RESEARCH IN LOGISTICS & PRODUCTION

OPTIMIZING TECHNOLOGY SELECTION IN MARITIME LOGISTICS

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Abstract In this study, we consider a technology selection problem in maritime logistics based on lifespan, brand value, maintenance, repair, operations and cost. Low cost, acceptable risk, and environment friendly form of transportation are primarily required for the logistics sector. In a conventional holistic approach, technology is firstly selected in terms of its cost. However, in the step-wise manner, it is obvious that other factors (i.e. reliability, sustainability, etc.) directly involve in to the selection process. By using conventional AHP method, we investigate the general tendency of the ship owners and its reflections to the maritime logistics.

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1. INTRODUCTION

Technology is a combined form of hardware (work stations, signal processors, chips, and circuits among others) and software (executable files, scripts, and operating systems among others) and technology management depends primarily on the needs, capabilities and perspective of the organizations. Therefore, technology management requires a managerial level of expertise and technological skills. In this study, we consider a technology investment problem for the maritime industry wherein the objective is to purchase the best optimum product among others in terms of lifespan, brand value, maintenance and cost of the technology (Miles, 1995).

There exist several electronic and mechanical devices, which are used in the maritime industry and especially on board ships. Electronic chart display and information system (ECDIS), one of the most significant and complex navigation equipment. ECDIS are robust indicators over product technology tendency of the shipowners and technological change decisions of the vessels in the maritime industry. For this purpose, after investigating all ECDIS companies, six brands are determined. After an expert consultation and the industry survey, under the analytical hierarchy process (AHP) framework, four criteria are determined as *lifespan, brand value, maintenance* and *cost*. Although a brand of a product takes an important role for the purchase process, and it may also cause biases. Therefore, due to ethical reasons we prefer to conceal the brand names of the ECDISes.

We live in technology era, thus maritime sector and especially vessels and maritime logistics companies impossibly stay insensitive to the new technologies in order to compete in the market. New technologies provide many practical facilities for the maritime sector as being for all other sectors (Senol, 2015). For instance, ECDIS utilizes position fixing, preparation of passage plan, applying chart corrections, identifying other ships with their names and other characteristics, trial evasive manoeuver, etc.

The structure of this paper is organized as follows: Section 2 formally defines the general definitions of main navigational technologies in order to contribute a perspective of marine equipment for readers. Section 3 provides definitions of the criteria. Section 4 presents methodology in detail. In Section 5 application and output of the empirical study are conducted. Lastly, conclusion and discussions are presented in Section 6.

2. NAVIGATIONAL TECHNOLOGIES FOR THE VESSELS

2.1. Automatic Radar Plotting Aid (ARPA) Radar

Radar is an object detection system which transmits and receives radio waves to determine the range, position and approximate size of the objects. Additionally, ARPA radar enables to track and calculate closest point of approach of the detected contacts. Furthermore, ARPA can estimate the risk of collision and provide an evasive manoeuver to assist the users. Therefore, ARRA radar provides navigational information by not only detecting the device but also calculating the all parameters to prevent any collision. ARPA radar is more preferred one due to its additional advantages. Accepting the International Maritime Organization (IMO) performance standards, ARPA radars are fitted many further characteristics, which determine user profile.

2.2. Electronic Chart Display and Information System (ECDIS)

ECDIS is a computer based navigation information system, which is used as an alternative of nautical paper charts. Apart from an alternative of paper charts, ECDIS utilizes position fixing, preparation of passage plan, applying chart corrections, identifying other ships with their names and other characteristics, trial evasive manoeuver and etc. All bridge navigational equipment have universal connections that are compatible and connected with ECDIS for data transfer. There exists two main types of ECDIS as electronic navigational charts (ENC) and raster charts. ENCs are vector charts and thus, provides unlimited usage and computation facilities. ENCs are compatible with all kind of digital supplements provided by hydrographic offices. Raster charts are produced by converting paper charts to image by scanner. According to IMO's regulations this type of charts cannot be used as primary equipment for navigation. In other words, raster charts are not a full alternative of paper charts. They can be used as secondary support system.

2.3. Automatic Identification System (AIS)

AIS is a tracking system for identifying and locating vessels by electromagnetic wave propagation mechanism in very high frequency (VHF) band. Each vessel transmits its own AIS data and receives surroundings simultaneously. AIS receives vessel's name, identification numbers, position, speed, heading, length, breadth, draft and cargo, number of crew information.

3. DEFINITION OF CRITERIA

3.1. Lifespan

Due to the nature of the global maritime transportation, merchant vessels navigate almost always at the international waters. The vessels might navigate at the south part of the world or/and at the cold weather conditions including the changing night and day circumstances. The work environment is fragile and harsh for the technological products especially for the navigational equipment. The time is vital for a vessel, therefore, a technological product is desired to be used as long as possible. In case of a break down, the link between the vessel at the international waters and the nearest shore or a yard can be hardly established. It might also cause extra time, oil consumption and expenditures

3.2. Brand Value

For the technology selection process, brand values take a significant role. A brand value indicates the transparency, validity, reliability, sufficiency, quality, and objectivity, financial, behavioural and legal position of the companies. The brands are valuated considering different approaches such as cost, market or sale comparisons and income of the companies. In this study, six different brands are determined and their values are estimated based on cost approach (Knapp, 2000).

3.3. Maintenance

Maritime transportation is the main form of logistics which is approximately 90% of world's trade. Due to the merchant vessels are almost always navigate at the international waters, the service network for a technology is of vital importance. All navigation and machine systems are connected each other, therefore, if one part of the mechanism is broken down, it may limit working performance of the vessels even it may stop the vessel.

The maintenance should be carried out in a periodical schedule. The maintenance should include the combination of all technical, administrative, managerial and supervision actions. In the vessel, in case of a technical break down of a technological equipment, the operational maintenance is conducted by vessel crew. However, preventive maintenance is compulsorily desired. If the purchased technology is under warranty/guarantee by the company, corrective maintenance is completed by the company. Reliability cantered maintenance is another selection criteria for a technology. Functions of this type of maintenance might include software tools, planning, maintenance service history, etc.

3.4. Cost

In the maritime sector, a cost represents monetary value (the currency of the US dollar) of expenditures for services, suppliers, labour, equipment and other items. Maritime technology increasingly proceeds by the development of computers, electric-electronic equipment and satellite services. International Maritime Organization establishes some performance standards and minimum requirements for the vessels. The costs might be separated as installation cost, capital cost and recurrent cost (per day) which includes periodical maintenance, repair and operation costs (Ison, 2007). For decision making process opportunity cost (economic cost) is generally preferred which represents the value of the best alternative.

4. METHODOLOGY

4.1. Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making method which treats as both qualitative and quantitative criteria. It is able to deal with multiple goals; it can also handle the complex nature of selection process of technological assets. AHP basically involves three steps: hierarchy structure, ratio of priorities and aggregation of the local weights into a global priority that measures the impact of all factors. The alternative rates of global weight give the selected technology.

Then, the following can be done manually or automatically by the AHP software. The steps written below are implemented:

1. Combinations of the pair-wise comparison matrix.
2. Calculating the priority vector for a criteria such as cost and then overall priority;
3. Calculation of the CI, consistency index,
4. Calculation of the consistency ratio;
5. Checking the consistency of the pair-wise comparison matrix to aware whether the experts' comparisons were dependable or not.

Inputs of AHP are gathered from multiple sources such as field experts, experienced captains, technology managers and academicians (Kum, 2015 & Sahin, 2015). A survey is conducted and experts are asked them to criticise the intended technology selection process and then rate the alternatives for each step. A questionnaire is employed for each expert step by step. Then, they filled out the relative scale measurement which is shown on the Table 1.

Table 1 Pair-wise comparison scale for AHP preferences

Numerical Rating	Verbal Judgements of Preferences
9	Extremely preferred
7	Very strongly preferred
5	Strongly preferred
3	Moderately preferred
1	Equally preferred

For AHP method, criteria and alternatives as used as inputs and the matrix produces the relative weights of elements. Particulars of the six technologies of different brands in the market (from T1 to T6) are provided in Table 2.

Table 2 Particulars of the technologies

Technologies (Brands)	Lifespan (LS)(years)	Brand Value (BV)($ bil.)	Maintenance (years)	Cost ($)
Technology 1 (T1)	5-7	0.3	Once in 6 quarters	55,000
Technology 2 (T2)	12-14	1.1	Twice a year	20,000
Technology 3 (T3)	13-15	1.2	Once a year	52,000
Technology 4 (T4)	6-7	0.87	Once in 7 quarters	60,000
Technology 5 (T5)	7-10	1.0	Once in 7 quarters	57,000
Technology 6 (T6)	10-12	0.65	Once in 9 quarters	63,000

The corresponding vector of weights is $w = w_1, w_2, ...w_n$ and the matrix is given below.

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_n \end{array} \\ \begin{pmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 \cdots w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 \cdots w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 \cdots w_3/w_n \\ \vdots & \vdots & \vdots \quad \vdots \\ w_n/w_1 & w_n/w_2 & w_n/w_3 \cdots w_n/w_n \end{pmatrix} \end{array}$$

The relative weights are obtained by multiplication of A and W, where

$$W = (w_1, w_2, \ldots, w_n) \tag{1}$$

$$A * W = n * W \tag{2}$$

n is the number of the elements, *n* and *W* are eigenvalue of the matrix algebra and eigenvector of matrix *A*.

Due to experts are not able to produce the accurate weights of matrix, the estimation of $\hat{W}$ is obtained as shown below:

$$\hat{A} * \hat{W} = \lambda_{\max} * \hat{W} \tag{3}$$

where $\hat{A}$ is observed matrix, λ_{max} is the largest eigenvalue of $\hat{A}$, $\hat{W}$ is the right eigenvector which is the estimation of W (weights i.e. priority vector).

Consistency Index (CI) is calculated from the formula of:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

λ_{max} is the largest eigenvector value.
Then, Consistency Ratio (CR) is ;

$$CR = \frac{CI}{RI} \leq 0.1 \tag{3}$$

Table 3 Random index

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Random Consistency Index (RI) is an average index of randomly generated weights which is shown in Table 3.

5. APPLICATION OF TECHNOLOGY SELECTION PROCESS BY USING AHP METHOD

For the technology selection process selected four criteria are represented as Lifespan (LS), Brand Value (BV), Maintenance (M) and Cost (C).

Table 4 Pairwise comparisons of criteria for the technology selection (CR=0.04)

	LS	**BV**	**M**	**C**	**Local PV**
LS	1,00	0,20	0,33	3,00	0,32
BV	5,00	1,00	3,00	7,00	0,22
M	3,00	0,33	1,00	5,00	0,28
C	0,33	0,14	0,20	1,00	0,17

The Table 4 shows the pairwise comparison of criteria for the technology selection and the normalized local priority vector (PV). Table 5 shows the pairwise comparisons among technologies on LS. As the value of CR is 0.1, the judgments are acceptable. Similarly, the pairwise comparison matrices and priority vectors for

the technology alternatives are calculated in Tables 6, 7, 8 and 9 respectively. Priority vector (PV) is shown at the right side of the tables.

Table 5 Pairwise comparisons among technologies on lifespan (CR=0.01)

	T1	T2	T3	T4	T5	T6	Local PV
T1	1,00	0,11	0,14	0,20	0,33	0,33	0,08
T2	3,00	1,00	1,00	1,00	1,00	3,00	0,07
T3	5,00	0,33	1,00	5,00	3,00	5,00	0,13
T4	1,00	0,14	0,20	1,00	1,00	5,00	0,13
T5	3,00	1,00	0,33	1,00	1,00	1,00	0,31
T6	3,00	0,33	0,20	0,20	1,00	1,00	0,20

Table 6 Pairwise comparisons among technologies on brand value (CR=0.03)

	T1	T2	T3	T4	T5	T6	Local PV
T1	1,00	0,14	0,20	1,00	0,33	0,33	0,08
T2	3,00	1,00	1,00	3,00	1,00	3,00	0,07
T3	5,00	0,33	1,00	5,00	3,00	5,00	0,13
T4	1,00	0,14	0,20	1,00	1,00	3,00	0,14
T5	3,00	1,00	0,33	1,00	1,00	1,00	0,32
T6	3,00	0,33	0,20	0,20	1,00	1,00	0,21

Table 7 Pairwise comparisons among technologies on maintenance (CR=0.09)

	T1	T2	T3	T4	T5	T6	Local PV
T1	1,00	0,20	0,33	3,00	3,00	5,00	0,10
T2	5,00	1,00	3,00	7,00	5,00	7,00	0,08
T3	3,00	0,33	1,00	5,00	5,00	7,00	0,16
T4	0,33	0,14	0,20	1,00	1,00	7,00	0,12
T5	0,33	0,20	0,20	1,00	1,00	3,00	0,33
T6	0,20	0,14	0,14	0,14	0,33	1,00	0,15

Table 8 Pairwise comparisons among technologies on cost (CR=0.08)

	T1	T2	T3	T4	T5	T6	Local PV
T1	1,00	0,79	0,85	0,77	0,56	0,68	0,12
T2	1,26	1,00	0,52	0,49	0,36	0,40	0,09
T3	1,17	1,93	1,00	0,59	0,67	0,81	0,15
T4	1,30	2,03	1,70	1,00	0,90	0,44	0,17
T5	1,80	2,81	1,50	1,11	1,00	1,92	0,25
T6	1,48	2,52	1,23	2,28	0,52	1,00	0,21

According to the empirical results, alternative T3 is found with higher contribution to cumulative technology selection process. Based on these results, brand value is indicated as the most important factor in the analysis (Table 9).

Table 9 Global Weights of Technologies

	L	B	M	C	
PV of Criteria	**0.12**	**0.56**	**0.26**	**0.06**	**Global PV**
T1	0,04	0,06	0,13	0,10	0,08
T2	0,23	0,26	0,44	0,43	0,31
T3	0,36	0,34	0,26	0,26	0,32
T4	0,12	0,10	0,07	0,08	0,09
T5	0,16	0,15	0,07	0,09	0,13
T6	0,09	0,09	0,03	0,05	0,07

Final results are calculated by using the conventional AHP approach. The priorities are obtained as 32%, 31%, 13%, 9%, 8% and 7% for the given technologies respectively in prior consultation. By using AHP approach, experts are asked for prioritisation of each criterion and alternatives in a stepwise process.

6. CONCLUSION

Technology transfer process is conducted after a proper expert consultation for the maritime logistic companies. Fuzzy extended analytical hierarchy process method is implemented as an empirical work of the intended technology asset selection problem. Lifespan, brand value, maintenance and cost are determined as main criteria for the technology selection process. Brand-concealed six products are presented as alternatives. Experts are asked to select the proper product among others. It is aimed to understand the tendencies of decision makers on the subject of technology selection by using pairwise comparison approach.

In the conventional approach, cost is believed as the most significant factor for purchase of a technology. However, brand value has the highest contribution to the technology selection process. In other words, in maritime logistics, decision makers (ship owners, technical managers, operation managers, etc.) regard brand value of a producer as the most prominent factor by considering its transparency, validity, reliability, sufficiency, quality, and objectivity, financial position, behavioural and legal position. Some technologies in maritime logistics are called even as the most favour producer's name.

Logistics involves all transportation processes including plans, sustain and control the storage of goods, services and relevant operations from the beginning point to destination. Sea borne shipping is one the major transportation in the

logistics sector. It is considered that some of the most significant functions of logistics depend on safe, economic and fast transportation. Therefore, due to 90% of world trade is carried by sea borne transportation, navigational safety has crucial importance in terms of finance, environment and health. ECDIS is one of the most important and convenient navigational equipment. For that respect, safe shipping operations will result safe, economic and fast logistics activities.

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BIOGRAPHICAL NOTES

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