An Assessment of Global Factors towards the Financial Performance of a Containership Using a Bayesian Network Method

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ABSTRACT

The movement of containerised goods made 2009 debatably the most dramatic year in the history of the box. A Bayesian network methodology associated with the cause and effect analysis technique is introduced to analyse the global economic conditions, the container market demand and the bunker fuel price in order to measure the financial performance of a containership. This method demonstrates the combination of qualitative and quantitative criteria in order to ensure that the best possible decision can be made by a shipping company. As a consequence, the result provided by the Bayesian Network method can be used as an indicator for helping shipping lines plan a cost-effective business strategy.

Keywords: Bayesian Network Method; Uncertainty Treatment; Vessel Speed; Containership; Decision Making Technique.

1. INTRODUCTION

Before the global crisis, most shipping companies enjoyed very high profit margin in business operations on all loops. However, from the middle of 2008, most shipping lines suffered in operating their vessels due to the global financial turmoil and the sharp increase of bunker fuel price (Barillo, 2011). Such issues created a bad phenomenon in the international maritime trade. As a result, a trade demand was dramatically decreased on all the major routes (UNCTAD, 2009; Clarkson Research Services, 2009) and ultimately it caused a surplus in the containership service (Kontovas and Psaraftis, 2011). Therefore, most shipping lines looked for the cost-effective business strategy to ensure that their trades can be smoothly operated.

In late 2008, the world faced a financial crisis and economic recession, and soon after, the increase of bunker fuel price. As a result, the world gross domestic product (GDP) fell by 1.9% (Kontovas and Psaraftis, 2011). In the years 2007 to March 2009, container market demands fell by up to 10% (UNCTAD, 2009). Such an issue was not only due to low container demand, but also the vessel supply side. In 2007 and 2008, a massive increase in the orderbook was witnessed before the economic and financial crisis globally (Kontovas and Psaraftis, 2011). An oversupply of containerships and a decline in the container demand occurred in the same year as the global issues. Also, there is high pressure for shipping companies to reduce emissions produced by the container shipping sector (IMO, 2010). Due to such issues mentioned above, the revenue of the container shipping sector fell by 45% in 2009 compared to 2007 especially for A.P. Moller Maersk Group (lost $1 billion based on 2009 revenue) (Siyu, 2011).

As a consequence, most shipping companies decided to adopt a low steaming speed (22 knots or less). Such a speed has been implemented in the liner shipping markets since the second half of 2008 (Cariou, 2010). Generally, the reasons of implementing such a speed were due to the global crisis as follows:

i)   The downturn in the global economy resulting in reducing transportation capacity demand (UNCTAD, 2010; Wiesmann, 2010; Clarkson Research Services Limited, 2012).

ii)   The substantial global orderbook for new tonnage, a legacy from the boom years, resulting in record high deliveries of new ships (Kontovas and Psaraftis, 2011).

iii)   The global financial crisis (Holt , 2011; Wiesmann, 2010).

iv)   High fuel costs (Barillo, 2011; Kontovas and Psaraftis, 2011).

v)   The sudden fall in ship values (Wiesmann, 2010).

vi)   Increase of operating costs (manning, lubricant oil, maintenance, *etc.*) (Wiesmann, 2010).

vii)   Falling freight rates (UNCTAD, 2010; Kontovas and Psaraftis, 2011; Wiesmann, 2010).

viii) Introduction of the new regulation of the global warming and gas emissions (IMO, 2010; Kontovas and Psaraftis, 2011; Wiesmann, 2010).

Hence, selection of an appropriate steaming speed of containerships for a specific leg or loop of trade service is one of the most important decisions shipping lines have to make in order to reduce vessels' expenditure costs together with providing a good service performance to customers. The implementation of different levels of steaming speed will automatically influence the vessels' expenditure costs together with other elements such as total journey time, total number of vessels deployed, total fuel consumption, *etc.*.

There are very few published publications related to the container market demand and global economic conditions which are in connection with the vessel's speed. Several published journal and conference papers relating to the bunker fuel, emission and vessel's speed are found to deal with the fuel and emissions (Curtis, 2009; Percy *et al.*, 1996; Haglind, 2008; Buhuag *et al.*, 2009; *etc.*), the vessel's speed and emissions (Corbett *et al.*, 2009; Fagerholt *et al.*, 2009; *etc.*) and also the speed of vessel and energy (Pakroo, 2000). Notteboom and Vernimmen (2009) have written a journal paper on the effect of high fuel costs on liner service configuration in container shipping by using a cost model analysis. The purpose of that paper is to simulate the impact of bunker cost changes on the operational costs of liner services. The analysis process has been conducted using bunker fuel prices as an indicator. As described earlier, there are three main global factors influence the liner sector in the decision making process. By analysing only one of them, it may be inappropriate to demonstrate the real phenomena faced by shipping lines.

A containership owned by a shipping line is investigated in this paper. Thus, all costs including the capital, operational and voyage costs have to be covered by the shipping line (Institute of Chartered Shipbrokers, 2009). The capital costs are known as "fixed or standing costs". Such costs remain constant for a long period and have to be expended by a shipping line on monthly, quarterly or yearly basis, no matter if the vessels are employed. However, the operational and voyage costs are the most important costs involved in operating a containership. These costs include the crew's expenditure, administration and insurances costs, *etc.* from the original port to the destination port. Some of the sub-costs under the operational and voyage costs are dependent on the speed of the containership. In this paper, the vessel's speed has been formed into two categories which are full steaming speed and low steaming speed (Bonney and Leach, 2010).

The objective of this paper is to analyse the global economic conditions, the container market demand and the bunker fuel prices in order to measure the financial performance of a containership under uncertainty using a Bayesian Network (BN) method.

2. METHODOLOGY
The BN method was developed by Bayes in 1761 and Bayes' Theorem was published in 1763 (Bernardo and Smith, 1994). This method presents the fundamental concept of probabilistic graphical models or probabilistic networks. The characteristics of the BN method are described as a Directed Acyclic Graph (DAG) consisting of nodes, arcs and an associated set of probability tables (Eleye-Datuba *et al.,* 2006). *A Conditional Probability Table (CPT)* associated with each node denotes the strength of such causal dependence. According to Wang and Trbojevic (2007), *nodes* (usually drawn as circles) represent random (i.e. chance) variables such as events that take values from the given domains. *Arcs* are used to represent the direct probabilistic dependence relations among the variables. Each relationship is described by an arc connecting an influencing (parent) node to an influenced (child) node and has its terminating arrowhead pointing to the child node. The types of node can be categorised into four groups which are the Parent Node (directly preceding variables), Child Node (a node which is dependent on other variables), Root Node (a node which has no parent) and also Leaf Node (a node without children) (Hansen, 2000).

Besides, the BN model encodes the dependencies and independencies between variables. Each variable in a BN model is independent of its ancestors given the values of its parents. For that reason, the D-separation technique that has been proposed by Pearl (1986, 1988) is applied. The definition of d-separation is that two sets of nodes X and Y are d-separated in a BN by a third set Z (excluding X and Y) if and only if every path between X and Y is "blocked", where the term "blocked" means that there is an intermediate variable which is different from X and Y. A detailed

explanation can be found in such literature as Kjaerulff and Madsen, (2005), Neapolitan, (2004), Shachter (1998) and Pearl (1986, 1988).

2.1 The Bayes's Theorem
Bayes's theorem is a mathematical algorithm used for calculating the posterior probabilities. The purpose of this theorem is to measure the rational belief of probabilities. It is governed by the laws of probability and leans heavily on conditional probabilities in the theory of evidence and model. The fundamental rule of the probability can be symbolised as follows:

$$P(A \mid B) = \frac{P(B \mid A)\, P(A)}{P(B)} \qquad \text{(Eq. 1)}$$

where "$\mid$" means "given" or "on the conditional of"; P(A) is usually called the prior probability of A occurring;

P(A$\mid$B) is called the posterior probability of A occurring given the condition that B has occurred; P(B$\mid$A) is called

the likelihood distribution (conditional probability) of A occurring given that B occurs too; P(B) is the marginal

probability of B occurring and is effectively constant for the obtained data at hand.

$$P(A, B) = P(A \mid B)\, P(B) \qquad \text{(Eq. 2)}$$

where $P(A, B)$ is called as a joint probability. Bayes' rule provides a method for updating beliefs about an event A given the information about another event B. Such algorithms allow the impact of evidence about one node to propagate to other nodes in multiple-connected trees for making the BN method as a reliable engine for probabilistic inference. For comprehensive coverage study of this method, there are several references that can be used as guidance such as Pearl (1988), Neapolitan (1990, 2004), Jensen (1996, 2001) and Korb and Nicholson (2003).

3. AN ASSESSMENT OF GLOBAL FACTORS TOWARDS THE FINANCIAL PERFORMANCE OF A CONTAINERSHIP
Step 1: Identify the significant evaluation variables or nodes
The cause and effect analysis technique is used for the process of identifying nodes in this study. This approach explains how something could happen in the vessel's financial performance due to uncertain conditions, while simultaneously looking for a mechanism that could be used to explain about causality. Also, this technique can be used to define the major causes, sub-causes and root causes that influence the vessel's financial performance. It is also easy to visualise the possible relationships between causes which may be creating problems financially. The development of such a technique is as follows: for example, the high bunker fuel price is influencing a shipping company to employ a lower steaming speed. By implementing the lower steaming speed, it influences a shipping company to add a number of vessels for maintaining the sailing frequency. At the same time, the total journey time will be influenced by the vessel's speed of a containership. As a result, 21 significant nodes have been identified for this study. These are 1) global economic conditions, 2) container market demand, 3) bunker fuel price, 4) vessel speed, 5) journey time, 6) fuel consumption, 7) additional vessel, 8) manning cost, 9) stores cost, 10) repair and maintenance cost, 11) insurance cost, 12) administration cost, 13) operational costs 1, 14) operational costs 2, 15) voyage costs 1, 16) voyage costs 2, 17) total operational costs, 18) total voyage costs, 19) total expenditure costs, 20) ship revenue and 21) financial analysis. Generally, the number of nodes could be different according to the types of route and containerships size used by the shipping companies. Shipping companies can simply add or drop any nodes from the model based on the uncertainty situation faced by them. After discussion session with the selected experts, 21 nodes have been addressed as a fundamental idea for developing the BN model incorporating the uncertain situation faced by shipping companies in 2008/2009. Such 21 nodes have been selected through the literature surveys and suggested by the experts.

Step 2: Determine a number of states of each variable
By using the similar techniques described in Step 1 together with a brainstorming technique, the states of all nodes are determined. For example, the states "*high*" and "*low*" for the node "Bunker Fuel Price" are defined as higher than the mean price and lower than the mean price over the period of interest, respectively. Furthermore, the states "*more*

cost", "*normal cost*" and "*less cost*" for the node "Total Voyage Costs" are defined as more than the mean cost, the mean cost and less than the mean cost over the period of interest, respectively. Each node listed in Step 1 has a minimum of two states and a maximum of three states to be studied. Each state has its specific meaning. The focal point of this study is the node "Vessel Speed". It contains two states of "*full steaming*" (23-25 knots) and "*low steaming*" (22 knots and less). Table 1 summarises a list of nodes and their states in this study.

Table 1: The list of nodes and states for measuring the financial performance

No.	Node	States
1	Global Economic Conditions (GEC)	booming, stable, recession
2	Container Market Demand (CMD)	increase, decrease
3	Bunker Fuel Price (BFP)	high, low
4	Vessel Speed (VS)	full steaming, low steaming
5	Journey Time (JT)	increase, normal
6	Fuel Consumption (FC)	normal, reduce
7	Additional Vessel (AV)	0, 1
8	Manning Cost (MC)	increase, normal
9	Stores Cost (SC)	increase, normal
10	Repair and Maintenance Cost (RMC)	increase, normal
11	Insurance Cost (IC)	increase, normal
12	Administration Cost (AC)	increase, normal
13	Operational Costs 1 (OC1)	more cost, normal cost
14	Operational Costs 2 (OC2)	extra cost, zero cost
15	Voyage Costs 1 (VC1)	more cost, less cost
16	Voyage Costs 2 (VC2)	extra cost, zero cost
17	Total Operational Costs (TOC)	more cost, normal cost
18	Total Voyage Costs (TVC)	more cost, normal cost, less cost
19	Total Expenditure Costs (TEC)	more cost, normal cost, less cost
20	Ship Revenue (SR)	more, less
21	Financial Analysis (FA)	more profit, normal profit, less profit

Step 3: Develop a BN model

A qualitative BN model representing the financial performance of the container shipping sector is developed according to the nodes and states identified in Table 1 (Figure 1). The hierarchy development of such a model is using the Top-Down and Bottom-Up approaches. A Top-Down approach is defined as an approach that begins at the highest conceptual level and works down to the details. For example, the node "Vessel Speed" is influenced by nodes "Container Market Demand", "Global Economic Conditions" and "Bunker Fuel Price". There is an independent relationship between the nodes "CMD" and "GEC". For instance, if the node "*GEC=stable*", the node "CMD" could be increase and decrease. There is no direct link between these two nodes. The selection of steaming speed made on the node "Vessel Speed" will affect the other two child nodes, namely "Journey Time" and "Fuel Consumption". However, a Bottom-Up approach is defined as an approach that begins with details and works up to the highest conceptual level. For example, the nodes "Total Operational Costs" and "Total Voyage Costs" are influencing the node "Total Expenditure Costs".
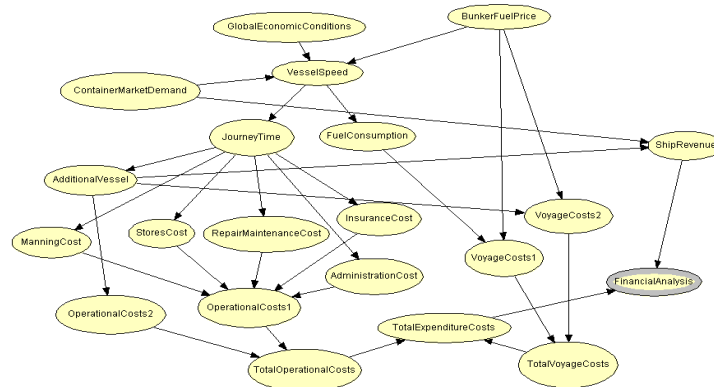
Figure 1: The BN model representing the financial performance of a containership

Step 4: Analyse the qualitative and quantitative data
The developed model can be mixture with both quantitative and qualitative dataset. The idea of using qualitative dataset in some parameters is to improve the prediction of the outputs when dealing with uncertainty situations. The outputs may be different if different outputs are used. In the real practice, shipping companies can use their own dataset in order to get the real output without affecting the model.

(i)   Quantitative data
There are two quantitative datasets in this study, namely 1) global economic conditions and 2) bunker fuel price. These datasets have been obtained from the Clarkson Research Services database. An analysis process has been conducted in order to obtain a probability value of each state of these two variables.
The time series data of the world GDP growth is collected from the year of 1998 to 2010 with the purpose of illustrating the performance of global economic conditions. There are 13 different growth rates of the world GDP for the period of 13 years. An indication has been determined to identify the difference between the three states of this node, "*booming*", "*stable*" and "*recession*". If the growth rate of the world GDP is below zero, it would automatically be grouped in the state "*recession*". 2009 falls into this category with -1.32% of growth rate. The other two states can be determined using a mean growth rate of the world GDP. The mean growth rate can be calculated as follows:

$$Mean = \frac{\Sigma X}{\Sigma N} \qquad\qquad\qquad (Eq. 3)$$

where *ΣX* is the total growth rate of the world GDP. It can be computed by adding up all growth rates of the world GDP from 1998 to 2010 and the result is 43.02%. *ΣN* is the total number of years. From 1998 to 2010, there are 13 years in total. By using Eq. 3, the mean growth rate of the world GDP is 3.309%. Thus, the percentage growth of the world GDP in the range between 0.00% and 3.309% will be grouped in the state "*stable*", while if the growth rate is 3.310% and above, then it would be grouped in the state "*booming*". As a result, the probability values of the states "*booming*", "*stable*" and "*recession*" are 0.538 (7/13), 0.385 (5/13) and 0.077 (1/13).

The same technique has been applied to the node "Bunker Fuel Price" in order to compute the probability values of the states "*high*" and "*low*". The 380cst of bunker fuel price ($/tonne) has been collected from Clarkson Research Services. Such a set of data contains 13 values representing annually data from 1998 to 2010. As a consequence, the probability values of the state "*high*" is (6/13) = 0.4615, while the probability values of the state "*low*" is (7/13) = 0.5385.

(ii)   Qualitative data
There are 19 qualitative datasets that have been gathered through a set of questionnaires and interview sessions with the selected shipping experts. In the set of questionnaires, each expert is required to tick a probability rate based on the situation discussed. Such a probability rate is divided into 2 parts which are 1) increase (right hand side) and 2) normal (left hand side). It starts from zero probability rate as a middle value to differentiate the probability rate between the

right and left hand sides. The terms used for both sides are depending on the states' names of each corresponding node. All probability rates given by the experts will be transformed into a probability value ranging from 0 to 1. Zero probability rate is a middle value that can be translated as 0.5000 of the probability value, while the probability rates from 1 to 5 on both right and left hand sides can be transformed to the probability value as shown in Table 2. The probability value of each node must be summed up to 1.0000, for instance 0.4300 (normal) + 0.5700 (increase) = 1.0000.

Table 2: The fundamental concept of the probability rate and probability value

0.0	0.1	0.2	0.3	0.4	**0.5**	0.6	0.7	0.8	0.9	**1.0**
5 normal	4	3	2	1	0	1	2	3	4	5 increase

Step 5: Prior and posterior probability distribution

The probability values of each node in the BN model will be computed using the *Hugin* software tool. The abbreviations listed in Table 1 are used to represent the corresponding nodes. To demonstrate the calculation process, the case in Figure 2 is examined.
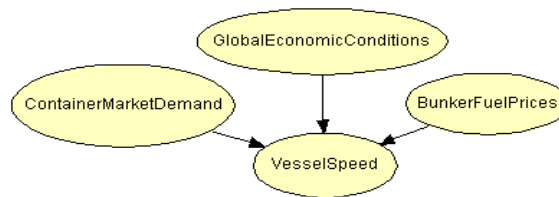

Figure 2: A BN model for analysing the conditional and unconditional probabilities

CPT for *Global Economic Conditions (GEC) (without conditions)*

GEC

booming	0.5380
stable	0.3850
recession	0.0770

For example, P(*GEC=recession*) = 0.0770

CPT for *Bunker Fuel Price (BFP) (without conditions)*

BFP

high	0.4615
low	0.5385

For example, P(*BFP=high*) = 0.4615

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CPT for *Container Market Demand (CMD) (without conditions)*

CMD

increase	0.5000
decrease	0.5000

For example, P(*CMD=decrease*) = 0.5000

CPT for *Vessel Speed (VS) (with conditions)*

Vessel Speed

GEC	booming				stable				recession			
CMD	*increase*		*decrease*		*increase*		*decrease*		*increase*		*decrease*	
BFP	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*
full steaming	0.8	1.0	0.1	0.6	0.733	0.995	0.05	0.5	0.6	0.8	0.0	0.1
low steaming	0.2	0.0	0.9	0.4	0.267	0.005	0.95	0.5	0.4	0.2	1.0	0.9

For example, P(*VS=full steaming* │ *BFP=high, CMD=decrease, GEC=recession*) = 0.0000

By using the conditional probability values given in the CPT for each node, the prior probability values can be obtained. For example, the prior probability value of the node "*VS=full steaming"* is calculated using Eq. 2 as follows:

$$P(VS = full\ steaming) = \Sigma P(BFP = high, BFP = low, CMD = increase, CMD = decrease, GEC = booming,$$

$$GEC = stable, GEC = recession)$$

$= (0.8 \times 0.4615 \times 0.5 \times 0.5380) + (1.0 \times 0.5385 \times 0.5 \times 0.5380) + (0.1 \times 0.4615 \times 0.5 \times 0.5380) + (0.6 \times 0.5385 \times 0.5 \times 0.5380) + (0.733 \times 0.4615 \times 0.5 \times 0.3850) + (0.995 \times 0.5385 \times 0.5 \times 0.3850) + (0.05 \times 0.4615 \times 0.5 \times 0.3850) + (0.5 \times 0.5385 \times 0.5 \times 0.3850) + (0.6 \times 0.4615 \times 0.5 \times 0.0770) + (0.8 \times 0.5385 \times 0.5 \times 0.0770) + (0.0 \times 0.4615 \times 0.5 \times 0.0770) + (0.1 \times 0.5385 \times 0.5 \times 0.0770)$

$= \underline{0.5974}$

The prior probability value of the node "*VS=full steaming*" is known to be 0.5974 while the one for "*VS=low steaming*" is 1.0000 – 0.5974 = 0.4026. Such values can also be calculated using the *Hugin* software tool as shown in Figure 3.
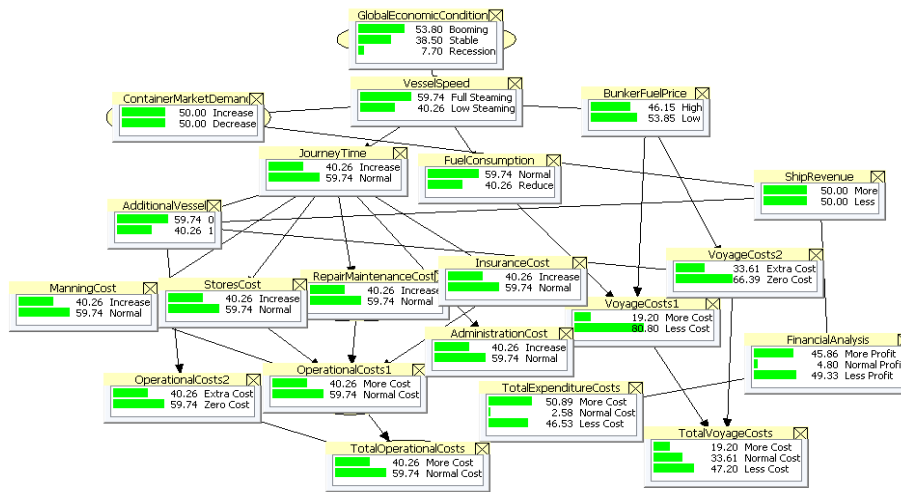
Figure 3: The pre-posterior probability value of the node "Vessel Speed"

The process of computing the prior probability values of the node "VS" is called pre-posterior analysis. To continue, a piece of evidence is entered to the node "*CMD=decrease*" with the purpose of determining the updated posterior probability values of the node "Vessel Speed". The posterior probability value of the node "*VS=low steaming*" given "*CDM=decrease*" is computed using Eq. 1.

$$P(VS = low\ steaming \mid CMD = decrease) = \frac{P(CMD = decrease, VS = low\ steaming)}{P(CMD = decrease)}$$

$$\frac{\Sigma P(CMD = decrease, VS = low\ steaming, BFP = high, BFP = low, GEC = booming,}{GEC = stable, GEC = recession)}$$

$$\frac{}{P(CMD = decrease)}$$

$$\frac{(0.9 \times 0.4615 \times 0.5 \times 0.5380) + (0.4 \times 0.5385 \times 0.5 \times 0.5380) + (0.95 \times 0.4615 \times 0.5 \times 0.3850)}{+ (0.5 \times 0.5385 \times 0.5 \times 0.3850) + (1.0 \times 0.4615 \times 0.5 \times 0.0770) + (0.9 \times 0.5385 \times 0.5 \times 0.0770)}$$
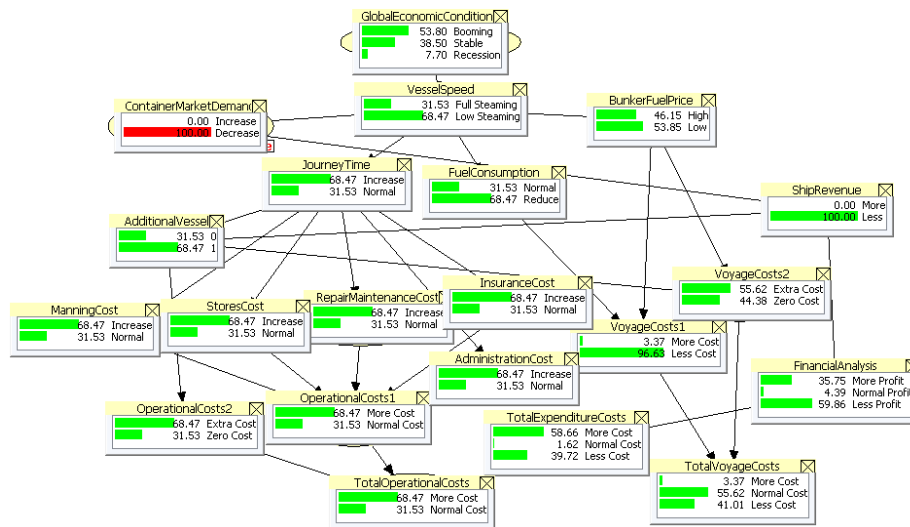
$$0.5000$$

$$= 0.6847$$

Figure 4: The analysis of the node "Financial Analysis" given evidence to the node "*CMD=decrease*"

After giving a piece of evidence to the node "*CMD=decrease*", the result shows that the new posterior probability value of the node "*VS=low steaming*" increases from 0.4026 to 0.6847 (Figure 4). Due to such an increase of the node "*VS=low steaming*", the posterior probability values of all nodes are significantly updated except the nodes "BFP" and "GEC" because there is no correlation between both nodes with the node "Container Market Demand". The idea of low steaming has been introduced in the shipping industry since the middle of 2008 when the container market demand slumped, the global economic recession and the sharp increase in bunker fuel price occurred. By giving evidence to the nodes "*CMD=decrease*", "*GEC=recession*" and "*BFP=high*", it drives shipping lines to 100% reduction of vessel's speed from full steaming to low steaming (Figure 5). By adopting the low steaming speed, the probability values of the node "*TEC=more cost*" is updated and increased from 0.5089 to 1.0000. Also, the node "*SR=less*" illustrates the increase of the probability values from 0.5000 to 1.0000. Finally, this model shows that the probability value of the goal node "*FA=less profit*" increases from 0.4933 to 1.0000.
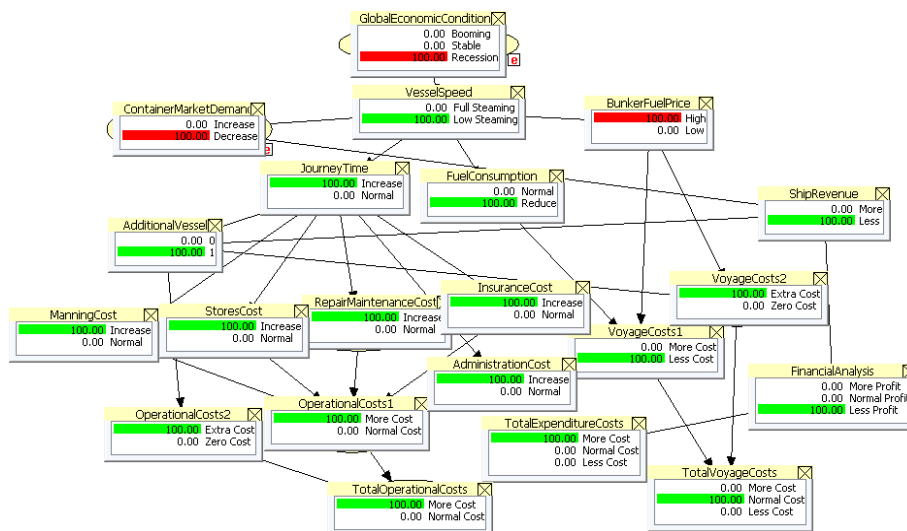

Figure 5: The analysis of the node "Financial Analysis" given evidence to the nodes "*BFP=high*", "*GEC=recession*"

and "*CMD=decrease*"

4. CONCLUSIONS

This paper uses a BN model for analysing the global economic conditions, the container market demand and the bunker fuel prices in order to measure the financial performance of a containership under uncertainty. A test case has been created with the purpose of demonstrating the general uncertain situations faced by shipping companies. The developed model is dynamic and enables to be used in different situation based on uncertain situations faced by shipping companies. In the real practice, shipping companies can add or drop any node or parameter based on the uncertain situation faced by them. The models can also be applied in different service routes due to the flexibility of dealing with uncertainty conditions. The output may be different if 1) different situations are adopted, 2) the total number of experts is more or less than three and 3) different inputs are included.

REFERENCES

Barillo, N. (2011). Slow steaming – NOI, Federal Maritime Commission. Washington, D.C. 1-8.

Bernardo, J.M. & Smith, A.F.M. (1994). Bayesian theory. John Wiley and Sons Ltd.

Bonney, J. & Leach, P.T. (2010). Slow boat from China. Journal of Commerce, February 1, 11 (5), 10-14.

Buhuag, O., Corbett, J.J., Endresen, O., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Mjelde, A., Palsson, C., Wanquing, W., Winebrake, J.J., & Yoshida, K., (2009). Second IMO greenhouse gas study. London: International Maritime Organization.

Cariou, P. (2010). The impact of speed reduction on liner shipping CO_2 emissions. WMU, Working Paper July.

Clarkson Research Services (2009). Shipping Sector Reports: Liner Vessels. Available from: http://www.clarksons.net.

Clarkson Research Services (2012). Containerships Deliveries 1996-2011. Clarkson Shipping Networks.

Corbett, J.J., Wang, H. & Winebrake, J.J. (2009). The effectiveness and costs of speed reductions on emissions from international shipping. Journal of Transportation Research Part D, 14 (8), 593-598.

Curtis, F. (2009). Peak globalization: climate change, oil depletion and global trade. Journal of Ecological Economics, 69 (2), 427-434.

Eleye-Datuba, A.G., Wall, A., Saajedi, A., & Wang, J. (2006). Enabling a powerful marine and offshore decision-support solution through Bayesian network technique. Risk Analysis, 26 (3), 695-721.

Fagerholt, K., Laporte, G. & Norstad, I. (2009). Reducing fuel emissions by optimizing speed on shipping routes. Journal of the Operational Research Society, 61 (3), 523-529.

Haglind, F. (2008). A review on the use of gas and steam turbine combined cycles as prime movers for large ships. Part III: Fuels and emissions. Journal of Energy Conversion and Management, 49 (12), 3476-3482.

Hansen, A.F. (2000). Bayesian networks as a decision support tool in marine applications. Department of Naval Architecture and Offshore Engineering, Technical University of Denmark.

Hayes, K. (1998). Bayesian statistical inference in ecological risk assessment. Centre for Research on Introduced Marine Pests, Technical Report 17.

Holt, T. (2011). Quantim – a containership for the future, Engineers Australia – Sydney Division Presentation, Joint RINA/IMarEst Technical Presentation, 2 March.

Institute of Chartered Shipbrokers (2009). Economics for sea transport and international trade. Seamanship International Ltd.

International Maritime Organization (IMO) (2010). Annex VI of the IMO MARPOL Convention, London.

Jensen, F.V. (1996). An introduction to Bayesian networks. Springer-Verlag New York, Inc.

Jensen, F.V. (2001). Bayesian networks and decision graphs. Springer-Verlag New York, Inc.

Jensen, F.V. & Nielsen, T.D (2007). Bayesian networks and decision graphs. 2nd ed.. Springer Science and Business Media, LCC.

Kjaerulff, U.B. & Madsen, A.L. (2005). Probabilistic networks — an introduction to bayesian networks and influence diagrams. Aalborg University Press, Denmark.

Kontovas, C.A. & Psaraftis, H.N. (2011). The link between economy and environment in the post crisis era: lessons learned from slow steaming. Available from: www.stt.aegean.gr/econship2011/index.php.

Korb, K.B. & Nicholson, A.E. (2003). Bayesian artificial intelligence. Chapman & Hall/CRC Press.

Neapolitan, R.E. (1990). Probabilistic reasoning in expert systems: theory and algorithms. John Wiley and Sons, Inc.

Notteboom, T.E. & Vernimmen, B. (2009). The effect of high fuel costs on liner service configuration in container shipping. Journal of Transport Geography, 17 (5), 325-337.

Pakroo, H. (2008). Impact of slow steaming options on energy efficiency. In: Tozer, D. (2008) Container ship speed matter. Lloyd's Register. 49-50.

Pearl, J. (1986). Fusion, propagation and structuring in belief networks. Artificial Intelligence, 29 (3), 241-288.

Pearl, J. (1988). Probabilistic reasoning in intelligent systems: networks of plausible inference. Morgan Kaufmann Publishers.

Percy, R., Vincent, J. & Fingas, M. (1996). Bunker 'C' fuel oil and the irving whale. Environment Canada, Government of Canada, Montreal.

Shachter, R.D. (1998). Bayes-ball: The rational pastime (for determining irrelevance and requisite information in belief networks and influence diagrams). Proceedings of the 14th Conference on Uncertainty in Artificial Intelligence, 480-487.

Siyu, Z. (2011). Moller-Maersk staying afloat, China Daily. Available from:
http://www.chinadaily.com.cn/bizchina/2011-12/22/content_14304715.htm

Ullman, D.G. & Spiegel, B. (2006). Trade studies with uncertain information. Sixteenth Annual International Symposium, INCOSE.

UNCTAD (2009). Review on Maritime Transport 2009. United Nations Publication.

UNCTAD (2010). Review on Maritime Transport 2010. United Nations Publication.

Waldo, J. (2009). Memphis role in the global/national transportation picture the importance of our infrastructure. Global Insight Inc.

Wang, J. & Trbojevic, V. (2007). Design for safety of large marine and offshore engineering products. Institute of Marine Engineering, Science and Technology.

Wiesmann, A. (2010). Slow steaming – a viable long-term option?. Wartsila Technical Journal, 2, 49-55.

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