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Applying ANP for Measuring the Performance of Marine Logistics Information Platform in Taiwan

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Abstract: This paper has conducted a trial in establishing a systematic instrument for evaluating the performance of the marine information systems. Analytic Network Process (ANP) was introduced for determining the relative importance of a set of interdependent criteria concerned by the stakeholders (shipper/consignee, customer broker, forwarder, and container yard). Three major information platforms (MTNet, TradeVan, and NiceShipping) in Taiwan were evaluated according to the criteria derived from ANP. Results show that the performance of marine information system can be divided into three constructs, namely: Safety and Technology (3 items), Service (3 items), and Charge (3 items). The Safety and Technology is the most important construct of marine information system evaluation, whereas Charger is the least important construct. This study gives insights to improve the performance of the existing marine information systems and serve as the useful reference for the future freight information platform.

Keywords: Analytic Network Process, Performance, Marine, Logistics Information Platform

1. Introduction

Marine information system (MIS) has become an essential part of the rapid and accurate transfer and processing of enormous volumes of data processed in international transport firms and port organizations. The proper management of MIS, which process this information and communicate it to those who manage port operations, is vital for efficient transport. Thus, performance of marine information system not only directly influences the operational efficiency of the maritime transportation participants, but dominates the competiveness of the ocean transportation industry in an international commercial harbor. Facing the fierce challenges from the neighboring harbors, how to develop a scientific evaluation procedure to measure the performance of marine information system therefore plays a critical role for monitoring the effectiveness of a marine information system.

However, little knowledge about the evaluation of marine information systems exists. This drawback may be due to the complexity of the relationships of marine supply chain.

Moreover, marine information system evaluation is a multi-criteria problem, and the criteria are usually interdependent. Although many methodologies of information system evaluation are proposed, their evaluation criteria are restricted to independent only. In order to fulfill both of the research gaps, this study aims to establish a systematic instrument for evaluating the performance of the marine information systems via an appropriate methodology and investigating the major members in marine supply chain.

2. Literature Review

There are plenty of studies have explored the performance evaluation of information system. The widely-applied methodologies for IS performance evaluation can be simply divided into 4 categories, namely the single-criteria cost/benefit analysis, the multiple criteria scoring models, ranking methods, and subjective committee evaluation methods.

Buss [1] attempts to provide an alternative approach to project selection with the ranking technique. The ranking method does not solve problems that require resource feasibility and an existing project interdependent property.

Lucas and Moore [2] and Lootsma et al. [3] both suggested a multiple-criterion scoring methods for IS performance evaluation.

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Muralidhar and Wilson [4] proposed a methodology for IS performance evaluation by using an analytic hierarchy process (AHP), however, they did not consider interdependence property but consider independence property among alternatives or criteria.

Ranking, scoring and AHP methods do not apply to problems having resource feasibility, optimization requirements or project interdependence property constraints. In spite of this limitation, the scoring and ranking method and AHP method have been much used with real problems because they are very simple and easy to understand, so decision-makers feel comfortable with them.

Consideration for these interdependencies among criteria provides valuable cost savings and greater benefits to organizations. Santhanam and Kyparisis [5] [6] proposed a mathematical methodology using nonlinear 0-1 programming for interdependent information system evaluation.

Their model considered project interdependence and resource optimization. They considered performance evaluation problems that have only one criterion not multiple criteria. In reality, it will be more appropriate to consider multiple criteria than to consider only one or two criteria in IS performance evaluation problems which have interdependence property. No prior study reported in the literature has ever demonstrated the solving methodology of an IS performance evaluation that have both multiple criteria and interdependence property. To achieve our trial, the Analytic Network Process (ANP) was introduced and applied in this study.

ANP is a comprehensive decision-making technique [7] that has the capability to include all the relevant criteria, which have some bearing, in arriving at a decision. AHP serves as the starting point of ANP.

The advantages of AHP in group decision-making are as follows: (i) both tangibles and intangibles, individual values, and shared values can be included in the decision process; (ii) the discussion in a group can be focused on objectives rather than on alternatives; (iii) the discussion can be structured so that every factor relevant to the decision is considered; and (iv) in a structured analysis, the discussion continues until relevant information from each individual member in the group is considered and a consensus is achieved. In addition to these merits of AHP, the ANP provides a more generalized model in decision-making without making assumptions about the independency of the higher-level elements from lower-level elements and also of the elements within their own level. A two-way arrow or arcs among different levels of criteria may graphically represent the interdependencies in an ANP model.

If interdependencies are present within the same level of analysis, a looped arc may be used to represent such interdependencies. The ANP methodology and its application for a case company in a multi-criteria decision-making environment are illustrated in the next section of this paper.

3. Methodology

This study tries to formulate a proper process to evaluate the performance of marine information systems. Basing on Boyson et al. [8], we define a marine information system is a site serving as a starting point for accessing the web and from which the user may enter other sites. The most important function is the collection of information about marine supply chains. The system makes the transaction easier for the member of supply chain, and the user can approach to certain information depending on his/her level of security clearance.

This partner selection process is not an easy task when viewed from a supply chain perspective as it involves a series of inter-related decision about suppliers [9] [10].

The complexity of this task as it is multi-objective in nature, and increases with an increase in the number of criteria selection [11].

Previous research agreed that partner selection criteria should relate to operation performance and competitive priorities, but increasingly exacting business environment signifies that the need for a wider range of criteria [12].

From the performance evaluation perspective, conductors have to assess the entire results of the past and identify the future position of the company in the top level, while performance measurement provides information about the defects and motivate for the upcoming activities [13].

Thus, performance evaluation can served as a part of a management process determining the quality of a particular process [14].

This process involves in choosing different criteria and generating a combined evaluation based on these criteria [15].

Therefore, we can infer that performance evaluation of marine information systems is a multi-criteria decision-making problem which involves multiple and inter-related criteria allow decision makers to deal with complex evaluation tasks to achieve a specific goal.

Among the methods that use to solve multi-criteria decision-making problems, researchers indicate that the analytic hierarchy process (AHP) and the analytic network process (ANP) are two famous methods [16].

Although AHP is a widely use method decomposing a problem into several levels in such a way that they form a hierarchy, but a major limitation of AHP is the assumption of independency among various criteria of decision-making [9].

The real world problems often consist of dependence or feedback between criteria [17]. Therefore, these decision making problems cannot be solved since they may involve dependencies in higher/lower leveler factors.

However, the ANP can be used as a more effective tool in those cases, where the interaction among the elements of a system form a network structure [18].

The ANP is a general form of AHP, and it does not need a hierarchical structure and thus can solve problems with complex inter-relationships among factors [9] [16]

[19]. The ANP constructs a network system in which all criteria and alternative involved are linked that accepts various dependencies.

More specific, ANP's network contains the factors of the problem and the logical groupings of these factors into clusters. Each decision network is composed of clusters, their elements, and links among the elements [19].

The links can further be distinguished into inner dependencies and outer dependencies, which the former is the links between elements within the same cluster, and the latter is the links between apparent element in one cluster and its given cluster in another [20].

Developing a network structure in this way allows AHP for more complex, interdependent, relationships, and feedback among elements in the hierarchy.

Basing on above-mentioned explorations, this study selects AHP as our analysis tool. The ANP is better to provide flexible model to solve real world problems, but there are few application in transportation research.

Shipahi and Timpr [17] categorized 323 articles from 2005 to 2009, 169 utilized the AHP method, but only 9 utilized the ANP method. Among these 232 articles, only 1 study used ANP in the transportation industry. This may due to ANP's complexity and time consuming nature. Thus, to our knowledge, this study is the first one that evaluates marine information system performance using ANP.

The challenge of ANP is to determine the priorities of the elements in the network and in particular the alternatives of the decision [15].

The qualitative assessments are presented numerically to make tradeoffs between objectives and criteria. Thus, researchers must make reciprocal pairwise comparisons in a carefully designed scientific way [18].

A priority vector is assessed by asking the decision maker for a numerical weight, but there may be less consistency. Inconsistency itself is important because without it, new knowledge that changes preference cannot be admitted [20].

Thus, researchers use consistency index (CI) to confirm the result steadiness of decision makers' priority. The CI of an evaluation matrix is calculated as:

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

The CI of a randomly generated reciprocal matrix shall be called to the random index (RI).

Table 1 gives average random consistency index computed for n<9 for large samples.

The last ratio that has to be calculated is consistency ratio (CR) which is formulated as CR=CI/RI [21]. If CR is less than 0.1, the assessments are consistent, so the derived weights can be used.

The priorities derived from pairwise comparison matrices are entered as parts of the columns of a super-matrix that represents the influence priority of an element with respect to a particular control criterion. A super-matrix with an example of it general entry matrices is shown in Eqs. (2).

Table 1 Random Index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45

In the ANP steady state priorities is looked for from a limit super-matrix which is raised to powers to be obtained. Each power of the matrix captures all transitivity of an order that is equal to that power [18].

$$W = \begin{bmatrix} 1 & W_{12} & \cdot\cdot & W_{1n} \\ W_{21} & 1 & \cdot\cdot & W_{2n} \\ \cdot & \cdot & \cdot\cdot & \cdot \\ \cdot & \cdot & \cdot\cdot & \cdot \\ W_{n1} & W_{n2} & \cdot\cdot & 1 \end{bmatrix} \tag{2}$$

4. Research Design and Results

In this research, ANP is adopted to identify performance evaluation criteria for marine information systems, and determine the weight of these criteria. For this purpose, we collected initial measurement items from the relative literature [22].

This study further conducts quantitative and qualitative surveys to select the final measurement items. In the quantitative survey, we distinguish the members in marine supply into carrier, supper/consignee, customer broker, forwarder, and container yard. The questionnaire was launched to a total member of 190 association members, and the response rate was 37%. Importance-performance analysis (IPA), a tool to identify improvement opportunities and to guide strategic planning efforts, is used to determine our final measurement items.

Basing on IPA framework, researchers can identify the major weakness attributes representing high importance and low performance. These kinds of attributes should be prioritized to improve a company's performance. According to the results of IPA, 9 items were selected as our final measurement items.

This study further conducts a qualitative survey to confirm the adaptability of our final items. We interviewed 6 superintendents in various areas including ministry of transportation and communication, directorate general of customs, and Taiwan electrical and electronic manufacturers' association.

The result suggests that the 9 items are appropriate for the performance evaluation of marine information systems, and should be distinguished into 3 higher-level concepts.

In applying ANP to solve a decision problem, the first step is to build the hierarchy at each level. According to our previous surveys in the performance evaluation criteria for marine information systems, the top level criteria are Service, Safety and Technology, and Charge in our model. These three criteria are served as the dimensions of the model which supports our research purpose.

In addition, each of the three dimensions has some measurement which helps to achieve that specific dimension. We adopted three items to measure the dimension of Service including information diversity, ease of use, and usefulness. There are also three items (i.e., system credibility, stability, and security) for assessment of Safety and Technology.

Another three items were adopted to measure the dimension of Charge including payment convenience, price fairness, and payment method (See Figure 1).

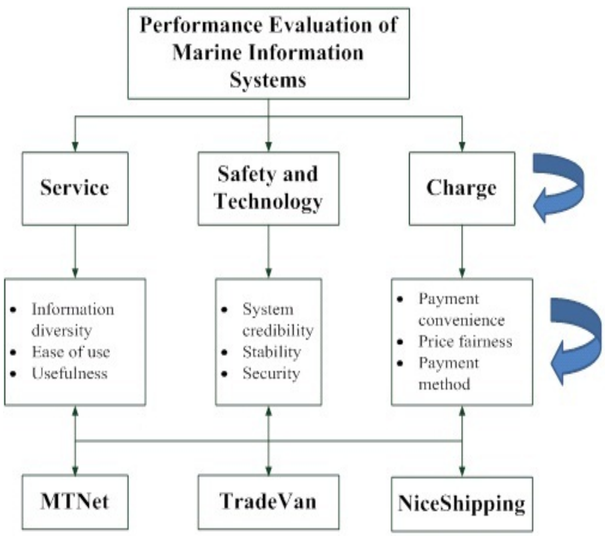

Figure 1 ANP Model for the Performance Evaluation of Marine Information Systems

Three marine information systems are selected to examine our model.

(1) Maritime Transport Network Portal (MTNet) is the construction of Marine Information Communication System incorporates the development of information and communication, simplifies the port operation, improve marine transit operation process and upgrade process quality to arrive at the ideal status of automated marine transit and port operation for promoting international competition strength.

(2) Trade Van was formed to ensure more effective utilization of Taiwan's first EDI information exchange network. It is developing e-commerce services to provide a one stop service for conducting international trade. Its core business is to provide value added information exchange services to the international trading community.

Trade Van started from customs cargo clearance and have developed a range of web based front end systems to enhance the competitive advantage and business performance of our customers.

(3) NiceShipping provides an interactive information platform for the marine supply chain member. Its functions include inquiry, booking, and business opportunities. It also provides various valuable services, such as cargo insurance, express, and financial service. Users can search for shipping schedule, carriers, forwarders, and related information in NiceShipping.

In this step, cluster comparisons and comparisons of elements should be calculated. The former refer to the performance paired comparisons on the cluster that influence a given cluster with respect to the control criterion for that network, whereas the latter is the performance paired comparisons on the elements within the clusters.

Furthermore, 13 experts are selected in the area of marine supply chain management among operators with professional experience in the domain of application. These experts are the core actors involved in the weighting process. They are asked to judge the relative importance of each item in influencing the relevance of any other items filling in pairwise comparison matrix. They can express relative dominance between each pair of items verbally from equally importance to extremely more important. These descriptive judgments would then be translated into numerical values 1, 3, 5, 7, 9 respectively with 2, 4, 6, 8 as intermediate values for comparisons between two successive points [19].

The compromising evaluation score from the 13 experts are entered into the ANP model. The inconsistencies of the pairwise comparison matrices have been checked and all the CR values are less than 0.1.

Based on the nine-point scale, normalized weights for the items of the main dimensions are derived as paired comparison of intensities. Finally, the ANP results for performance evaluations of marine information systems are obtained as in Table 2.

According to the results, Safety and Technology is the most important dimension in marine information system evaluations (WSafety and Technology = 0.6046), and Charge is the last important dimension (WCharge = 0.1260).

Among the items in Service dimension, information diversity is the major one (Winfomation diversity = 0.5520).

Security is the primary item in the Safety and Technology dimension (Wsecurity = 0.4449), and the price fairness is the principal item in the Charge dimension (Wprice fairness = 0.5985).

After considering the relative weights of all the dimensions and items, the aggregate ranking list of the items is Wsecurity > Wsystem credibility >

Table 2 ANP Results

Dimensions	Items	Relative Weights		
		Dimension	Item	Aggregation
Services		0.2694		
	Information Diversity		0.5520	0.1487
	Ease of Use		0.1789	0.0482
	Usefulness		0.2691	0.0725
		0.6046		
Safety and	System Credibility		0.3229	0.1952
Technology	Stability		0.2322	0.1404
	Security	1	0.4449	0.2690
		0.1260		
Charge	Payment Convenience		0.2221	0.0280
	Price Fairness		0.5985	0.0754
	Payment Method		0.1794	0.0226

Table 3 Performance of marine information systems for alternatives (PMIS)

Dimensions	Items	MTNet	Trade Van	NiceShipping
Services	Information Diversity	0.0495	0.0495	0.0495
	Ease of Use	0.0161	0.0161	0.0161
	Usefulness	0.0242	0.0242	0.0242
Safety and	System Credibility	0.0836	0.0836	0.0278
Technology	Stability	0.0562	0.0562	0.0281
	Security	0.1076	0.1076	0.0538
Charge	Payment Convenience	0.0153	0.0058	0.0069
		0.0436	0.0142	0.0177
		0.0123	0.0046	0.0057
	PMIS	0.4084	0.3618	0.2298

Winformation diversity > Wstabilty > Wprice fairness > Wusefulness > Wease of use > Wpayment convenience > Wpayment method.

The three of the weightiest items in our model are security (Wsecurity = 0.2690), system credibility (Wsystem credibility = 0.1952), and information diversity (Winformation diversity = 0.1487).

Whereas, three of the minor items in the evaluation of marine information systems are payment method (Wpayment method = 0.0226), payment convenience (Wpayment convenience = 0.0280), and ease of use (Wease of use = 0.0428).

After the assessment of the relative weight of each item, we further calculate the performance of the three marine information systems.

According to the research results (see Table 3), MTNet is the best major information system among the three. MTNet not only perform well in Services, and Safety and Technology, but have a better achievement than other two systems in Charge (MTNet = 0.0712 > Trade Van = 0.0246 > NiceShipping = 0.0303). This significant vantage is due to its free usage of the system.

The second marine information system is Trade Van which perform as good as MTNet in the dimensions of services, and Safety and Technology.

But Trade Van's drawback is the way it charge and price fairness.

Although NiceShipping is the third marine information system, it has a good performance in Service and Charge. Since NiceShipping is not as famous as the other two systems, users'major concern is its Safety and Technology.

5. Conclusions

Marine information system evaluation is a multi-criteria problem, and the criteria are usually interdependent. This Analytic Network Process (ANP), which provides a more generalized model in decision-making without making assumptions about the independency of the higher-level elements from lower-level elements and also of the elements within their own level, was applied in this study to achieve the evaluation of marine information system.

A qualitative survey to confirm the adaptability of our final items was conducted in the beginning. Six superintendents in related areas (including ministry of transportation and communication, directorate general of customs, and Taiwan electrical and electronic manufacturers' association) suggested that nine items are appropriate for the performance evaluation of marine information systems.

These nine items were further categorized into three higher-level concepts, namely "Service", "Safety and Technology", and "Charge", which formulated the fundamental hierarchy in this model.

In the empirical study, three marine information systems (MTNet, TradeVan, and NiceShipping) in Taiwan are chosen to be evaluated.

Thirteen experts, selected from various area of marine supply chain management among operators with professional experience in the domain of application, play as the core actors in the following weighting process.

They are asked to judge the relative importance of each item in influencing the relevance of any other items filling in pairwise comparison matrix. Specifically, the relative dominance between each pair of items verbally was shown from equally importance to extremely more important, which can be interpreted into numerical values 1, 3, 5, 7, 9 respectively with 2, 4, 6, 8 as intermediate values for comparisons between two successive points.

The empirical results show that "Safety and Technology" is the most important dimension in marine information system evaluations and "Charge" is the last important dimension.

The dominating importance of "Safety and Technology" pointed out that marine information system users/clients chiefly concern the performance of System Credibility, Stability, and Security in the marine information system. Among them, Security is the primary item that concerned.

Besides, Information Diversity is the key item in the Service dimension and the Price Fairness is the major item in the Charge dimension.

From the overall viewpoint, the aggregate ranking list indicated that three weightiest items in this model are Security, System Credibility, and the Information Diversity.

This finding directly tells that the marine information system users/clients attach most importance to the reliability of the information system. They hope that information exchanged in such platforms can be correctly recorded and reserved.

Information Diversity plays the 3rd ranking role was an interesting finding in this study. It somehow indicates that the clients are no longer receptive users; they care about the diversity of marine information system, hope to choose the most appropriate system to satisfy their need.

This pointed out that marine information system clients hope that, in addition to the all-applicable information exchanging platform, some tailor-made function or customized mechanism can be provided in the subsection of the marine information system.

After the assessment of the relative weight of each item, we further calculate the performance of the three marine information systems.

MTNet is the best major information system among the three. MTNet not only perform well in Services, and Safety and Technology, but also have a better achievement than other two systems in Charge.

MTNet was funded by the official port authorities, which was funded to simplify the port operation, improve marine transit operation process and upgrade process quality. With the governmental supports and supervision, MTNet plays the leading role in the marine information system competition is reasonable and fair.

The second marine information system is Trade Van which perform as good as MTNet in the dimensions of services, and Safety and Technology. But Trade Van's drawback is the way it charge and price fairness. From the historical records, Trade Van was formed to ensure more effective utilization of Taiwan's first EDI information exchange network.

The original goal is to provide value added information exchange services to the international trading business in Taiwan.

Although NiceShipping is the third ranking marine information system in our empirical study, it still has a good performance in Service and Charge.

NiceShipping was founded by civil international logistics service providers, is related young and not as famous as the other two systems.

Performance of NiceShipping in the "Safety and Technology" dimension was relatively weak. In addition to improve the information system security, how to promote the brand image of NiceShipping in order to attract more marine information system clients will be another key issue of this information platform.

After all, this study provides a more complete framework to evaluate the performance of marine information systems.

Results from this study can provide more insights to improve the performance of the existing marine information systems and be the useful reference for the future freight information platform.

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