International Journal of Operations Research

International Journal of Operations Research Vol.8, No. 4, 3−9 (2011)

The Critical Factors: An Evaluation of Schedule Reliability in Liner Shipping

Cheng-Chi Chung[1*] and Chao-Hung Chiang[2]

[1]Department of Shipping and Transportation Management, National Taiwan Ocean University,

Keelung, Taiwan, ROC

[2]Institute of Traffic and Transportation, National Chiao Tung University, Taipei, Taiwan, ROC

Received April 2011; First Revised May 2011; Second Revised August 2011; Accepted September 2011

Abstract — In today's ever-increasing competitive environment, container shipping plays a significant part in the supply chain. Schedule reliability of shipping lines affect hinterland transport and shippers. Thus service quality of schedule reliability has an important influence on the operational performance of container shipping lines. The main purpose of this study was to analyze and investigate the key influential factors of schedule reliability by using the Fuzzy Analytic Hierarchy Process. Results indicated that the most important object is 'process management in shipping lines', and that the important criteria were 'well-arranged time window,' 'transship arrangement,' 'planning the suitable ports,' 'planning the berth and warehouse beforehand,' and 'control and management staff in the terminal'.

Keywords — Container shipping lines, schedule reliability, fuzzy AHP

---

1. INTRODUCTION

Due to a highly competitive atmosphere, container shipping lines face several challenges. The process of shipping is not only important to shipping lines, but it also plays a crucial part of a supply chain; therefore, schedule reliability of container shipping lines play a key role in the global supply chain. It is proven that schedule reliability affects hinterland transport and logistics costs to the shippers.

Although container shipping lines operate on fixed-day weekly schedules, the survey of Drewry Shipping Consultants shows that more than 40% of the vessels deployed on worldwide liner services were delayed one or more days (Vernimmen *et al.*, 2007). Drewry (2007-2009) calculated the schedule reliability of global container shipping lines from 2007 Q3 to 2009 Q2 as shown in Table1. It indicates that most of the lines cannot call the vessels on time.

In addition, Vernimmen *et al.* (2007) stated that schedule reliability levels of different trade routes were noticeably different. North America and Indian Subcontinent routes arrive on time at least 70% of the time; however, the Asia and East Coast South America routes only arrive on time 40% or less of the time. Moreover, the Asia / North Europe / Mediterranean trade route's proportion of containerships arriving on time declined from 46% in the fourth quarter of 2006 to 37% in the first quarter of 2007. In transatlantic routes, the on-time arrival rate of the fourth quarter of 2006 decreased from 53% to 27% in the first quarter of 2007 (Shippers Today, 2007). However, the improvement of transatlantic routes is better than the Asia / North Europe / Mediterranean trade route. Therefore, in this study the scale of service was divided into Asia routes (*i.e.*, shortsea shipping) and American routes (*i.e.*, deepsea shipping) to explore whether or not there are

---

* Corresponding author's email: jackie@mail.ntou.edu.tw

different critical factors of schedule reliability.

This study began with literature reviews, followed by the conduction of the expert questionnaire survey to collect data required for the main purposes of exploring the influential factors on schedule reliability. It is proven that fuzziness and vagueness are common characteristics in many decision processes; thus the Fuzzy Analytic Hierarchy Process (FAHP) was applied to analyze the important degree of each criterion to explore the significance of factors, which added the concept of weight values. The survey also explored two different routes, (Asia routes and American routes) to see whether or not experts make different decisions to determine in determining factors of schedule reliability.

The rest of the study is organized as follows: The relevant literature is surveyed in section 2. Section 3 describes research design and methods. Section 4 presents empirical results, followed by conclusions and suggestions in section 5.

Table 1 Global container shipping lines' schedule reliability statistics

Year / Quarter	No. of Calling Times	No. of Shipping Lines	On-time Rate (%)	100	90	80	70	60	50	40	30	20	10	0
2007/Q3	2,237	66	No. of Shipping Lines	0	7	3	2	12	18	8	8	6	1	1
2007/Q4	2,145	65		4	1	0	4	13	16	8	7	6	4	2
2008/Q1	2,130	66		0	1	3	6	11	19	10	8	2	3	3
2008/Q2	1,935	60		1	1	0	6	6	11	9	10	7	4	5
2008/Q3	1,891	58		1	1	2	4	14	11	11	3	6	1	4
2008/Q4	1,641	57		0	4	0	1	5	6	19	7	3	7	5
2009/Q1	1,633	54		0	2	1	3	7	18	4	5	7	2	5
2009/Q2	1,712	61		0	0	6	8	13	10	11	4	3	1	5

Source: Drewry (2007-2009).

2. LITERATURE REVIEW

2.1 The impact of schedule reliability on shippers

Due to low-cost trend, the transport demand of container shipping is increasing recently. The system of container shipping is structured under tight schedules. Schedule reliability might be the reference for shippers when selecting container shipping lines and planning their supply chains with realistic expectations of delivery time. Thus delays might not only decrease the reliability of the liner service, but also increase logistics costs to the customers, such as additional inventory costs or additional production costs, *e.g.*, a production stop due to a late delivery of materials (Notteboom, 2006).
The unreliability of liner schedule causes a knock-on effect on the hinterland supply chains. More serious delays might lead to significant time-losses for the cargoes involved, the loss of the cargo altogether, ship collisions or ship groundings, (Vernimmen *et al.*, 2007) and even the loss of potential customers. Thus most liner carriers are paying attention to their service reliability, such as schedule reliability. The better reliability might be the proper combination of carrier actions and the alleviation of port congestion delays. However, liner schedule unreliability will also increase the operating costs of shipping lines (Vernimmen *et al.*, 2007).

Consequently, schedule reliability is important to companies when addressing cargo activities. On-time deliveries can reduce warehouse storage time and inventory costs. It also enables companies to plan pick-ups and deliveries in advance to reduce costly demurrage and charge backs that result from early or late deliveries. Besides that, it can help companies maintain supply chain integrity by improving product supply flows.

2.2 INFLUENTIAL FACTORS ON SCHEDULE RELIABILITY

Carey (1999) stated that measures of reliability and punctuality of scheduled services are important in planning, management, operating and marketing of the services. Schedule design is a strategic planning problem in container shipping lines (Fagerholt, 2004), and it should meet customers' requirements in terms of frequency, transit time and price (Notteboom, 2006). Vernimmen *et al.* (2007) showed that low schedule reliability can be caused by a number of factors, many of them beyond the control of container shipping lines. For instance, vessel delays are mainly due to bad weather, port congestion, and labor strikes and so on. Two stages of schedule arrangement are port assignments and navigation by sea. Consequently, it divided into four aspects to explore influential factors of schedule reliability in this study.

(1) Operating strategy of shipping lines

Container shipping lines perfect the schedule plan most of the time. Container shipping lines can improve their efficiency of schedule reliability by performing different strategies, such as avoiding unreliable ports or using the chase strategy and so on. Shippers Today (2007) said that the unwillingness of carriers to make up for lost time by increasing vessel speed also affect schedule reliability. In addition, some shipping companies increase the control in the supply chain, reduce waiting times and guarantee high vessel productivity by investing in port operating business, such as investing in dedicated facilities (Chiang and Hwang, 2009; Dynamar, 2005).

(2) Staff in shipping lines

The Human factor is a key component in schedule reliability; for example, every staff member has a sense of commitment towards their duty. For instance, the ports of Cape Town and Port Elizabeth have been closed on a number of occasions in the past due to employee strikes which caused further schedule unreliability (Vernimmen *et al.*, 2007). Good coordination of market players (*ex*. port authority and customs) will be helpful to decrease waiting time and to increase efficiency.

(3) Process management in the shipping lines

Planning the berthing windows is an important design in container shipping lines. Wang *et al.* (2010) also emphasized that minimum average schedule missed hours of ships between the ship schedule departure time and the actual departure time will enhance the schedule reliability of ships. Well-arranged berthing windows can reduce the loss in customers and shipping lines; moreover, schedule reliability will increase. After one vessel arrives at port on time, it still has to wait in a queue and consequently misses the berthing window. Drewry mentioned that most container lines do not provide sufficient buffer time in their weekly schedules for contingencies, because some container shipping lines consider that buffer time is too expensive (Vernimmen *et al.*, 2007). In addition, it also needs to take care of the transit time; then containers might be shifted. If a container shipping line is behind the scheduled transit time which might shift containers to other vessels/ports, it will abolish the fixed schedule. Thus the reliability of transit times between two ports is also a key factor which will affect the punctuality of further transport. Sözer and Dogan (2007) pointed out that a good reputation of high schedule reliability also has high transit time reliability.

(4) Port's condition

Notteboom (2006) pointed out that port congestion is one of the factors that can disrupt schedules, negatively affecting schedule reliability. Thus the increased port congestion and infrastructure constraints are some of the reasons that will compel the services of container shipping lines. Drewry also agreed that the deterioration of liner schedule reliability was caused in part by port congestion (Shippers Today, 2007). Therefore, the characteristics of vessel schedules such as liners' schedule reliability are also an important factor of port selection (Lee et *al.*, 2007; Malchow and Kanafani, 2004). In addition, schedule reliability also needs efficient terminal planning, especially in those ports that are non-first port of call (Vernimmen *et al.*, 2007). Thus depending on berth allocation and terminal efficiency, the schedule of next ports could be negatively influenced.

3. RESEARCH DESIGN AND METHODOLOGY

The expert questionnaire is used to analyze the reliability of schedule. Fuzzy Analytic Hierarchy Process is applied to analyze the degree of importance of each criterion to explore the significance of factors.

3.1 Design and survey of expert questionnaire

The initial questionnaire was pre-tested and revised before it was sent out to selected experts who are also the managers of container shipping lines. The questionnaire is divided into two parts. The first part of the questionnaire contains 12 items measuring schedule reliability. All the factors were selected and modified on a basis of reviewing past literature in relation to influential factors on schedule reliability, and uses nine points ranging from 1 being 'weakly important' to 9 being 'strongly important'. Part two is the socio-economical attributes of shipping experts. Out of the 30 surveyed samples in total, 23 questionnaires were returned with a response rate of 77%.

Among the experts are top managers with at least ten years of experience in shipping lines. There are 11 experts who work in the American routes and 12 experts who work in the Asia routes. The fact that the decision-makers in different shipping routes may have different actions was kept in careful consideration when the survey was conducted.

3.2 Fuzzy analytic hierarchy process

The traditional AHP cannot adequately handle the inherent uncertainty and imprecision (Deng, 1999). The fuzzy AHP (FAHP) technique was regarded as an advanced analytical method which developed from the traditional AHP. Since fuzziness and vagueness are common characteristics in many decision processes, a FAHP method could be able to tolerate vagueness or ambiguity (Mikhailov and Tsvetinov, 2004). The steps of FAHP are as follows.

Step 1: Construct the hierarchical structure. The top of hierarchy is the goal, and the second level is the general criteria. The secondary subcriteria's respective dimensions are placed at third level.

Step 2: Set up the pairwise comparison matrix. Compare the relative importance between various factors that obtain the relative importance of paired criteria factors from selected experts, after the definite values are converted to fuzzy numbers according to the definitions in Table 2.

Table 2 Transformation between linguistic responses and fuzzy membership functions

Likert scale (Fuzzy number)	Definition
1=(1,1,1)	Equally important
2=(1,2,3)	Judgment values between equally and moderately
3=(2,3,4)	Moderately more important
4=(3,4,5)	Judgment values between moderately and strongly
5=(4,5,6)	Strongly more important
6=(5,6,7)	Judgment values between strongly and very strongly
7=(6,7,8)	Very strongly more important
8=(7,8,9)	Judgment values between very strongly and extremely
9=(8,9,9)	Extremely more important

Step 3: Calculate the triangular fuzzy numbers. Concerning the relative importance of each individual evaluation construction in the pairwise comparison matrix, triangular fuzzy number was used to integrate all experts' opinions and to the calculating function is as follows.

$$\tilde{\alpha}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

where

$\tilde{\alpha}_{ij}$: Triangular fuzzy number; a_{ij} : The minimum of the j^{th} subcriteria subordinated to the i^{th} general criterion; b_{ij} : The geometric mean of the j^{th} subcriteria subordinated to the i^{th} general criterion; c_{ij} : The maximum of the j^{th} subcriteria subordinated to the i^{th} general criterion.

Step 4: Construct the fuzzy positive reciprocal matrix. The fuzzy positive reciprocal matrix *A* can be further built after Step 3.

$$A = [\tilde{\alpha}_{ij}]$$

Step 5: Calculate the fuzzy weight of fuzzy positive reciprocal matrix. It used the method which was developed by Buckley (1985) and was improved by Hsu (1998) to calculate the fuzzy weights. It was based on the experts' apprised values and synthesized the experts' opinions with the geometric mean instead of the fuzzy numbers being input directly by experts. Through the following formulas, the positive reciprocal geometric mean Z_i of triangular fuzzy numbers and the fuzzy weight W_i can be obtained.

$$Z_i = [\tilde{\alpha}_{i1} \otimes \ldots \otimes \tilde{\alpha}_{in}]^{1/n}, \forall_i$$
$$W_i = Z_i \otimes (Z_1 \oplus \ldots \oplus Z_n)^{-1}$$

Let $\tilde{\alpha}_1 = (a_1, b_1, c_1)$ and $\tilde{\alpha}_2 = (a_2, b_2, c_2)$ be two triangular numbers. According to the extension principle (Zadeh, 1965) the algebraic operations of any two triangular fuzzy numbers $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ can be expressed as:

$$\tilde{\alpha}_1 \otimes \tilde{\alpha}_2 \cong (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2),\ a_1 \geq 0, a_2 \geq 0$$
$$\tilde{\alpha}_1 \oplus \tilde{\alpha}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$
$$\tilde{\alpha}_1^{-1} \cong (c_1^{-1}, b_1^{-1}, a_1^{-1}), a_1 > 0$$
$$\tilde{\alpha}_1^{1/n} \cong (a_1^{1/n}, b_1^{1/n}, c_1^{1/n}), a_1 \geq 0$$

Step 6: Defuzzification. It used centroid method to defuzzy in the study because the solution can be figured out quite quickly. The defuzzified weight W_i calculated as follows.

$$W_i = \frac{W_{ai} + W_{bi} + W_{ci}}{3}, \text{ where}$$

W_{ai}: The left-end value of the fuzzy weight; W_{bi}: The value of the fuzzy weight with the degree of membership as 1; W_{ci}: The right-end value of the fuzzy weight.

Step 7: Ranking. It can use the value in Step 6 to rank the criteria.

4. EMPIRICAL STUDY

Reviewing relevant literatures about influential factors in schedule reliability of container shipping lines, the empirical study proposes the hierarchy model of influential factors on schedule reliability as depicted in Table 3 in response to the goal of influential factors on schedule reliability.

4.1 The hierarchy structure and the results

A general consensus among experts can establish a hierarchical structure. Using the FAHP method, the importance of influence factors on schedule reliability based on four objects and twelve criteria was caculated. The four objects include 'operating strategy of shipping lines,' 'staff in shipping lines,' 'process management in shipping lines' and 'ports' condition.' Thus, the influential factors in schedule reliability of container shipping lines are shown in Table 3, and evaluation criteria weight of experts from different fields are as shown in Table 4.

The results showed that according to the overall evaluation, experts of two fields pay relatively consistent attention to the 'process management in shipping lines,' which is the most important object for schedule reliability in container shipping lines. Between the different fields, 'staff in shipping lines' is probably the more important object than that of which is in Asia route, while 'ports' condition' is the more important object than that of which is in American route.

Table 3 Influential factors in schedule reliability of container shipping lines

Goal	Object	Criteria	Statement of Criteria
Influential Factors on Schedule Reliability	O1: Operating Strategy of Shipping Lines	O11: Planning the suitable ports	Shipping lines need to choose the suitable ports according to the port condition, cargo volume and so on.
		O12: Chase strategy	Whether shipping lines execute the chase strategy or not.
		O13: Specialized terminal investment	Shipping lines has invested in or specialized terminal.
	O2: Staff in Shipping Lines	O21: Staff's sense of mission	Every staff has strong sense of mission in their duty.
		O22: Coordination ability of staff with external relations	Staff should have good coordination ability with market players (ex. port authority and customs) to decrease waiting time and to increase efficiency.
		O23: Control and management staff in the terminal	The shipping lines should control and manage the staff in the terminal effectively to avoid strike or slowness at works.
	O3: Process Management in Shipping Lines	O31: Well-arranged time window	Shipping lines should plan the time window appropriately.
		O32: Planning the berth and warehouse beforehand	Before arriving to the port, shipping lines should plan the berth and warehouse in advance.
		O33: Transship arrangement	Shipping lines should transship properly to avoid delays in delivery.
	O4: Ports' Condition	O41: Freely flowing of ports' access roads	Access roads of a port are freely flowing.
		O42: Berth allocation	Berth allocation will influence the operating time.
		O43: Terminal efficiency	Terminal efficiency will influence the operating time.

Table4 Evaluation criteria weight of experts from different fields

Object	Weights			Criteria	Overall		Asia route		American route	
	Overall	Asia route	American route		Weights of Criteria in Each Object	Global Weight	Weights of Criteria in Each Object	Global Weight	Weights of Criteria in Each Object	Global Weight
O1	0.211 (2)	0.266 (2)	0.112 (2)	O11	0.735(1)	0.155(3)	0.714(1)	0.196(2)	0.739(1)	0.082(4)
				O12	0.189(2)	0.040(7)	0.184(2)	0.050(6)	0.164(2)	0.021(9)
				O13	0.075(3)	0.016(10)	0.102(3)	0.020(9)	0.098(3)	0.008(12)
O2	0.138 (3)	0.101 (3)	0.108 (4)	O21	0.174(3)	0.024(9)	0.302(2)	0.018(10)	0.084(3)	0.019(10)
				O22	0.302(2)	0.042(6)	0.174(3)	0.031(8)	0.327(2)	0.033(7)
				O23	0.524(1)	0.072(5)	0.524(1)	0.053(5)	0.589(1)	0.057(6)
O3	0.589 (1)	0.563 (1)	0.667 (1)	O31	0.544(1)	0.320(1)	0.587(1)	0.306(1)	0.650(1)	0.363(1)
				O32	0.126(3)	0.074(4)	0.103(3)	0.071(4)	0.098(3)	0.084(3)
				O33	0.330(2)	0.194(2)	0.310(2)	0.186(3)	0.252(2)	0.220(2)

O4	0.061 (4)	0.070 (4)	0.112 (2)	O41	0.144(3)	0.009(12)	0.098(3)	0.010(12)	0.236(2)	0.016(11)
				O42	0.237(2)	0.014(11)	0.164(2)	0.017(11)	0.116(3)	0.027(8)
				O43	0.619(1)	0.038(8)	0.739(1)	0.043(7)	0.648(1)	0.069(5)

2 . Discussions

Schedule reliability is important for container shipping lines when addressing cargo activities; however, liner schedule unreliability will cause a knock-on effect on the hinterland supply chain and increase the cost of container shipping lines. It used the FAHP method to consult experts' opinions to select the importance of the influence factors on schedule reliability in this study.

Meeting the timings as announced in the published schedules is significant to container shipping lines. Results showed that the 'process management in shipping lines' is the most influential object for schedule reliability, in which the 'well-arranged time window' is the most important factor for schedule reliability. It's not only in the overall evaluation, but also in Asia route and American route; therefore, providing more buffer time of the weekly schedules such as extending the round-voyage times can be suggested to container shipping lines to improve the on-time arrival rate of schedule.

Furthermore, the top-five criteria were 'well-arranged time window,' 'transship arrangement,' 'planning the suitable ports,' 'planning the berth and warehouse beforehand,' and 'control and management staff in the terminal,' and their total weight is 81.50%. It is shown that the port time is the main source of schedule unreliability which means that choosing the ports of call and arranging the order of ports is critical.

5. CONCLUSION AND SUGGESTION

(1) Schedule reliability is important for container shipping lines when addressing cargo activities. Delays in delivery will decrease the reliability of the liner service, which cause a knock-on effect on the hinterland supply chain, and also increase logistics costs to the shippers. Thus schedule reliability is important for container shipping lines handling cargo by sea.

(2) The result demonstrated that the 'process management in shipping lines' is the main consideration in the evaluation process by using the FAHP method. 'Well-arranged time window' is the most important criterion from overall perspectives. Those results might be the direction for container shipping lines to improve their reliability.

(3) Compare the Asia routes with American routes; the critical influential factors between them are not significantly different. It is implied that the critical factors of schedule reliability are almost the same, regardless of whether shortsea shipping lines or deepsea shipping lines are taken into consideration.

(4) In the results of this study, it is shown to container shipping lines that the 'process management in shipping lines' is the most important, especially 'well-arranged time window.' Thus liner carriers should plan sufficient buffer time in schedules for unexpected situations such as bad weather and port congestion. In addition, shippers can also build more buffer time in their supply chains to cover the damage risk of variability in liner schedules.

(5) Service quality of schedule reliability might have a bigger influence on freight rate negotiations between contracting parties, *i.e.*, carriers and shippers; meanwhile, it will also influence the performance of container shipping lines. Therefore, schedule reliability is a key performance indicator in the container shipping lines.

ACKNOWLEDGEMENTS

We would like to thank all the referees for their constructive comments that improved both the content as well as the presentation of the paper. This research is partially supported by the National Science Council of Taiwan, ROC, under Grant No. NSC 99-2410-H-019-005-MY3.

REFERENCE

1. Buckley, J. J. (1985). Fuzzy Hierarchical Analysis, *Fuzzy Sets and Systems*, 17(3): 233-247.
2. Carey, M., (1999). Ex ante Heuristic Measures of Schedule Reliability, *Transportation Research Part B*, 33(7): 473-494.
3. Chiang, C. H. and Hwang, C. C. (2009). Competitiveness of Container Ports in a Region with Cooperation and Integration, *Journal of the Society for Transportation and Traffic Studies*, 1: 77-91.
4. Deng, H. (1999). Multicriteria Analysis with Fuzzy Pairwise Comparisons, *International Journal of Approximate Reasoning*, 21: 215-231.
5. Dynamar (2005). *Post-Panamax Terminals in North-West Europe and the Spectre of Congestion*, Alkmaar, 181.

6. Drewry (2007-2009). Container Shipping Insight, Drewry Consultant Institution.
7. Fagerholt, K. (2004). Designing Optimal Routes in a Liner Shipping Problem, *Maritime Policy and Management*, 31(4): 259-268.
8. Hsu, T. H. (1998). The Fuzzy Delphi Analytic Hierarchy Process, *Journal of Chinese Fuzzy Systems Association*, 4(1): 59-72.
9. Lee, S. Y., Chan, Y. T., and Lee, P. T. W. (2007). Determinants of Port Selection: Heterogeneity among Major Market Players, *International Conference on Logistics, Shipping and Port Management*, Taiwan, 1-13.
10. Malchow, M. B. and Kanafani, A. (2004. A Disaggregate Analysis of Port Selection, *Transportation Research Part E*, 40(4): 317-337.
11. Mikhailov, L. and Tsvetinov, P. (2004). Evaluation of Services Using a Fuzzy Analytic Hierarchy Process, *Applied Soft Computing*, 5(1): 23-33.
12. Notteboom, T. (2006). The Time Factor in Liner Shipping Services, *Maritime Economics and Logistics*, 8(1): 19-39.
13. Shippers Today (2007. Drewry Survey Shows Liner Schedule Reliability at Record Low, 30(3), Retrieved on Dec. 5, 2010, from http: //info.hktdc.com/shippers/vol30_3/vol30_3_ocean01.htm.
14. Sözer, C. and Dogan, Y. (2007. Key performance Indicators for Maritime Transport System: A Feasibility Study on Swedish Maritime System, Master's Thesis, Göteborg University, Logistics and Transport Management.
15. Vernimmen, B., Dullaert, W., and Engelen, S. (2007). Schedule Unreliability in Liner Shipping: Origins and Consequences for the Hinterland Supply Chain, *Maritime Economics and Logistics*, 9(3): 193-213.
16. Wang, L., Li, A., and Wu, D. (2010). Vessel Schedule Reliability Optimization for Container Terminal Based on Adaptive Differential Evolution, *International Conference on Intelligent Control and Information Processing*, Dalian, 475-478.
17. Zadeh, L. A. (1965).Fuzzy Sets, *Information and Control*, 8(3): 338-353.