the most effective factors. For this purpose, DEMATEL technique has been used.

DEMATEL is abbreviated form of decision making trial and evaluation (Genç and Masca, 2018). This technique uses paired comparisons method which is capable of variables ranking in a network (Falatoonitoosi et al., 2013). Based on paired comparisons, using the opinion of experts in achieving the factors of a system and regulated shaping via graph theory. This method presents a hierarchy structure consist of the factors in system with effective relations and mutual effects such that the intensity of the relations is determined numerically (Bagheri Moghaddam et al., 2010).

To compare factors with each other, five values are applied which are mentioned in the Table 1.

Table 1 Criteria value

Name	*Value*
No effect	0
Low effect	1
Moderate effect	2
High effect	3
Very high effect	4

To study the criteria, views of p experts (which in this case $p = 12$) are used in the matrices. X_{ij} is as view of each expert and $X_{ij} = 0$ ($i = j = 1, 2, 3, \ldots, n$) are all null (the main diagonal is null). To consider all expert views, as the formula (1), arithmetic mean is used:

$$z = \frac{x^1 + x^2 + x^3 + \ldots + x^p}{p} \tag{1}$$

In the above formula, P is the number of experts and $x^1, x^2, \ldots, x_p$ are progressively paired comparison matrices of the experts 1, …, p. Then, in order to normalise the matrix, the following formula is used:

$$H_{ij} = \frac{z_{ij}}{r} \tag{2}$$

In which r is achieved as follows:

$$r = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} Z_{ij} \right) \tag{3}$$

After having calculated the above matrices, fuzzy relations matrix is achieved by the bellow formula:

$$T = \lim_{k \to +\infty} (H^1 + H^2 + \cdots + H^k) = H \times (I - H)^{-1} \tag{4}$$

In which I is identity matrix. The next step is to gain the sum of rows and columns of T. Sum of rows and columns is obtained by the following relations:

$$(D)_{n \times 1} = \left[\sum_{j=1}^{n} T_{ij} \right]_{n \times 1} \tag{5}$$

$$(R)_{1 \times n} = \left[\sum_{i=1}^{n} T_{ij} \right]_{1 \times n} \tag{6}$$

That D and R are $n \times 1$ and $1 \times n$ respectively.

The next stage determines importance of indicators ($D_i + R_i$) and the relation between the criteria ($D_i - R_i$) is identified. If ($D_i - R_i$) > 0 the related criterion is effective and otherwise it is impressionable.

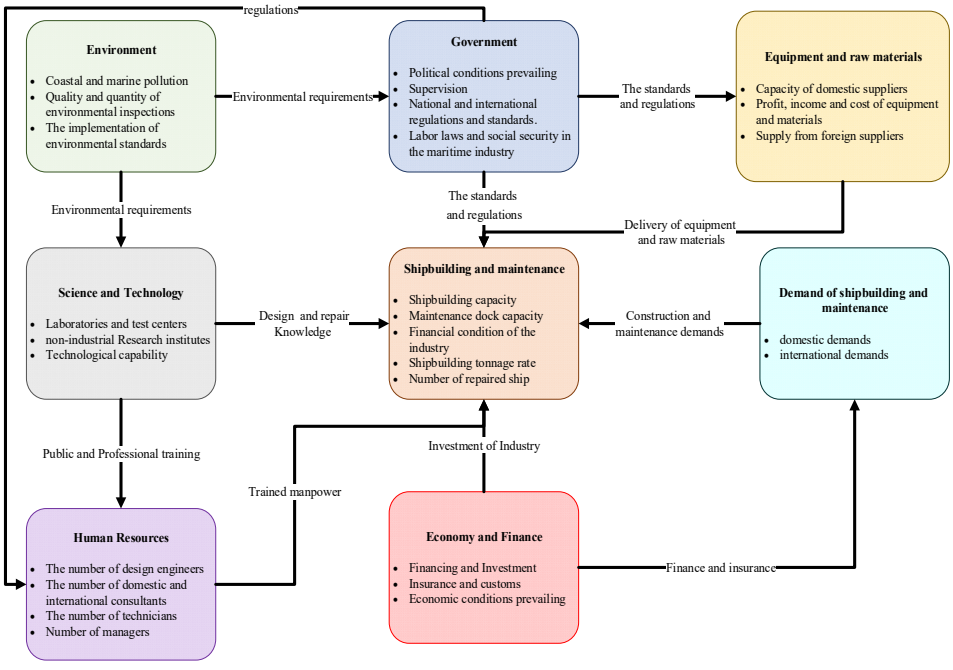
Finally, a diagram will be depicted that shows value of importance and effectiveness and impressionability among the criteria. The horizontal line of the diagram will indicate to the importance of the criteria and the vertical one indicates to the effectiveness or impressionability of the criteria. At the final step, for determining key factors, distance of

points from median of points, will calculate. The variable with high distance from median consider as key factors.

4 System conceptualisation

System conceptualisation, shapes the effective subsystems, in order to show physical and information flows among different subsystems and to determine the modelling borders (Sterman, 2000). In this case, Iran's marine industry is divided into eight main subsystems that are: government, supply of equipment and raw materials, environmental issues, demand for shipbuilding and maintenance, science and technology, economy and finance, and human resources (Figure 6).

Figure 6 Subsystem diagram of marine industry (see online version for colours)



Government subsystem consists of the political situation, state and international rules that affect marine industry.

Supply of equipment and raw materials subsystem delivers basic need of shipbuilding and maintenance, from domestic and foreign supplier to shipbuilding and maintenance complexes.

Environmental issues subsystem transfers environmental regulation in both shipbuilding and maintenance to government subsystem in order to be considered in rules and transfers them to science and technology subsystem to be more developed in environmentally friendly processes (Anne et al., 2015).

Demand subsystem consists of effective factors on demand and competitiveness in shipbuilding and maintenance (Stott, 2018).

Shipbuilding and maintenance subsystem is considered as the main subsystem in the marine industry and to some extent is related to all other subsystems (Wada et al., 2017).

Economic and finance subsystem consists of factors effective on economic conditions of insurance and customs in the industry that affect the amount of demand and competitiveness directly. Moreover, methods of finance for marine industry projects is determined in this subsystem (Ok and Feng, 2017).

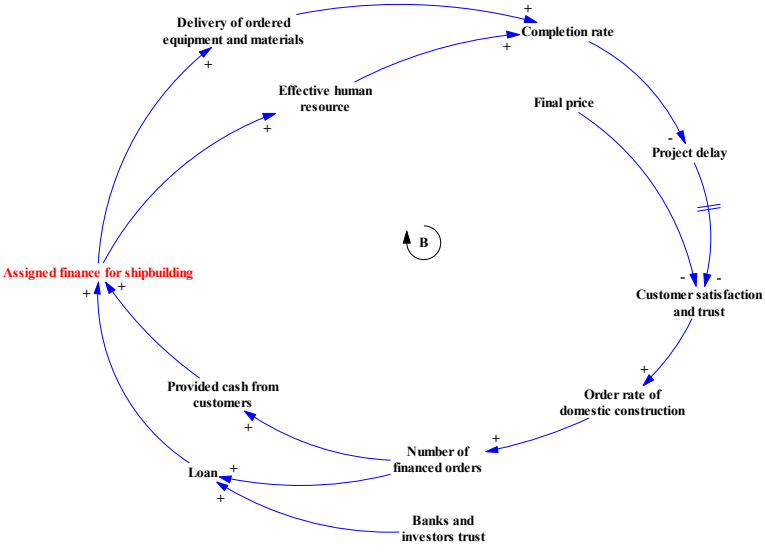
Human resource subsystem consists of effective factors on recruitment and training of specialist and experienced manpower to the industry's need. This subsystem, takes knowledge from science and technology subsystem and gives experts and specialists in shipbuilding and maintenance group (Bruintjes et al., 2017).

In this paper, loops are consist of economic financial problems, insurance services, investment in processes development, overhead costs, investment in capacity and identified infrastructure, un-competitiveness, supply chain problems, mismanagement and human resources efficiency.

4.1 Economic financial problems

Economic and financial problems are of the most important ones cause not to assign sufficient investment budgets to projects and therefore the delivery delays emerge. In other words, while finance activities is not on time and continuous, human resource efficiency is decreased and supplying the equipment and raw material will be delayed or stopped which result in considerable delay in delivery. When the customers see delays in projects, refuse to order in domestic enterprises and prefer supplying from abroad and so the income caused by the customer, loans paid by banks will decrease which lead to limited financial resources more and more (Figure 7).

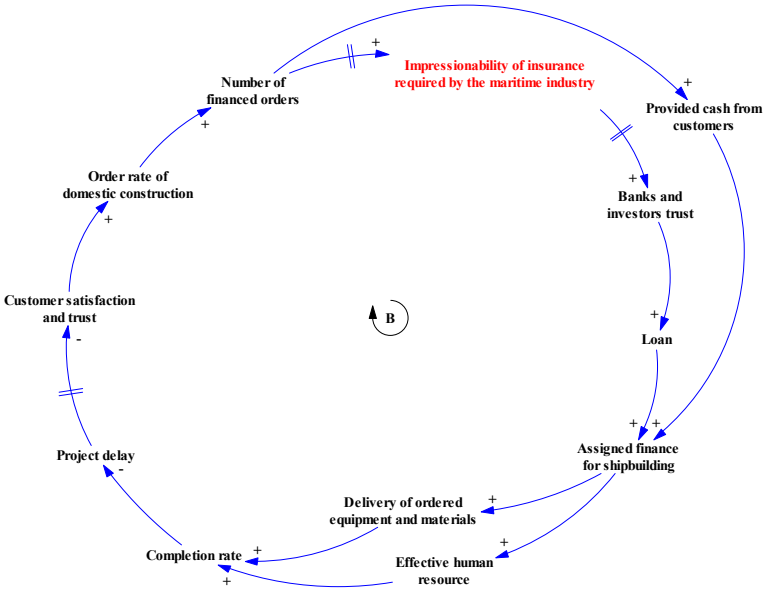
Figure 7 Casual loop diagram of financial effect on marine industry (see online version for colours)



4.2 Insurance services

Insurance services leads to decrease investment risks. Thus insurance services result in increase of bank and private sector investments and so will strengthen the financial resources of the industry. While financial resources increase, workload increase and the delivery delays decrease. This decrease leads to customer satisfaction and the domestic orders raises and insurance coverage will develop and the loops continues (Figure 8).

Figure 8 Casual loop diagram of insurance service effect on marine industry (see online version for colours)



4.3 Capacity building and developing the infrastructures

Investment in developing the infrastructures and capacities will cause to gain more orders. This development needs evaluation of development profitability. In other words, before any development, investment rate of return must be determined. Development of shipbuilding infrastructure will lead to increase in orders and production rate and as a result the final cost decreases. Decreasing final costs of projects, the income increases and possibility of more investment for developing the infrastructure will be economically explainable (Figure 9).

4.4 Investment in processes development

Investing in processes development causes to more efficiency of decision making and human resources, which increases the mean value of workload. This item results in decrease of delays in one hand and increase of final price on the other.

Suitable prices make customers order for domestic production and so the volume and profitability will raise which at last leads to more investment and improving the efficiency (Figure 10).

Figure 9 Casual loop diagram of developing infrastructure investment in shipbuilding capacity (see online version for colours)

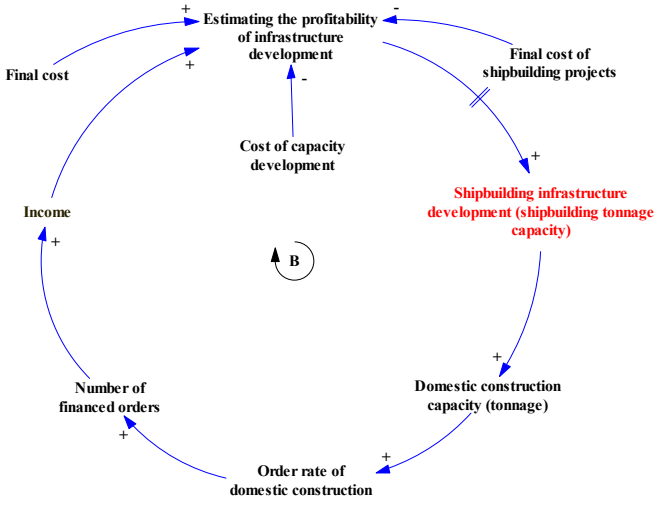
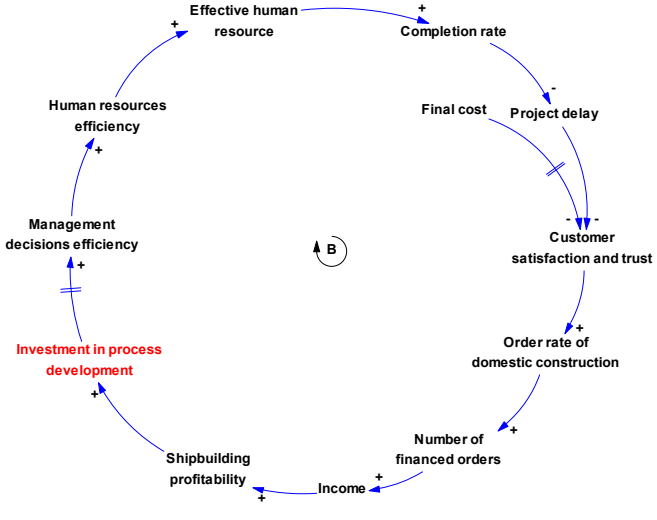


Figure 10 Casual loop diagram of investment on improving organisation function (see online version for colours)



4.5 Overhead costs

The delays in projects not only affect customer's satisfaction and trust in a negative manner, but also increase the overhead costs of the project. In other words, overhead

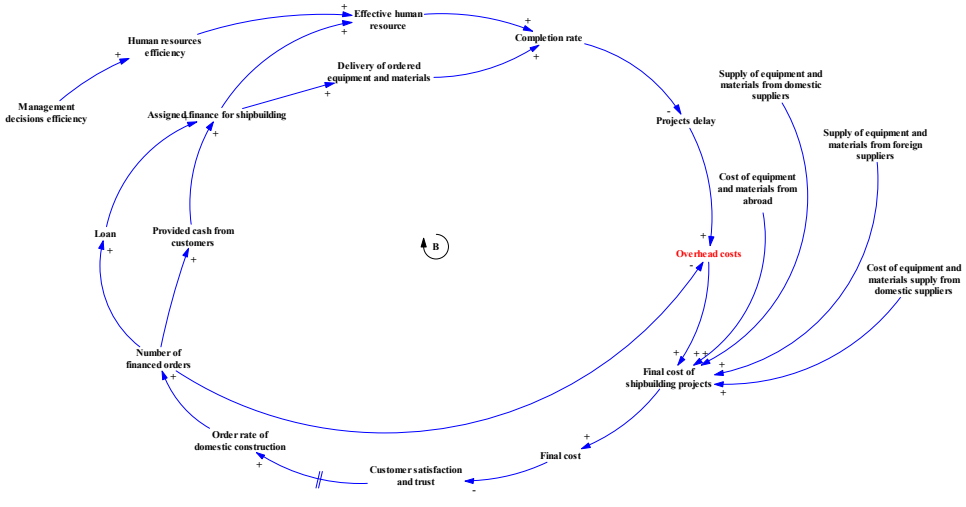
costs such as infrastructure costs, salary, and, etc., continue during the project and so the costs of the project will increase.

This increase of costs will add to the cost of the ship and will decrease domestic orders. Therefore the production and thus income and profitability of the industry will decrease which implies a decrease of financial resources in the industry, restriction of supply, decreases in effective human resources and increases in delivery delays in projects (Figure 11).

4.6 Lack of competitiveness in attracting demands

Competitiveness in absorption of domestic demand is affected by the country economic situation. GDP is used to define a suitable variable to evaluate the economic situation. When GDP increases, the demand of marine transportation and the demand for more shipbuilding increases that the need can be provided by domestic or foreign market. Shipbuilding capacity in the country leads to attract the demand such that few ones order abroad. These orders, to be executed, need to be financed which ultimately the final number of real orders which are financed will be determined. Another important factor is delivery delay and the ship's price which directly affect customer's satisfaction and consequentially order absorption (Figure 12).

Figure 11 Casual loop diagram of delay project effect on final cost (see online version for colours)



4.7 Supply chain problems

One of the main problems that plays a major role in delivery delays in marine industrial projects is supply chain performance. Sometimes, the absence of a parts will put over constructing a ship to some months later. In the first loop (Figure 13), the effect of domestic supply chain capacity on industry performance is shown. The larger the capacity, the more expected delivery of equipment and materials, and so, completion rate will increase. Thus the delivery delays decrease and customer satisfaction and trust is

achieved. Orders and the demand for equipment and raw materials supply will increase as a result.

Continues demand increase, leads to the development of equipment and raw materials supply capacity in the country and consequently domestic supply increases. Price and delivery time are two important factors that affect how to choose among foreign and domestic suppliers.

Figure 12 Casual loop diagram of shipbuilding demands (see online version for colours)

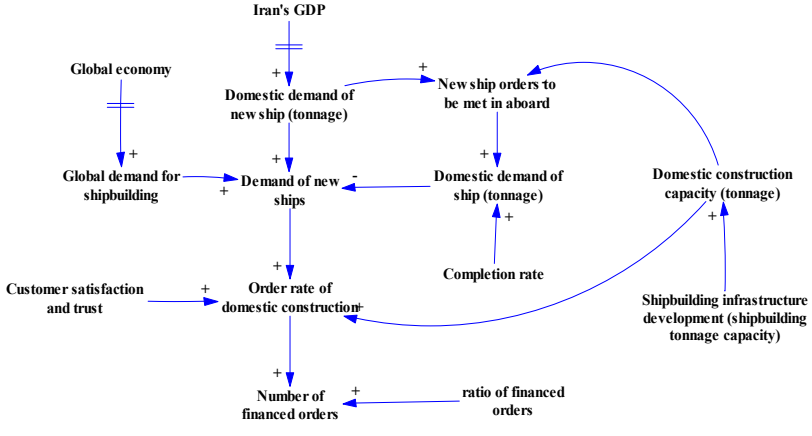
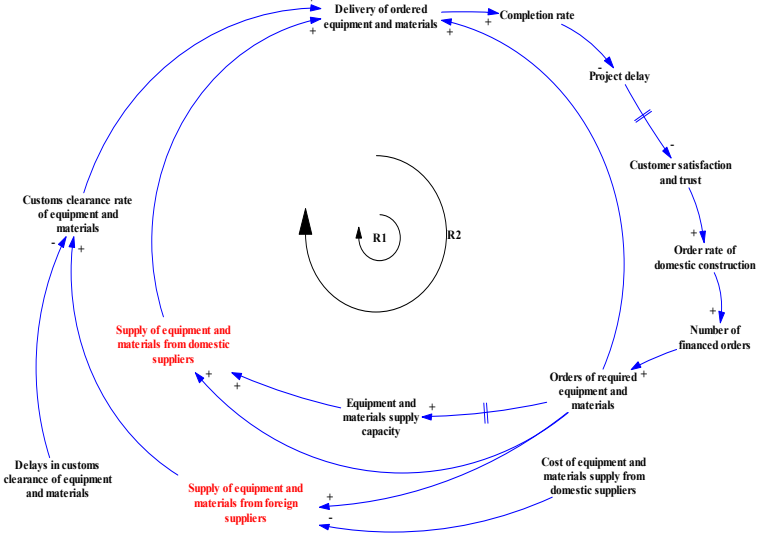


Figure 13 Casual loop diagram of marine industry supply chains (see online version for colours)

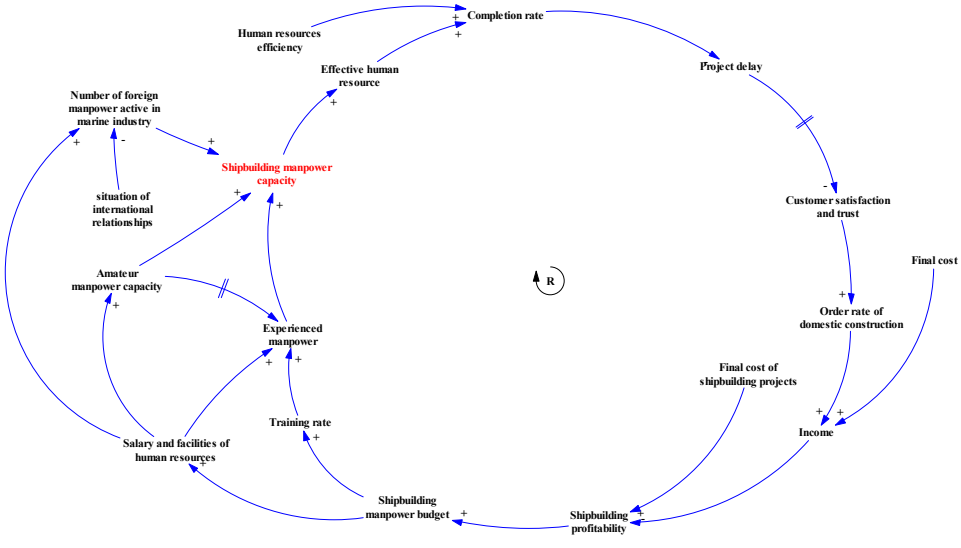


In the second loop, the effect of foreign supply of equipment and material is presented. The country's international relations level influence the supply and also the constraints such as delays in customs clearance impact on the supply of equipment and materials of industry. The late supply of equipment makes completion rate go lower and delay increases, eventually as a result customer satisfaction and trust will come down. A reduction in customer satisfaction and trust, will result in a decrease in domestic orders decrease and so the need for material and equipment will decrease and consequently the domestic capacity for the supply of equipment is to be depreciated and the supply will be limited.

4.8 Mismanagement and human resources efficiency problems

Human resources is one of the important factors in marine industry performance. Lack of effective human resources capacity results in delay in delivery of projects and consequently decreases the satisfaction and trust. Therefore a decrease in domestic orders occurs and profitability and income of industry and so human resources budget to provide the salaries and facilities decrease (Figure 14).

Figure 14 Casual loop diagram of human resource (see online version for colours)



Generally the situation of marine projects is located in bad weather regions in the south of the country far from civil atmosphere. Therefore, the labour attraction decreases, which implies that facilities, and salary, and benefits is important in attracting human resources. Human resource capacity of the industry consists of specialists and amateurs who gradually and after having trained and experienced, turn to specialists. Decreasing the budget of human resources, the benefits and salaries and consequently the attraction decrease as well. Also the budget affects the training rate and makes it come down. Thus

human resources capacity and the effective man – hour capacity of the industry diminishes which itself reduces the labour rate. Aggregating the effective loops of causal loops diagram which indicate to the links among the factors and variables are as the following. Causal loops only show the relations among the factors, but how much any factor can affect or be impressed is not trivial in the diagram. In order to reach this purpose, the DEMATEL weighting approach is applied. The following table shows the effectiveness and impact of each factor.

In the next stage importance of indicators ($D_i + R_i$) and the relations among the criteria ($D_i - R_i$) are identified. If $D_i - R_i > 0$ then the related criterion is effective and if $D_i - R_i < 0$ it has interaction. Tables 2–3 shows $D_i + R_i$ and $D_i - R_i$.

5 Discussion

As mentioned before, to calculate key factors, the score of Tables 2 and 3 considered. Based on above score, according to Table 4, high score variable had formed to ten key factors which has most influence in marine industry development.

Table 2 Ranking of the most important factors

Row	*Variable name*	$D_i + R_i$
1	Final cost of shipbuilding projects	2.837
2	Number of financed orders	1.935
3	Supply of equipment and materials from domestic suppliers	1.655
4	Shipbuilding profitability	1.597
5	Order rate of domestic shipbuilding	1.454
6	Final cost	1.435
7	Completion rate	1.365
8	Shipbuilding manpower capacity	1.349
9	Supply of equipment and materials from foreign suppliers	1.347
10	Estimating the profitability of infrastructure development	1.295

Table 3 Ranking of the most interaction factors

Row	*Variable name*	$D_i - R_i$
1	Supply of equipment and materials from domestic suppliers	0.896
2	Salary and facilities of human resources	0.675
3	Number of financed orders	0.625
4	Orders of required equipment and materials	0.573
5	Ratio of financed orders	0.507
6	Domestic shipbuilding capacity	0.403
7	Equipment and materials supply capacity	0.377
8	Supply of equipment and materials from foreign suppliers	0.349
9	Impressionability of insurance required by the maritime industry	0.324
10	Situation of international relationships	0.302

Table 4 Ranking of key factors

Row	*Variable name*
1	Final cost of shipbuilding projects
2	Estimating the profitability of infrastructure development
3	Effective human resource
4	New ship orders to be met in aboard
5	Order rate of domestic shipbuilding
6	Shipbuilding profitability
7	Customer satisfaction and trust
8	Domestic demand of ship
9	Cost of equipment and materials supply from foreign suppliers
10	Experienced manpower capacity

According to the importance of effectiveness and interactions of each factor calculate in Table 4, the following strategies are suggested for growth and development of the marine industry in developing countries.

a *Domestic supply chain development:* due to lack of infrastructure of value chain in the developing countries (such as Iran), equipment and materials supplied from abroad (Rathod et al., 2019). Because of probable inappropriate international relationships, the dealers are proposed and consequently the expenses increase. Also import tariffs and delivery delays increase the expenses more and so the time of providing material and equipment raises. The mentioned problem sometimes made delay in completion of a project due to delay of providing a piece. Thus, domestic supply chain development in order to increase the domestic supply share in shipbuilding is recommended (Christopher and Holweg, 2017).

b *Special rights and benefits for employees:* most yards and centres concerned with marine industries are located in remote areas and recruitment of specialists accompanies by special benefits, otherwise there will be no job attraction. Also, in order to recruit foreign specialists, some facilities must be provided. For instance, in South Korea, for the manpower from other countries, gold visas and special benefits are awarded (Chen et al., 2017).

c *Increase in manpower efficiency:* manpower efficiency in Iran is as 130 MH/CGT whereas in a country such as South Korea it is by 10.7 MH/CGT (Safargholi et al., 2017), which shows that it is low in Iran and so as to increase it, it is necessary to make a serious investment. Furthermore, well-timed and cost-effective delivery of a ship, requires planning in project activities and phases, hence a more relaxed labour and social security laws for employees suggested in the developing countries.

d *Demand absorption:* one of the problems in the way of domestic development, is distrust about domestic productions. Establishing a section for marketing the domestic production and capability, is effective in attracting the demands as the leading countries insist on the marketing (Jiang et al., 2013).

e *Low-interest loans with suitable guaranties:* it is suggested that governmental banks offer an integrated loan-guarantee-insurance services for mega project and big shipbuilding orders (Jiang et al., 2013).

f *Effective and integrated management:* one of the most important problems in marine industry is the lack of sponsorship and integrated management. Inconsistencies between the organisations, causes that the performances are at odds with each other. Hence, a need to have an organisation, the role of which is to coordinate activities of different parts of industry is obviously felt. Therefore, a separate and independent office in the government is suggested (Li et al., 2018).

6 Conclusions

The goal of this paper is to analyse the effective factors on the growth shipbuilding industry in developing countries. At first, according to this goal, systems approach has been used. Based on that, a comprehensive understanding about the complicated system of marine industry has been made. Studying the similar cases all over the world and presenting the expert's viewpoints, causal diagram of effective loops in marine industry has been identified. Finally, eight main and effective loops and the main variables and the relations among them has been considered. The most important and interacting factors are determined by means of DEMATEL technique. Domestic supply chain development, special rights and benefits for employees, increase in manpower efficiency, demand absorption, low-interest loans with suitable guaranties, effective and integrated management are the key factors and main issue in developing country marine industry. Considering the importance mentioned above about the industry, for future studies, it is recommended that a quantitative system dynamics model be developed in order to verify, analyse, and evaluate the problem more precisely and formulate more real and integrated strategies.

References

Anne, O., Burskyte, V., Stasiskiene, Z. and Balciunas, A. (2015) 'The influence of the environmental management system on the environmental impact of seaport companies during an economic crisis: Lithuanian case study', *Environmental Science and Pollution Research*, Vol. 22, No. 2, pp.1072–1084.

Bagheri Moghaddam, N., Sahafzadeh, M., Shafei Alavijeh, A., Yousefdehi, H. and Hosseini, S.H. (2010) 'Strategic environment analysis using DEMATEL method through systematic approach: case study of an energy research institute in Iran', *Management Science and Engineering*, Vol. 4, No. 4, pp.95–105.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E. and Geeves, W. (2003) 'Marine invasive alien species: a threat to global biodiversity', *Marine Policy*, Vol. 27, No. 4, pp.313–323.

Bruintjes, R., Harding, H.R., Bunce, T., Birch, F., Lister, J., Spiga, I. and Tyler, C.R. (2017) 'Shipbuilding docks as experimental systems for realistic assessments of anthropogenic stressors on marine organisms', *BioScience*, Vol. 67, No. 9, pp.853–859.

Cakravastia, A. and Diawati, L. (1999) 'Development of system dynamic model to diagnose the logistic chain performance of shipbuilding industry in Indonesia', *International System Dynamics Conference*, Wellington, New Zealand.

Chen, F., Lu, W. and Cai, J. (2017) 'Research on land use pattern and employment-housing space of coastal industrial town based on the investigation of Liaoning Province, China', *World Academy of Science, Engineering and Technology, International Journal of Urban and Civil Engineering*, Vol. 4, No. 9, pp.13–28.

China Leads in Shipbuilding (2018) *By the British Shipbuilding Analysis Agency*, Clarkson Research Services.

Christopher, M. and Holweg, M. (2017) 'Supply chain 2.0 revisited: a framework for managing volatility-induced risk in the supply chain', *International Journal of Physical Distribution & Logistics Management*, Vol. 47, No. 1, pp.2–17.

Dutta, G. and Ashtekar, M. (2017) 'A system dynamics simulation model of a blast furnace for project evaluation', *International Journal of Business and Systems Research*, Vol. 11, No. 3, pp.325–343.

Esmaeili, E., Karimian, H. and Bisheh, M.N. (2019) 'Analyzing the productivity of maintenance systems using system dynamics modeling method', *International Journal of System Assurance Engineering and Management*, Vol. 10, No. 2, pp.201–211.

Falatoonitoosi, E., Leman, Z., Sorooshian, S. and Salimi, M. (2013) 'Decision-making trial and evaluation laboratory', *Research Journal of Applied Sciences, Engineering and Technology*, Vol. 5, No. 13, pp.3476–3480.

Forrester, J.W. (1961) *Industrial Dynamics*, MIT Press Cambridge, MA.

Genç, T. and Masca, M. (2018) 'An application of fuzzy VIKOR method on evaluation of the university students' preferences on selected Turkish banks', *International Journal of Business and Systems Research*, Vol. 12, No. 1, pp.13–24.

Hosseini, S.H. and Shakouri, H. (2016) 'A study on the future of unconventional oil development under different oil price scenarios: a system dynamics approach', *Energy Policy*, Vol. 91, No. 1, pp.64–74.

Hosseini, S.H., Shakouri, G.H. and Akhlaghi, F.A.R. (2012) 'A study on the near future of wind power development in Iran: a system dynamics approach', *2012 Second Iranian Conference on Renewable Energy and Distributed Generation*, IEEE, pp.183–188.

Hosseini, S.H., Shakouri, G.H., Kiani, B., Mohammadi Pour, M. and Ghanbari, M. (2014) 'Examination of Iran's crude oil production peak and evaluating the consequences: a system dynamics approach', *Energy Exploration & Exploitation*, Vol. 32, No. 4, pp.673–690.

Hwang, I. and Park, J.H. (2018) 'The international competitive relationships of three leading countries in the global shipbuilding industry', *The Korean Journal of Policy Studies*, Vol. 33, No. 3, pp.73–91.

Jiang, L., Bastiansen, E. and Strandenes, S.P. (2013) 'The international competitiveness of China's shipbuilding industry', *Transportation Research Part E: Logistics and Transportation Review*, Vol. 60, No. 1, pp.39–48.

Lashgarian Azad, H.R., Khorshidi, H.A., Hosseini, S.H. and Mizamohammadi, S. (2010) 'Fight or flight: using causal loop diagram to investigate brain drain in developing countries', *International Journal of Society Systems Science*, Vol. 2, No. 3, pp.285–296.

Li, J., Sun, M., Han, D., Wu, X., Yang, B., Mao, X. and Zhou, Q. (2018) 'Semantic multi-agent system to assist business integration: an application on supplier selection for shipbuilding yards', *Computers in Industry*, Vol. 96, No. 1, pp.10–26.

Marakhimov, A., Joo, J. and Yim, J. (2018) 'Customer participation in business ecosystems: an integrated approach of system dynamics and fuzzy sets', *International Journal of Business and Systems Research*, Vol. 12, No. 3, pp.290–316.

McCue, T.P. (1997) *The Dynamics of Naval Shipbuilding. A Systems Approach*, Office of Naval Research Arlington VA.

Munitic, A., Simindic, S. and Dvornik, J. (2003) 'Shipbuilding organization simulation modeling', *International Conference of the System Dynamics Society*, New York, USA.

Ok, Y. and Feng, G. (2017) 'Analysis of the efficiency of Chinese repair shipbuilding industry', *Korean Port Economics Journal*, Vol. 33, No. 4, pp.117–134.

Overview of the Shipbuilding and Maintenance in Iran report (2014) *Iran Marine Fund Organization*, Report No. 2, Iran Ministry of industry, Mine, and Trade [online] http://www.mimt.gov.ir (accessed 2018).

Rafiei, H., Rabbani, M. and Hosseini, S.H. (2014) 'Capacity coordination under demand uncertainty in a hybrid make-to-stock/make-to-order environment: a system dynamics approach', in *Scientia Iranica*, Vol. 21, No. 6, pp.2315–2325.

Rathod, G.H., Puranik, V.S. and Hiremath, V. (2019) 'Developing agility system in supply chains', *International Journal of Business and Systems Research*, Vol. 13, No. 2, pp.247–258.

Safargholi, A., Mohammadi, A., Najartabar, M. and Hajmohammadi, A. (2017) *Iran Marine Statistics*, Iran Vice Presidency for Science and Technology.

Saleck Pay, B., Hosseini, S.H. and Shakouri, H. (2013) 'Why do students use virtual social networks in Iran: a system approach', *Interdisciplinary Description of Complex Systems*, Vol. 11, No. 1, pp.108–122.

Samuel, N., Ahn, N., Peyanard, M., Pupipat, P. and Zhong, S. (2010) 'Competition in the shipbuilding industry: sustaining competitive advantage in the global economy', *International Conference of the System Dynamics Society*, Seoul, Korea.

Sterman, J.D. (2000) *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Vol. 19, Irwin/McGraw-Hill Boston.

Stopford, M. (2017) *Global Shipping & Shipbuilding Markets Overview & Outlook*, Clarkson Research Services Limited, Clarkson Publication, London, United Kingdom.

Stott, P.W. (2018) 'Shipbuilding innovation: enabling technologies and economic imperatives', *Journal of Ship Production and Design*, Vol. 34, No. 2, pp.144–154.

Sushil, S. (1993) *System Dynamics: a Practical Approach for Managerial Problems*, Wiley Eastern Publication, New Delhi, India.

Transport Research Market Uptake (Market-up) (2015) *Recommendations for Better Market Uptake of Transport Results and Involvement of Actors – Deliverable 5.1*, European Commission [Under Seventh Framework Programme (FP7)].

Wada, Y., Hamada, K., Hirata, N., Seki, K. and Yamada, S. (2017) 'A system dynamics model for shipbuilding demand forecasting', *Journal of Marine Science and Technology*, Vol. 23, No. 2, pp.1–17.

Xiang, J. (2010) *Marine Science and Technology in China: a Roadmap to 2050*, Springer Science and Business Media publication, Berlin, Germany

Notes

1 Decision making trial and evaluation.