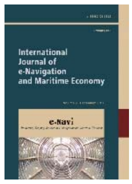
e-Navi

Available online at www.e-navigation.kr
e-Navigation Journal



Original article

Analyzing and Predicting a Containership's Departure Punctuality in Liner Operations under Different Environments ☆

N. H. MOHD SALLEH[a], A. H. SAHARUDDIN[b*]

[a] School of Maritime Business and Management, Universiti Malaysia Terengganu, Malaysia, haqimin@umt.edu.my
[b *]School of Maritime Business and Management, Universiti Malaysia Terengganu, Malaysia, sdin@umt.edu.my, Corresponding Author

Abstract

The punctuality of containerships has become the prevalent issue in container liner shipping operations, as the on-time arrival of a containership at the next port of call is paramount. When a delay occurs at the previous port of call, it may also cause a delay at the next port of call. This paper proposes a departure punctuality model of analysis. This model employs a Fuzzy Rule-Based Bayesian Belief Network (FRBBN) for predicting the departure punctuality of a containership. To ensure the reliability of the model, two containerships were tested. The results show that the prediction values from the model are between 95.6% and 99% accurate provided that no tactical strategy is implemented during the voyage. In addition, the most significant factors that determine the punctuality of departure were found to be punctuality of arrival at the same (base) port prior to departure, dangerous events and other unexpected delays during the port stay. It is expected that this model is capable of helping researchers and practitioners to understand the influence of the dynamic environment and to make predictions on the departure punctuality of containerships.

Keywords: Departure punctuality, liner operations, schedule reliability, Fuzzy Bayesian Belief Network, Fuzzy Rule-Based

Peer review under responsibility of International Association of e-Navigation and Ocean Economy.

☆ This is a revised version presented at the 4th Ai-MAST held at Mokpo, Korea, December 12-14, 2016.

1. Introduction

In today's liner shipping operations, managing time has become a critical task for Liner Shipping Operator (LSO). The statistics in 2015 have shown that only 73% of containerships achieved their punctuality target on all trades (Drewry Shipping Consultants, 2015). Although this figure was the highest ever recorded, it needs to be improved through every possible mechanism. Containership delay can cause substantial handling disruption and underutilization of resources for both port and LSO, which finally results in high financial consequences. Containerships may be delayed due to port congestion, port inefficiency, poor vessel conditions, rough weather, and the incapability and unreliability of agencies that represent the LSO at each port of call (Mohd Salleh et al., 2016). These are all major factors that may obstruct LSOs from offering punctual services to shippers. It is noteworthy to mention that in determining the punctuality of a containership, two aspects are considered: the arrival and departure of containerships to/from a port of call. In liner shipping operations, these two aspects are interrelated. If a containership is delayed during her arrival to a particular port of call, there will be a delay in her departure from the same port. Based on Mohd Salleh et al.'s study, the sensitivity analysis has shown that, if a containership has a serious departure delay (i.e. more than 48 hours) from her previous port of call, the probability of a containership to arrive at the next port of call on-time is 0%. Therefore, this paper will focus on analyzing and predicting the departure punctuality of a containership from a port of call in different environments.

The remainder of this paper is organized as follows. The literature review is explained in Section 2. Section 3 demonstrates the research methodology for analyzing and predicting departure punctuality of a containership. A test case is shown in Section 4 and their results are further discussed in Section 5. Finally, the conclusions are given in Section 6.

2. Literature Review

Punctual performance depends on many factors such as port conditions, vessel conditions, process management efficiency (i.e. agency) and the knock-on effects of delays. Port congestion has a profound influence on both arrival and departure punctuality. Notteboom (2006) claimed that port congestion remains by far biggest cause of containership delay where the density of the service input has exceeded the maximum capacity of a port's normal operation. Gurning (2011) argued that port congestion can lead to consequences for the port operations that then result in the unreliability of the liner operations. Firstly, it can minimize the accessibility and availability of various port and shipping services by generating delays or additional waiting time for ships and cargos. Secondly, port congestion can reduce the utilization of port facilities. Finally, port congestion ultimately diminishes the availability of essential services such as cargo handling operations at berth, yard, warehouse and open-shed, hinterland connection and inland container depot.

Due to the increase in the volume and capacity constraints in many ports around the globe, berth availability on arrival at a port is not always guaranteed (Notteboom, 2006). Containership departure can be disrupted by a restrictive tidal window, the delay of pilotage and towage, and the weather conditions at a port (Jason et al., 2002; Merrick and Dorp, 2006; Gurning, 2011). In some conditions, the access channel is clear but the containership is still unable to berth on-time due to poor terminal performance (e.g. inefficiency of administrative processes and inland corridor congestion) and congestion, leading to long queues of containerships. Terminal performance is a significant factor for determining the departure punctuality. Departure delays at ports of call mainly happen because of low terminal performance. To determine the performance of a terminal, two main areas (i.e. berthing area and port yard conditions) can be assessed (Gurning, 2011). The berthing area can be assessed using a berth occupancy ratio (BOR), while port yard can be assessed using yard utilization (Mwasenga, 2012).

Outside of port channel conditions and terminal performance, several other factors such as administration processes, inland corridors and country reliability also can cause a delay to a containership's arrival and departure (Sawhney and Sumukadas, 2005; Lewis et al., 2006; Woodburn; 2007; Gurning, 2011). Gurning (2011) argued that customs procedures and port clearance processes are still very severe logistical hindrances. Containership delays and rerouting may occur due to slow tracking including the inspection of cargo handled by customs at ports. Gurning (2011) also claimed that inland access roads must always flow freely in order to ensure that a port is operating smoothly.

Vessel conditions also have a profound influence on arrival and departure punctuality. Delays can happen due to the unreliability of a containership. When a containership is unable to transport containers and crew in a safe, secure and timely manner, it is called unreliable. In this paper, vessel conditions that may affect the departure punctuality were grouped into two main areas; vessel operational performance and unforeseen events during port stay. Williams and Treadaway (1992) and Shrivastava (1993) claimed that, although port congestion was the main source of schedule unreliability with regard to liner operations, onboard machinery breakdown also to a smaller extent also contributed to the unreliability of a vessel. Machinery breakdown (e.g. engine failure) could happen during a voyage or during a port stay. If it happens during a voyage, the probability of a delayed arrival is high while if it happens during a port stay and is not fixed immediately, the probability of departure delay is also high.

Gaonkar et al. (2011) stated that containerships face several unforeseen events such as dangerous events (e.g. pirate attacks, armed robbery, looting and ship hijacking, *etc*.) and other unexpected delays (e.g. war, ship captain or crew deaths, detained by port authority, *etc.*). These events can cause unexpected setbacks which can lead to departure delays or stoppages. Although the likelihood of these unforeseen events is occasional, they have the potential to disrupt the vessel's operation.

Container shipping lines can improve their containership punctuality by improving process management efficiency such as by having a good coordination of market players (e.g. port authority, customs, forwarder and shippers), enhancing staff's sense of mission and having an efficient local strategy at each port of call. At each port of call, an agency plays all these roles on behalf of its LSO (Mohd Salleh et al., 2015). An agency is designated to handle shipments and cargo at a port on behalf of its LSO. They have to ensure that essential supplies, crew transfers, customs documentation and waste declarations are all arranged with the local port without delay. The duties of the agency consist of many matters such as providing suitable office premises equipped with telecommunication facilities and computer systems installed with the necessary software and hardware, as well as maintaining all systems of the shipping line within the territory for running the business and electronic data exchange with the LSO, other agencies, and third parties relating to its shipping operation. In addition, the agency is also responsible for providing qualified staff to carry out all shipping line services and business activities; to arrange pilotage and towage, mooring, and other necessary requirements for containership arrival and departure; to keep operations smooth and punctual, including preparing all the necessary shipping documents correctly and in time for meeting the operation and customs/ authorities' formal requirements. Based on the above duties, agencies play an important role in maintaining the reliability of the liner operation as well as ensuring the smoothness of a containership's arrival and departure. If agencies are not performing their duties well, the liner operation may be affected, which results in delays to containership's arrival and departure.

One of the main factors influencing departure punctuality from port of call is formed by the knock-on effects of a delay (Vernimmen et al., 2007). An arrival delay occurring at the port of call will usually cause a departure delay from the same port of call. The knock-on effects of a delay will spread throughout the whole network if there is no strategy in place to address this.

The deviation of the estimated time of departure (ETD) compared to actual time of departure (ATD) can be formulated as follows:

$$\Delta\ Departure = ATD – ETD \quad (1)$$

2.1. Fuzzy Rule-Based Bayesian Belief Network (FRBBN)

A FRBBN is a hybrid method that results from a combination of two methods; Fuzzy Rule-Based (FRB) and Bayesian Belief Network (BBN). Generally, this hybrid method employs IF-THEN rules which can simply adapted by fuzzy conditional statements (Sii et al., 2001; Mohd Salleh et al., 2016). For example, IF the occurrence of flood (X_1) is frequent and its severity (X_2) is disastrous and the impact cost is very high (X_3) THEN the risk level of flood (Y) is very high.

A foundation of FRBBN formula can be calculated using Eq. 2 as follows (Yang et al., 2009):

$$IF\ X_1, X_2\ and\ \ldots\ X_N,\ THEN\ Y \quad (2)$$

where X_i $(i = 1, 2, \ldots, N)$ is the ith piece of evidence and Y is a hypothesis suggested by evidence. Each X_i and the hypothesis (Y) of a rule are propositional statements. Later, it is able to incorporate with the belief rule-base and can be defined as follows (Yang et al., 2009; Zhou et al., 2011):

$$R_k: IF\ X_1^k,\ X_2^k\ and\ \ldots X_M^k,\ THEN\ \{(\beta_{1k}, Y_1), (\beta_{2k}, Y_2), \ldots (\beta_{Nk}, Y_N)\} \quad (3)$$

where X_j^k $(j \in \{1, 2, \ldots, M\}; k \in \{1, 2, \ldots, L\})$ is the referential value of the jth antecedent attribute in the kth rule, M is the number of *antecedent* attributes used in the kth rule and L is the number of rules in the rule-base. β_{ik} $(i \in \{1,2,\ldots,N\};\ k = \{1,2,\ldots,L\}$, with L as the number of the rules in the rule-base) is a belief degree to Y_i $(i \in 1, 2, \ldots, N)$ called the *consequent* if, in the kth packet rule, the input satisfies the packet antecedents $X^k = \{X_1^k, X_2^k, \ldots, X_M^k\}$.

For determining the conditional probability table (CPT) by using an FRBBN, Eq. 3 can be further expressed as shown in Eq. 4 (Zhou et al., 2011):

$$P(Y_i | X_1^k, X_2^k, \ldots, X_M^k) = \beta_{ik} \quad i = 1, 2, \ldots, N \quad (4)$$

Finally, Bayes' chain rules can be used to calculate combination of rules and generate final values.

3. Methodology

The aim of the paper is to analyze the departure punctuality of a containership from a port of call in uncertain environments by using a hybrid technique, which is the FRBBN. For analyzing and predicting the departure punctuality of a containership, as shown in Figure 1, six main steps are followed.

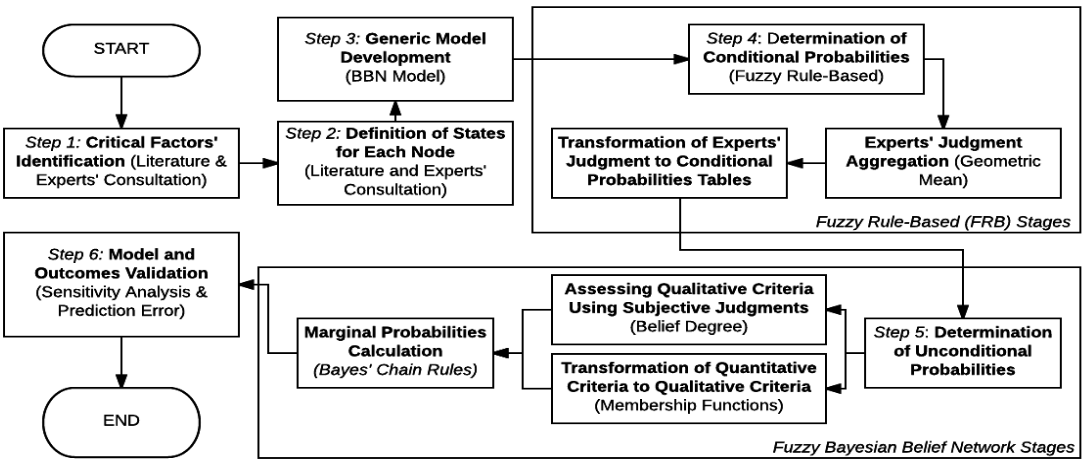


Figure 1: Research Methodology for Analyzing and Predicting a Containership's Departure Punctuality

Step 1: The critical influential factors for analyzing and predicting departure punctuality are identified.

Step 2: States of each node are defined by reviewing the literature as well as by consulting with experts.

Step 3: The model for analyzing and predicting the departure punctuality is constructed using a BBN model.

Step 4: The strength of the direct dependence of each child node to its associated parents is quantified by assigning each child node a CPT by using an FRB approach.

Step 5: The unconditional probabilities are determined by the collection of data and assigning assessment grades to them.

Final step (Step 6): The departure punctuality model and its outcomes are validated by using sensitivity analysis and prediction errors.

4. Test Case

In order to ensure the proposed model can be employed in a real situation, this departure model will be tested by using two cases. Test case 1 will be shown in this section while only the final result of test 2 will be shown. The details of the containership (*Vessel*$_A$) and port (*Port*$_A$) involved in this case are listed in Table 1 and 2 respectively.

Table 1: ANNs output performance

Details	Vessel$_A$
Vessel Type	Container Ship
Gross Tonnage	17068
Deadweight	21206 tons
Length x Breadth	186 m x 25 m
Year Built	2009
Draught	9.5 m
Distance	554 nm

Table 2: The Background of Port$_A$

Details	Port$_A$
Berths Capacity	12 Berths forming 4.3km of linear wharf
Yard Capacity	200,000 TEUs
Annual Handling Capacity	8,400,000
Quay Crane Capacity	44 Quay-side cranes
Berth Occupancy Ratio	57.45%
Yard Utilization	54.79%
Average Truck Turnaround Time	24.20inutes

4.1. Identifying the Critical Influential Factors

The process of identifying the critical influential factors involves several steps such as listing of influential factors, and then analyzing them by using a cause and effect analysis. An extensive literature review and consultations with experts are used to identify the critical factors that influenced the departure punctuality of a containership. Through the extensive literature review, firstly, the 28 influential factors (i.e. nodes in the model) are identified. Secondly, these factors are further revised and reduced (i.e. 22 factors) by the domain experts (i.e. due to the complexity of the model and some eliminated factors are not significantly determined the punctuality of a liner vessel). Finally, as shown in Table 3, the revised influential factors are selected.

Table 3: The Summary of Identified Factors for Analyzing the Departure Punctuality

Main Criteria	Sub-criteria	Sub-sub-criteria	References
Port Conditions	Channel Conditions during Departure Process	Punctuality of Pilotage Operation	Jason *et al*., (2002), Sawhney and Sumukadas (2005), Lewis *et al.* (2006), Merrick and Dorp (2006), Notteboom (2006), Woodburn (2007), Bosch (2008), and Gurning (2011).
		Weather Condition at Port	
		Tidal Window	
	Terminal Conditions	Berthing Area Condition	
		Port Yard Condition	
		Miscellaneous Factors	
	Miscellaneous Factors	Port Administration Process	
		Inland Corridors	
		Country Reliability	
Vessel Conditions	Vessel Operational Performance	Machinery Breakdown	Williams and Treadaway (1992), Shrivastava (1993), Notterboom (2006), Gaonkar *et al.* (2011), Rodrigue and Notteboom (2013).
		Ship Staff's Reliability	
	Unforeseen Events	Dangerous Events	
		Other Unexpected Delays	
Arrival Punctuality at the Same Port			Vernimmen *et al*. (2007).
Agency			Mohd Salleh *et al*. (2015).

4.2. Defining the States of the Nodes

In step 2, the number of states of each node has is identified by using an extensive literature review. A discrete fuzzy set membership function can be applied to define the states of each node. A consistent numbers of states for each node can provide simplicity in the process of evaluation as decision-makers can perform the evaluation based on an identical number and term of linguistic variables. It is worth mentioning that the number of states of each node used in the model can affect the complication of the calculations (i.e. CPT and Bayes' chain rules); therefore, it needs to be carefully defined. As a result, the states of each node in the departure model are illustrated in Table 4.

Table 4: The Summary of Identified Factors for Analyzing the Departure Punctuality

No	Nodes	States
1.	Departure Punctuality	On-time, Delay, Serious Delay
2.	Port Conditions	Smooth, Crowded, Densely Congested
3.	Vessel Conditions	Good, Average, Poor
4.	Agency	Highly Reliable, Medium Reliable, Lowly Reliable
5.	Arrival Punctuality at the Same Port	On-time or Resolved, Delay, Serious Delay
6.	Channel Conditions during Departure Process	Smooth, Average, Poor
7.	Terminal Conditions	Smooth, Crowded, Densely Congested
8.	Miscellaneous Factors	Smooth, Average, Poor
9.	Vessel Operational Performance	High, Medium, Low
10.	Unforeseen Events	Not Occurred, Occurred
11.	Weather Condition at Port	Excellent, Moderate, Rough
12.	Punctuality of Pilotage Operation for Departure Process	On-time, Delay, Serious Delay
13.	Tidal Window	Not Restrictive, Restrictive
14.	Berthing Area Condition	Smooth, Crowded, Densely Congested
15.	Port Yard Condition	Smooth, Crowded, Densely Congested
16.	Port Administration Process	Highly Efficient, Medium Efficient, Lowly Efficient
17.	Inland Corridors	Freely Flow, Crowded, Densely Congested
18.	Country Reliability	High, Medium, Low
19.	Ship Staff's Reliability	Highly Reliable, Medium Reliable, Lowly Reliable
20.	Machinery Breakdown	Not Occurred, Minor Breakdown, Major Breakdown
21.	Dangerous Events	Not Occurred, Occurred
22.	Other Unexpected Delays	Not Occurred, Occurred

4.3. Developing a Model for Departure Punctuality

In this paper, a departure punctuality model is developed by using a BBN model. Based on the identified factors and their states as discussed in Sub-sections 4.1 and 4.2, the BBN model for the departure punctuality is shown in Figure 2. As shown in Figure 2, the node "departure punctuality (DP)" has four parent nodes, namely "arrival punctuality at the same port (APSP)", "port conditions (PC)", "vessel conditions (VC)" and "agency (AGENCY)". The parent nodes that influence the node "PC" consist of "channel conditions during departure process (CCdDP)", "terminal conditions (TC)" and "miscellaneous factors (MISC)". The parent nodes that influence the node "CCdDP" consist of "punctuality of pilotage operation for departure process (PPfDP)", "tidal window (TW)" and "weather condition at port (WCaP)". The node "TC" has two parent nodes, namely "berth area condition (BAC)" and "port yard condition (PYC)"; whereas the node "MISC" has three parent nodes, namely "port administration process (PAP)", "inland corridors (IC)" and "country reliability (CR)". The node "vessel conditions" has two parent nodes, namely "vessel operational performance (VOP)" and "unforeseen events (UE)". "Machinery breakdown (MB)" and "ship staff's reliability (SSR)" are the two parent nodes of the node "VOP". Finally, "dangerous events (DE)" and "other unexpected delays (OUD)" are the two parent nodes that influence the node "UE".

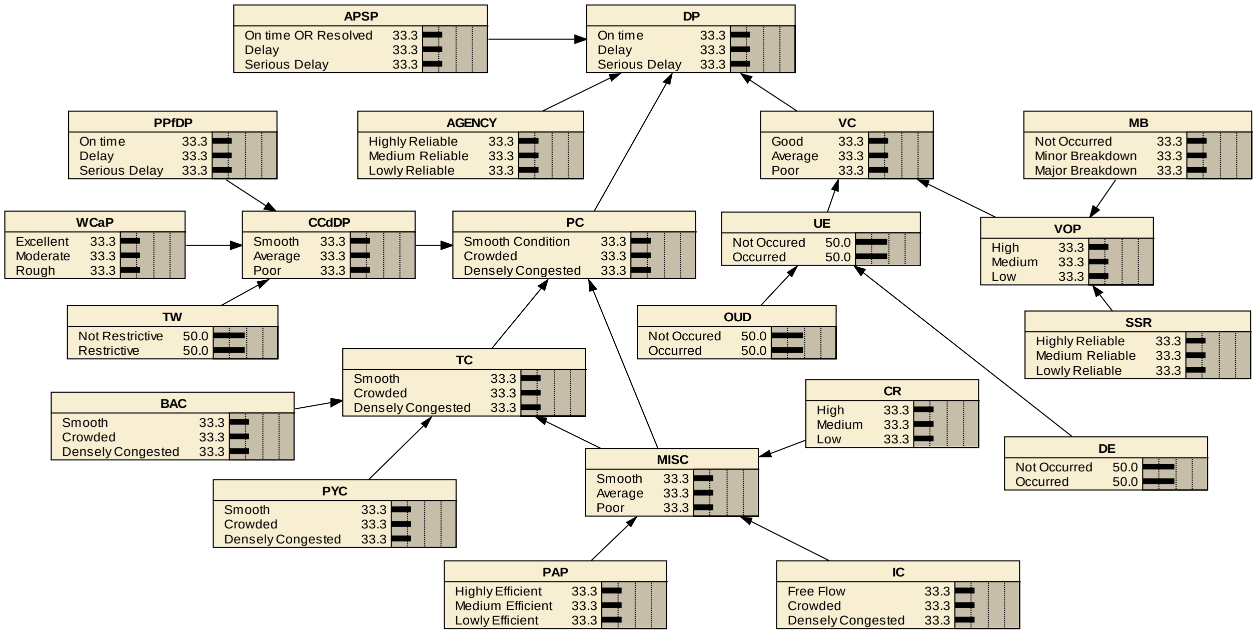


Figure 2: A BBN Model for Departure Punctuality (Without Data)

4.4. Determining the Conditional Probabilities

For determining the conditional probability distributions for the child nodes (i.e. “CCdDP”, “TC”, “MISC”, “VOP”, “UE”, “PC”, “VC” and “DP”) in the departure punctuality model, the FRB approach will be used. To assign conditional probability distributions using the FRB approach, four domain experts with more than 15 years of experience in the liner shipping operations are selected. The details of the four experts are listed as follows:

1. A ship manager/planner of an international liner shipping company in Malaysia who has been involved in industrial operations for more than 18 years.
2. A senior ship manager of an international liner shipping company in Malaysia who has been involved in industrial operations for more than 15 years.
3. A senior lecturer who has been involved in the maritime industry for more than 20 years.
4. An operations executive of an international liner shipping company in Malaysia who has been involved in liner shipping operations for more than 15 years.

4.5. Determining the Unconditional Probabilities

For assessing the unconditional probabilities of all the root nodes, membership functions need to be constructed. For example, the unconditional probabilities of root nodes for the arrival punctuality at the same port (APSP) are assessed as follows:

Based on Figure 3, if a vessel arrives at a port of call on her ETA, then the vessel is considered as on-time. If a vessel arrives at a port 24 hours after her ETA, then the vessel is considered delayed. If a vessel arrives at a port 48 hours or more after her ETA, then the vessel considered as seriously delayed. Prior to the departure, $Vessel_A$ arrived 18 minutes earlier than her ETA. As a result, the set for the arrival punctuality at the same port is evaluated as:

1. H_n is On-time
2. H_{n+1} is Delay
3. $h_i = 0$, $h_{n,i} = 0$ and $h_{n+1,i} = 24$
4. $\beta_{n,i} = (24\text{-}0) / (24\text{-}0) = 1$ with On-time

$APSP$= {(On-time, 1), (Delay, 0), (Serious Delay, 0)}

The sets for all the root nodes are obtained and shown in Table 5. These sets are used for the evaluation of the unconditional probability distribution of the root nodes.

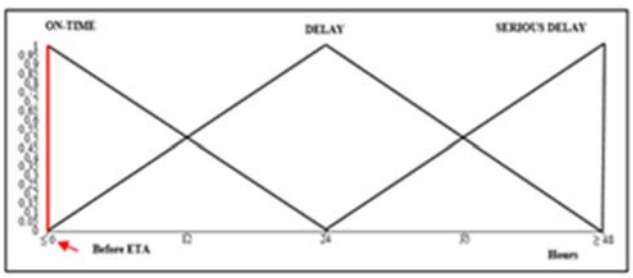


Figure 3: Membership Functions for the Node “APSP”

Table 5: The Belief Degrees of all Root Nodes

Root Nodes	Sets
APSP	{(On-time, 1), (Delay, 0), (Serious Delay, 0)}
WCaP	{(Excellent, 1), (Moderate, 0), (Rough, 0)}
PPfDP	{(On-time, 1), (Delay, 0), (Serious Delay, 0)}
TW	{(Not Restrictive, 0.3333), (Restrictive, 0.6667)}
BAC	{(Smooth, 1), (Crowded, 0), (Densely Congested, 0)}
PYC	{(Smooth, 1), (Crowded, 0), (Densely Congested, 0)}
PAP	{(Highly Efficient, 1), (Medium Efficient, 0), (Lowly Efficient, 0)}
IC	{(Smooth, 1), (Crowded, 0), (Densely Congested, 0)}
MB	{(Not Breakdown, 1), (Minor Breakdown, 0),(Major Breakdown, 0)}
SSR	{(Highly Reliable, 0.8413), (Medium Reliable, 0.1587), (Lowly Reliable, 0)}
DE	{(Not Occurred, 1), (Occurred, 0)}
OUD	{(Not Occurred, 1), (Occurred, 0)}
CR	{(Highly Reliable, 0.3429), (Medium Reliable, 0.5788), (Lowly Reliable, 0.0783)}
AGENCY	{(Highly Reliable, 0.7700), (Medium Reliable, 0.2092), (Lowly Reliable, 0.0208)}

Once conditional and unconditional probabilities have been obtained, the marginal probabilities can be calculated by using Bayes' chain rules. In this paper, the *Netica* software is employed to perform this calculation. As a result, based on Figure 4, the marginal probability of *Vessel$_A$* departing from *Port$_A$* on-time is 59.4% (i.e. test case 1).

4.6. Validating the Model and Results (Step 6)

For the validation through sensitivity analysis, test case 1 is chosen and the two Axioms described as follows, are used (Mohd Salleh et al., 2016).

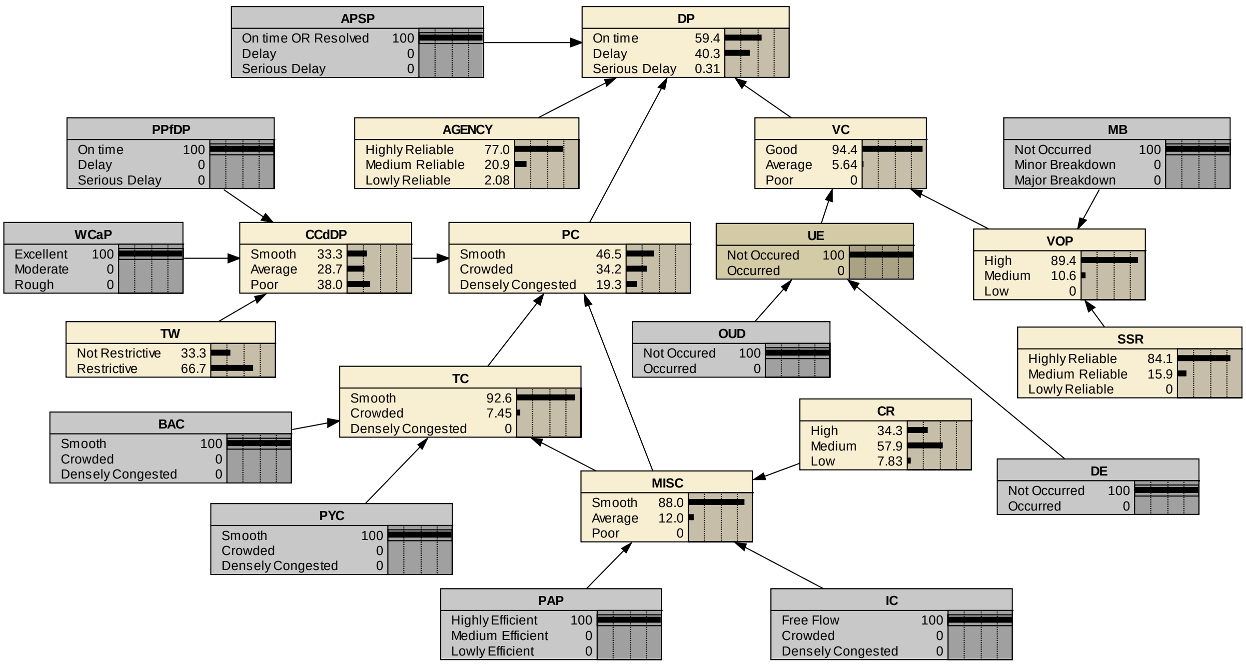


Figure 4: The Probability Set for the Departure Punctuality (Test Case 1)

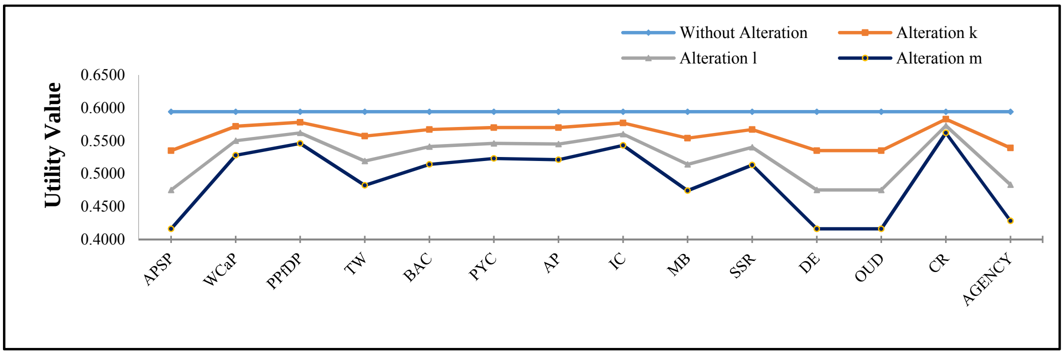


Figure 5: Representation of Axioms 1 and 2

Axiom 1: A slight increase or decrease in the degree of membership associated with any states of an input node will certainly result in a relative increase or decrease in the degree of membership of the highest-preference state of the model output.

Axiom 2: If the degree of membership associated with the highest-preference state of an input node is decreased by l and m (simultaneously the degree of membership associated with its lowest-preference state is increased by l and m ($1>m>l$)), and the values of the model output are evaluated as U_l and U_m respectively, then U_l should be greater than U_m.

The degree of membership for the highest preference state of an input node is decreased by 0.1, 0.2 and 0.3 respectively and simultaneously the degree of membership for the lowest preference state is increased by 0.1, 0.2 and 0.3 respectively. The "on-time" values are assessed in Figure 4 and the results shown in Figure 5. The obtained results are in harmony with the two Axioms.

To test the accuracy of the model, the model is validated by using prediction error. Based on Figure 4 (i.e. test case 1), the outcome of the model (i.e. the marginal probability of $Vessel_A$ departing from $Port_A$ on-time) was evaluated at 59.4%. Based on the real record obtained from the ship manager of $Vessel_A$, the Δ departure of $Vessel_A$ from $Port_A$ is +8 hours and 42 minutes and can be considered to be on time 63.8% of the time ((24 hours–8.7 hours) / (24 hours–0 hours) × 100%). The prediction error is calculated as 4.4% (i.e. 59.4% - 63.8%). As a result, the outcome of test case 1 is considered to be reasonable (i.e. less than 10%) and it can be concluded that the developed result in this model is reasonable. The summary of prediction errors for test cases 1 and 2 is presented in Table 6.

Table 6: The Belief Degrees of all Root Nodes

Test	Model Output	Real Time	Difference
1	59.4%	63.8%	4.4%
2	68.9%	67.9%	1%

5. Result and Discussions

The departure punctuality value is not fixed and it will change with its associated criteria. In order to test the most significant events, the degree of membership for the lowest preference state of each criterion is assigned at 100%. Based on Figure 4, the marginal probabilities of $Vessel_A$ departing from $Port_A$ on-time are evaluated and shown in Table 7.

Table 7: Departure Punctuality's Value at Different Situations

Change of Event	On-time	Rank
Arrival punctuality is 100% serious delay	0%	1
Weather condition at port is 100% rough	43.2%	10
Pilotage operation punctuality is 100% serious delay	37.4%	8
Tidal window is 100% restrictive	47%	11
Berthing area condition is 100% densely congested	32.6%	4
Port yard condition is 100% densely congested	35.5%	7
Administration process is 100% low efficiency	35%	6
Inland corridors is 100% densely congested	42.5%	9
Machinery breakdown is 100% major	19.4%	3
Ship's staff are 100% low reliability	33.7%	5
Dangerous events occur	0%	1
Other unexpected delays occur	0%	1
Country reliability is 100% low reliability	51.1%	12
Agency is 100% low reliability	11.6%	2

As shown in Table 7, the model output is more sensitive to the arrival punctuality prior to the departure time, dangerous events and other unexpected delays, respectively. The reliability of agency is ranked 2nd and a vessel's machinery breakdown during her port stay is ranked 3rd. As a result, by guaranteeing the arrival punctuality, minimizing the possibility of an unforeseen event, enhancing the reliability and capability of an agency, and minimizing the possibility of a vessel's machinery breakdown during her port stay, the probability of $Vessel_A$ departing from $Port_A$ on-time is enhanced.

The influence of the arrival punctuality of $Vessel_A$ at $Port_A$ based on her departure punctuality from that port was proven. If the arrival punctuality of $Vessel_A$ to $Port_A$ is assessed as a 100% serious delay, the probability of $Vessel_A$ departing from $Port_A$ on-time is 0%. As a result, to enhance the departure punctuality of a vessel, a ship manager should ensure that the containership under his/her supervision always arrives on-time to a port of call. This objective can be achieved by having efficient process management (i.e. agency) and excellent coordination between a containership and a port.

Based on the analysis results obtained from the departure punctuality model, it is noteworthy to mention that unforeseen events (i.e. dangerous events and other unexpected events) have a significant effect on both arrival and departure punctuality models. Based on Table 7, if unforeseen events occur during the port stay of $Vessel_A$, the probability of $Vessel_A$ departing from $Port_A$ on-time is nil. In addition, agency is one of the most significant criteria for assuring the departure punctuality of $Vessel_A$. The probability of $Vessel_A$ departing from $Port_A$ on-time is 11.6%, if the reliability value of the agency at $Port_A$ is 100% low. As a result, agencies play important roles in the liner operation and they have to quickly and efficiently take care of all the regular routine tasks.

6. Conclusions

Within this paper, a departure punctuality model has been developed. Firstly, the critical factors for analyzing and predicting departure punctuality have been identified through an extensive literature review and a consultation with domain experts. Secondly, the states of each node were defined by using literature and expert opinion. Thirdly, a model for assessing departure punctuality was constructed using an FBBN technique. Fourthly, the strength of direct dependence of each child node to its associated parents was quantified by assigning each child node a CPT using the FRB and the symmetric model. Fifthly, unconditional probabilities were determined by assigning assessment grades to all the root nodes in the BBN model. Finally, the outcomes of the proposed model were validated by using a sensitivity analysis and prediction error.

Based on the sensitivity analysis, the most significant factors in the developed model for analyzing the departure punctuality of a containership were found to be the punctuality of arrival at the same port (i.e. prior to the departure), dangerous events and other unexpected delays during port stay. In conclusion, it is noteworthy to mention that a containership's arrival and departure punctuality are two interactive factors in the form of knock-on effect of delays. This model is capable of helping researchers and practitioners to understand the influence of dynamic environments on the departure punctuality of a containership.

Submitted : Feb. 28, 2017
Accepted : November 15, 2017

Reference

Drewry Shipping Consultants (2015), Container performance insight [Online] Available from: http://www.drewry.co.uk, last accessed in January 2016.

Gaonkar, R.S.P, Xie, M., Ng, K.M. and Habibullah, M.S. (2011), Subjective operational reliability assessment of maritime transportation system, *Expert Systems with Applications*, Vol. 38, No. 11, pp. 13835–13846.

Gurning, R.O.S. (2011), Maritime Disruptions in Australian-Indonesian Wheat Supply Chain: An Analysis of Risk Assessment and Mitigation Strategies', *PhD Thesis*, University of Tasmania.

Jason, R.W.M., Dorp, J.R.V., Thomas, M. and John, R.H. (2002), The Prince William sound risk assessment, *Interfaces*, Vol. 32, No. 6, pp. 25-40.

Lewis, B., Erera, A. and White, C. (2006), Impact of temporary seaport closures on freight supply chain costs, *Transportation Research Record: Journal of the*

Transportation Research Board, Vol. 1963, No. 1, pp. 64-70.

Merrick, J.R. and Dorp, R.V. (2006) Speaking the truth in maritime risk assessment, *Risk Analysis*, Vol. 26, No. 1, pp. 223-237.

Mohd Salleh, N.H., Riahi, R., Yang, Z. and Wang, J. (2015), Supply chain risk management in the container liner shipping industry from a strategic point of view, *European Journal of Business and Management*, Vol. 7, No. 24, pp. 155-163.

Mohd Salleh, N.H., Riahi, R., Yang, Z., Wang, J. and Othman, R. (2016), Adopting a Fuzzy Rule-Based Bayesian Network (FRBBN) for analyzing and predicting a vessel's arrival punctuality in liner operations, *Proc. of the Conference on International Association of Maritime Economists (IAME 2016)*, Paper ID 20, Hamburg, Germany.

Mwasenga, H. (2012), Port Performance Indicators: A Case of Dar es Salaam Port, In: United Nations Conference on Trade and Development (UNCTAD) 2012 [Online]. Available from: http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=175 last accessed in January 2014.

Notteboom, T. (2006), The time factor in liner shipping services, *Maritime Economics and Logistics,* Vol. 8, pp. 19-39.

Sawhney, R. and Sumukadas, N. (2005), Coping with customs clearance uncertainties in global sourcing, *International Journal of Physical Distribution & Logistics Management*, Vol. 35, No. 4, pp. 278-295.

Shrivastava, P. (1993), Crisis theory/practice: towards a sustainable future, *Industrial and Environmental Crisis Quarterly*, Vol. 7, No. 1, pp. 23-42.

Sii, H.S., Ruxton, T. and Wang, J. (2001), A fuzzy-logic-based approach to qualitative safety modelling for marine systems, *Reliability Engineering & System Safety*, Vol. 73, No. 1, pp. 19–34.

Vernimmen, B., Dullaert, W. and Engelan, S. (2007), Schedule unreliability in liner shipping: origins and consequences for the hinterland supply, *Maritime Economics and Logistics*, Vol. 9, pp. 193-213.

Williams, D.E. and Treadaway, G. (1992), Exxon and the Valdez accident: A failure in crisis communication, *Communication Studies*, Vol. 43, pp. 56-64.

Woodburn, A. (2007), The role for rail in port-based container freight flows in Britain, *Maritime Policy & Management*, Vol. 34 No. 4, pp. 311-330.

Yang, C.C., Marlow, P.B. and Lu, C.S. (2009), Knowledge management enablers in liner shipping, *Transportation Research Part E: Logistics and Transportation Review*, Vol. 45, No. 6, pp. 893-903.

Zhou, Z.J., Hu, C.H., Xu, D.L., Yang, J.B. and Zhou, D.H. (2011), Bayesian reasoning approach based recursive algorithm for online updating belief rule base expert system of pipeline leak detection, *Expert Systems with Applications*, Vol. 38, pp. 3937-3943.

There is no conflict of interest for all authors.