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Comparative analysis of port performance indicators: Independency and interdependency

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ABSTRACT

Port performance measurement (PPM) and comparison research, presenting a multiple criteria decision making (MCDM) issue in nature, has been intensively conducted by researchers from both decision science on modelling and port studies from empirical perspectives. Assigning an appropriate weight to each defined port performance indicator (PPI) is essential for rational decision and precise performance measurement. However, PPIs are often presented in a hierarchy, having the interdependency among them ignored. It causes concerns on the accuracy of PPIs' weight allocation and arguments on the performance measurement results, revealing a significant research gap to be addressed. As far as MCDM modelling is concerned, the importance of criteria has been studied utilising either absolute or relative comparisons, while the calculation of their importance also takes into account both independency and interdependency factors. However, there is lack of empirical studies in the literature to provide supporting evidence to distinguish the different impacts of the two factors. This study aims to compare the analysis of PPIs importance when taking into account their independent relationship using an analytic hierarchy process (AHP) and their interdependent relationship using a decision making trial and evaluation laboratory (DEMATEL) incorporating an analytic network process (ANP), respectively. The same domain experts are invited to evaluate the importance of the defined PPIs based on both approaches. The results demonstrate that a similar variance of relative importance across the PPIs but a clear difference on their importance scores and ranking. As a result, the results make contributions to fulfil the research gap on consideration of interdependency among PPIs in PPM and on the provision of convincing empirical evidence to highlight the impact of interdependency of criteria on MCDM modelling. Another practical significance draw from this study is that use of DEMATEL can aid port stakeholders to make more rational decision as to whether the interdependency among PPIs should be taken into account in PPM and/or port choice.

1. Introduction

Container ports are playing a pivotal role in facilitating global logistics and supply chains. In the era of global supply chains, the port industry has however been facing the challenges, arising on the one hand from the different interests of port stakeholders and on the other hand from the increasingly competitive business environments. Conflicts of interests between the stakeholders require one (of them) to interpret the others' assertiveness rightly by delivering mutual benefits to all

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related parties. Consequently, the analysis of their interests and needs on various dimensions of port activities becomes essential. The process of the analysis is in nature a multiple criteria decision making (MCDM) problem that involves multiple criteria of both quantitative and qualitative features.

The literature with regard to the methods of weighting criteria in the context of MCDM has been carefully reviewed, including the studies such as Gabus and Fontela, 1973; Saaty, 1980, 1996; Hwang and Yoon, 1981; Chen, 2000; Yang, 2001; Liou et al., 2007; Wang and Chang, 2007; Shieh et al., 2010; Chen and Chen, 2010; Najmi and Makui, 2010; Yang et al., 2011; Buyukozkan and Cifci, 2012. Using absolute or relative comparisons, the weights can be assigned to each criterion. In the weight assignments, the criteria in a MCDM problem are considered independently or interdependently. The former is formed as a linear hierarchy whilst the latter is demonstrated as a non-linear network. Although many MCDM problems have been studied using both approaches, it is not true that one always presents better results than another (Saaty, 2001), requiring more evidence obtained from empirical studies. Meantime, it has been widely recognised but not well addressed yet that despite many advanced approaches in MCDM, scholars and practitioners have done little on the comparative analysis of independency and interdependency among criteria to provide empirical evidence to assess the influence of their interdependency. Furthermore, based on the search on Web of Science, in all the relevant papers dealing with "port choice", "port selection", and "port competitiveness", the factors/attributes influencing decision making have been considered independently (Yeo et al., 2014), although the existence of the interdependency among the factors has been widely recognised (Lee et al., 2013). To address this research need and also fulfil the gap on PPIs' independency study in port studies, this study uses an analytic hierarchy process (AHP) to conduct independent weight assignments, while applying a decision making trial and evaluation laboratory (DEMATEL) incorporating an analytic network process (ANP) to catch interdependent features between the criteria. The use of the hybrid of DEMATEL and ANP in this study is because of their capability of dealing with (1) complex decision problems, (2) both quantitative and qualitative PPIs and (3) group decision-making with a relatively small sample size for analysis (Shieh et al., 2010; Buyukozkan and Cifci, 2012; Ha et al., 2017). Furthermore, using DEMATEL to screen significant interdependency among the PPIs can avoid costly and time-consuming data collection when requiring various types of questionnaire surveys, while having ANP to quantify the interdependency based on its sound mathematics and psychology leads to improved judgements reliability. The same group of domain experts are invited to evaluate the importance of PPIs based on both approaches of AHP only and the hybrid of DEMATEL and ANP. The comparative analysis provides the stakeholders especially for ports (i.e. terminal operators, port authorities) with valuable insights to prioritise investment for competitiveness improvement by adjusting their strategies based on the relative importance of criteria.

In the next section, theoretical background of the AHP, DEMATEL and ANP as well as their associated calculation algorithms are introduced. In Section 3, the selection of port performance indicators (PPIs) is carefully described. In Section 4, the process of analysing the relative importance of the PPIs obtained by AHP and DEMATEL-ANP is presented in Section 5. It is complemented by the detailed comparative analysis with respect to the most important PPIs from the two approaches and provides useful practical guides for the development of investment strategies. Section 6 concludes the paper with its insights and limitations.

2. Methodology

2.1. The use of AHP to PPIs' independency

The AHP introduced by Saaty (1980) assumes independence of one cluster from another but it does not allow for feedbacks between clusters in a hierarchy (Saaty, 2001). Accordingly, the hierarchy is a simple structure to decompose a complex problem through identifying unidirectional cause effect explanations with a linear chain (Saaty and Takizawa, 1986). This tool is useful for dealing with MCDM problems and aids decision makers to capture both subjective and objective aspects of a decision (Saaty, 2001). The decision is made based on scores obtained by pairwise comparisons between the criteria, in other words, the higher the score is, the more important the criterion.

In this study, the relative weights of the independent PPIs at the same level can be obtained using pair-wise comparisons. A number of selected experts are approached to respond to a question such as "which PPI should be emphasized more in a port performance management (PPM), and how much more?" A series of pairwise comparisons are developed based on the Saaty's nine-point scale ranging from 1 (equal) to 9 (extreme). Then, the local weights of PPIs can be obtained by following Eqs. (1)–(3) (Saaty, 1980). Let e_{ij}^l be the relative importance judgement on the pair of PPIs P_i and $P_j (i,j = 1, 2, \ldots n)$ by lth expert. Then, the aggregated weight comparison between P_i and P_j by m experts ($l \in m$) can be obtained by Eq. (1).

$$e_{ij} = \frac{1}{m}\left(e_{ij}^1 + \ldots + e_{ij}^l + \ldots + e_{ij}^m\right) \tag{1}$$

Next, the synthesised *ith* criterion weight comparison between P_i and P_j by m experts can be calculated using Eq. (2).