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Transportation Research Procedia00 (2018) 000–000

Transportation Research Procedia

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World Conference on Transport Research - WCTR 2019Mumbai 26-31 May 2019

A Framework for evaluating the potential for using air-maritime integration in modern supply chains

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Abstract

This paper presents a framework for evaluating the potential for implementing air-maritime integration. Ten most influencing factors for air-maritime integrated logistics are established using expert opinion and literature. Two methods of integration Substitution and complementary are considered. AHP analysis was used to derive important weights to influencing factors and to determine the best method of integration. IPA analysis was used to interact relative importance and current performance of individual factors and classify them to four quadrants. Future actions required for implementing air-maritime integrated logistics were discussed based on the IPA classification. The framework was applied to assess the air-maritime integration potential of Sri Lanka. As per the results of the analysis, the best suited method for Sri Lanka was found to be the complementary method. Results also suggested worldwide connectivity and centralized location are the most important criteria for implementing integrated logistics.

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*Keywords:*Air-Maritime integration, Complementary, Substitution, AHP, IPA

1. Introduction

Integrating different transportation modes have become crucial for achieving cost and time savings in most supply chain systems. We can use this integration method for both cargo and passenger transportation. But in this paper we mainly focus on cargo movements. Different modes have different characteristics of transportation cost, delivery speed, reliability and safety. Thus, proper integration can optimize supply chain costs by maximizing the benefits of each mode. In today's economic context most supply chains are global and complex. Integration of land transport modes with sea or air is commonly found in practice and various related issues being discussed in research

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as well (César Ducruet, 2009). However, integration between air and maritime transportation is rarely found is practice as well as in research studies. Mainly Air transport is more dense, easy accessible and have more connectivity than maritime transport. But it is worthy to measure the possibility of integrating air and sea transport modes to optimize the efficiency in supply chain by maximizing the time, reliability benefits through air transport mode and cost, safety benefits through sea transport modes. Significant incompatibility between the two modes of transportation is one reason for not receiving much attention in this regard. However, When considering airport and seaport as major components, air-maritime integration could facilitate the optimization of a supply chain by utilizing favorable characteristics of each mode (James J. Wang, 2010) (OR) so it is worth studying to evaluate the potential for using air-maritime integration in modern supply chain transportation and supply chain management knowledge domain lacks a proper framework to evaluate the potential for air-maritime integration to take place in a given region or country. Such a framework can give policy makers and investors a methodical approach for assessing feasibility of integration as well as alternative strategies. Hence the objective of this study is to fill the above gap in knowledge. The methodology will be developed by taking Sri Lanka as a possible region for implementing the strategy.

Sri Lanka has two international airports and three main seaports which generate a considerable economic impact to the country. Colombo Port is the largest port in Sri Lanka. It is a rapidly growing maritime hub of the South Asia Region. Cargo originating from and destined to Europe, East and South Asia, the Persian Gulf, and East Africa is connected through the Colombo Port. In 2015, it handled about 5.7 million TEU of containerized cargo (Dailymirror, 2017). Hambanthota and Trincomalee are other major ports in Sri Lanka. Bandaranayake international airport (BIA) is the main international airport in Sri Lanka. In 2016 BIA handled close to 62,000 aircraft movements connecting Sri Lanka to Asia, Middle East, Australia and Europe with direct flights. Mattala international airport (MRIA) is the second international airport located in the southern part of the country (AASL Annual report, 2016).

2. Air-Sea Integration

Integration of air and sea transportation cannot be achieved simply by transferring cargo from one mode to another. Given the fundamental differences in mode characteristics, it is necessary to have intermediate handling of cargo or passengers in order to achieve integration between air and maritime transportation. Air-maritime integrated logistics is currently viewed by the industry as a solution in between pure maritime and pure air freight. According to various industry claims it gives a 30% cost saving and 50% time saving compared to air pure air and maritime options respectively (Web-8). Dubai, Los Angeles, Hong-Kong, Miami and Panama are among the main hubs which currently facilitate air-maritime integration.

Dubai is one of best examples for facilitating air-maritime integration. They offer simple custom formalities to increase the efficiency of the cargo movement between airport and sea-port (Haq, 2009). Dubai is well connected to major economic centres of the world with maritime and air networks. Nearly 3 million tons of cargo is handled at Dubai international airport annually, and 10% of it is related to air-maritime logistics (Rodrigue, 2016).

Accordingly, air-maritime integrated transportation can take place using two methods such as; substitution and complementary. The two methods are further described below. Figure 1 gives a graphical representation of the two methods discussed above.

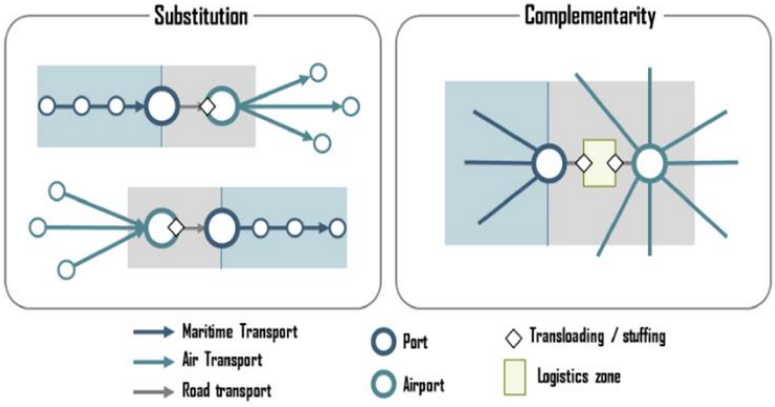

Fig. 1. Methods of air-maritime integration. Source (Rodrigue, 2016).

2.1. Air – Maritime Substitution

Substitution appears either when maritime transport is used for the first transport segment and air transport for the second segment, or other way around (Rodrigue, 2016). Simply the process is bringing cargo from one mode of transport, break-bulking or consolidating at an intermediate point between airport and seaport, and then resending the goods using the other transport mode. Bringing cargo from ships to Sri Lanka in containers, separating them to small units and sending them through air to land-lock countries like Nepal can be cited as an example. At the same time, we can get the advantage of time by changing and balancing the rhythm of the supply chain from days (or weeks) in maritime shipping to hours in air transport (Haq, 2009). This type of integration is essentially transshipment of cargo between the two modes. Thus, the overall cost and time benefit compared to pure modes depends highly on the location of the integration and the transit-time within the integration hub. As in the Dubai example, seamless government formalities and good coordination between two types of ports are essential for minimizing the transit time. Due to additional handling of goods is involved in the process of integration, efficient and secure cargo loading, unloading and transporting need to be in place for minimizing the possible time lost within the hub and minimizing the damage to cargo.

High road connectivity, efficiency at airport and port, as well as the efficiency at customs are the biggest challenges to implement substitution method.

Currently there is no maritime-air integration taking place according to substitution technique in Sri Lanka. However, there is a vast potential to establish an integration hub given the availability of port and airport capacity, convenient connectivity between them and the central location with respect to key points of demand and supply of cargo. Figure 2 shows the maritime connectivity of Sri Lanka. Sri Lanka is already playing the role as the regional transhipment hub.

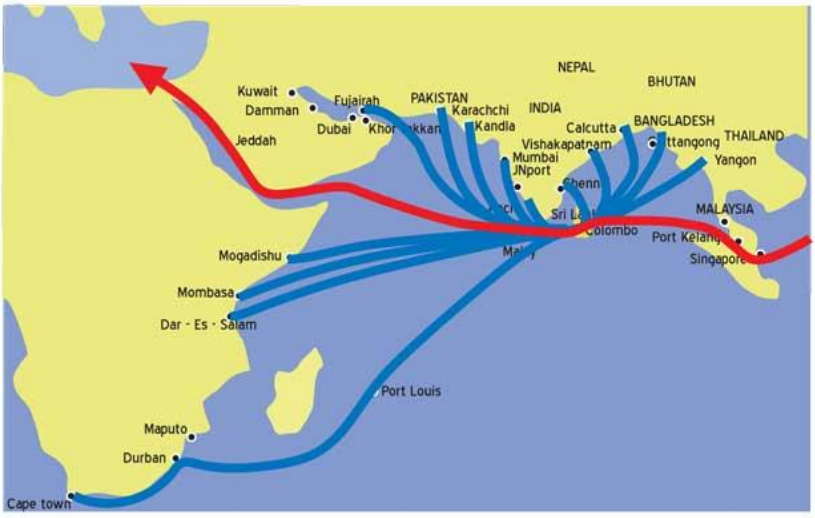

Fig. 2. Maritime connectivity of Sri Lanka, Source: (Dailymirror, 2017)

2.2. Air – Maritime Complementary

Complementary appears when maritime and air cargo operations are jointly used in supply chain management. Simply it is bringing raw material from one transport mode, manufacturing or value adding at a logistic hub in-between and resending through other transport mode. This type of integration requires establishment of special economic zones located with good connectivity between air and sea ports. This method works quite well for

products where the finished good is transported to markets by air rather than the other way around. Availability of a good air network is vital to efficiently transport final products to markets. Furthermore, products with high weight to value ratio such as precision tools, electronic components, aircraft and automobile parts are possible candidates to benefit from such integration. As significant value addition is required, availability of new technology (efficiency and accuracy of exchanging details between airline, sea line and custom, speed of clearing goods from custom), infrastructure facilities for a logistic zone (land availability, condition of land road system between airport and sea port) and high skilled work force is also vital. (Developing those facilities at once is the biggest challenge when developing these methods in a country.)

Sri Lanka currently has several well-established value-adding industries such as garments, pharmaceuticals and electronic components. However, there is no formal structure to integrate maritime and air transportation (complementary method) for optimizing their supply chains. Figure-3 shows the top 10 exports from Sri Lanka according to value by air mode. As can be seen form Figure-3 Sri Lanka's top exporting products includes high weight to value ratio items such as textile and electrical components. Most of these products use raw materials and other production inputs imported by maritime transportation. Thus, complementary type integrated logistics could facilitate cost and time savings for these industries. As you can see complementary integration method is operating in Sri Lanka informally. Figure-3 shows the examples for this, but need formal setup to have the benefits from this method in every industry within Sri Lanka. Below are some examples for this and more activities can be generated by formalizing and more industries can be attracted.

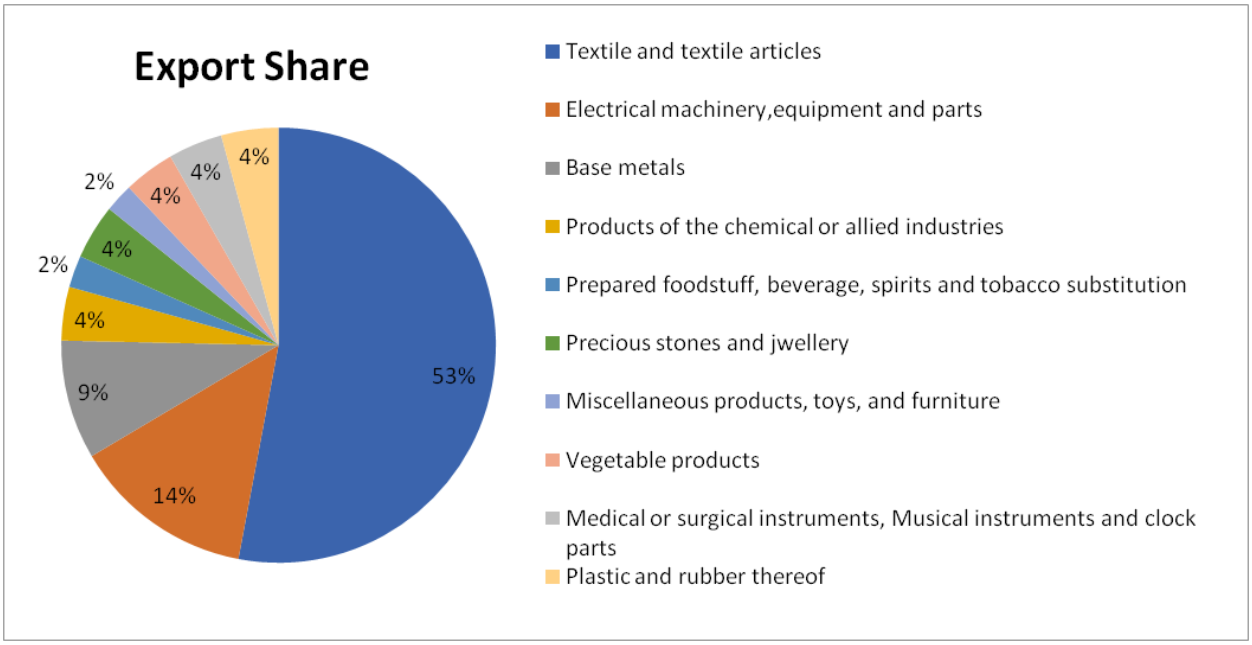

Fig. 3. Percentage share of exports (value) from Sri Lanka by air

3. Conceptual frame work

The main objective of the study is to develop a framework for assessing the potential to operate a logistics hub for integrating maritime and air transportation in a given region. Hence one of the critical sub-objectives was to define a set of independent criteria influencing the potential to integrate maritime and air transportation. Data on the integration using substitution method was limited as currently this type of integration is not happening in Sri Lanka. Export commodity data from Sri Lanka customs and structured interview data from industry experts were used to determine the potential industries to benefit from complementary type integration. Then an AHP analysis was

carried out using the inputs from 10 industry experts in order to determine the relative importance of the identified criteria and the overall preference for the two integration techniques. The research frame work is shown in Figure 4.

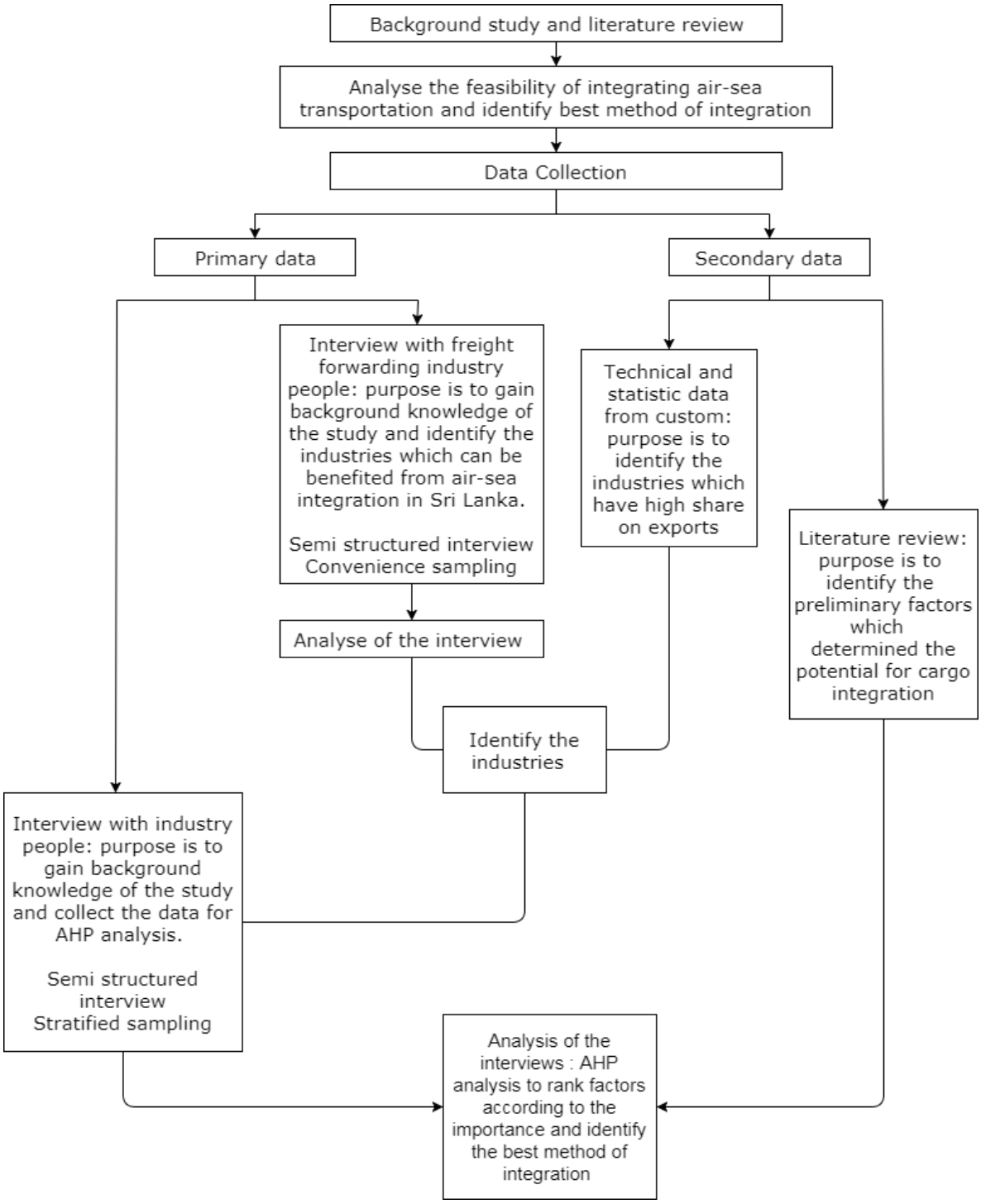

Fig. 4. Conceptual framework

Convenience Sampling (Also known as Haphazard Sampling or Accidental Sampling) - Is a type of nonprobability or nonrandom sampling where members of the target population that meet certain practical criteria, such as easy accessibility, geographical proximity, availability at a given time, or the willingness to participate are included for the purpose of the study.

Stratified Sampling - Divide the whole heterogeneous population into smaller groups or subpopulations, such that the sampling units are homogeneous with respect to the characteristic under study within the subpopulation and heterogeneous with respect to the characteristic under study between/among the subpopulations.

3.1. Identified different criteria of factors

Identifying the factors which influence air-maritime is one of major objectives of this research. Influencing factors were identified through literature review and interviews with industry experts. A list of ten factors was determined using literature review. In a preliminary survey with experts in the freight forwarding industry, they were requested to add new factors to the list and rate the relative importance. Final list of factors to be used for the detailed survey and AHP analysis is given in Table 1.

Table 1.Influencing factors for air-maritime integration

Factor	Description	Source
F1 :Worldwide connectivity	• Linkage with air/sea port network • Flight/ships frequency • Number of airlines/shipping lines	(Raguraman, 1997)
F2 :Central location	• Geographical location between supply and demand regions • Advantages of international air and sea routes	(James J. Wang, 2010)
F3 :Infrastructure capacity	• Capacity of cargo terminals • Availability of handling equipment's • Aircrafts/ships parking availability • Slot availability	(Raguraman, 1997)
F4 :Ground handling efficiency at air and sea ports	• Operation efficiency of ramp services • Overall turnaround time	(Raguraman, 1997)
F5 :Convenience of clearing government procedures for cargo/passenger movements to and from ports	• Custom clearance time and other documentation procedures	(James J. Wang, 2010)
F6 :Effective land transport system	• Access time between ports and logistic zone • Quality of land transport infrastructures • Traffic convenience between ports and service cities	(James J. Wang, 2010)
F7 :Economic activities	• Local business activities around the air and sea ports (Freight forwarders activity, production activity)	(James J. Wang, 2010)
F8 :Land availability in the region	• For future expansion of airport and seaport	(John Mangan, 2008)

F9 :Ownership or authority power	• For future expansion of economic activity • The support you receive from the airport and the port authority	(John Mangan, 2008)
F10 :Influence of policy makers	• Free from taxes	Added by experts

3.2. Analytical Hierarchy Process (AHP)

Analytical hierarchy process was used to determine the relative importance among the set of identified factors and to determine the overall preference between the two integration techniques according to the opinion of a panel of industry experts (Saaty, 2008). Panel of experts were chosen to represent freight forwarding sector as well as the manufacturing sector. Managerial level staff of three leading freight forwarding companies were included. Manufacturing industries with the most potential to benefit from complementary type air-sea integration was selected. Data from export commodities from Sri Lanka by air was used to rank the industries according to the percentage weight and value. Based on the above analysis, textile and textile articles, Electrical machinery equipment and parts, Products of the chemical or allied industries (Pharmaceuticals), prepared foodstuff, beverage, spirits and tobacco substitution were selected. An AHP questionnaire was presented to the managerial level staff of the above organization categories. Surveys were performed by personal interviews. Inputs from 10 experts were selected for further analysis. (The number of expertise who have the knowledge on supply chain and logistics field are less. In Sri Lanka, there are only small amount of big industries and the interweavers are from managerial level and the number of interweavers are limited.)

According to the weightings obtained from AHP analysis, the factors were prioritized over one another. At the final stage, the suitable method of integration was identified through the comparison of the two methods with respect to each influencing factor. The decisions structure involved in the AHP analysis is shown in the below Figure 5

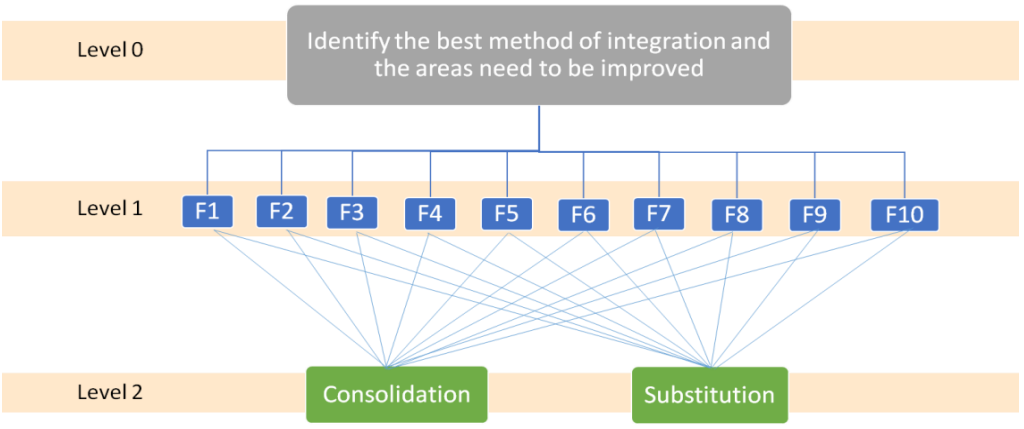

Fig. 5.AHP analysis process

Number of possible pair wise comparisons was identified as 45 and the data gathered through the survey questionnaire was converted to an AHP applicable scale (1/9 to 9). Through the calculations of AHP analysis process following results were obtained:

Consistency Index (CI) = **11.287**
Random Consistency Index (RI) - **RI = 1.49**
Consistency Ratio (CR) - **CR =0.096 = 9.6%**

In order to validate the inconsistency, the CR value should be less than 10%. As the determined value for CR, 0.096 is less than 0.1 it can be concluded that the subjective evaluation about preference is consistent. Since the study dealt with human judgment, a 100% consistency level cannot be obtained due to variations in practical application.Figure-6 shows the comparison of relative weights obtained for the selected influencing factors. According to the results the most important influencing factor for the potential for air-sea integration was worldwide connectivity, followed by centralized location and infrastructure capacity.

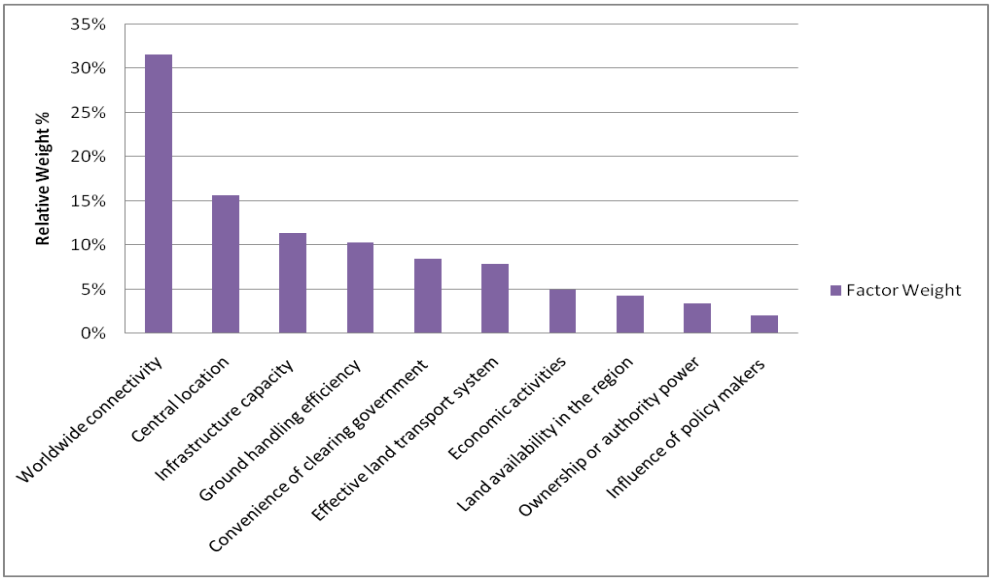

Fig. 6. Importance of factors

As the final step of the AHP analysis, two methods of integration are compared with respect to each influencing factor (Bhushan N., 2004). Table 2 gives the final calculation for obtaining the overall weights of two methods. According to the results shown complementary method of integrations is preferred over the substitution method. Interestingly, complementary method is preferred under all the 10 influencing factors. The concept of value addition in the complementary method generates more opportunity for economic contribution to the country.

Table 2.Paired comparison matrix

Factor	Factor Weight	Complementarity	Substitution
F1	0.32	0.80	0.20
F2	0.16	0.71	0.29
F3	0.11	0.73	0.27
F4	0.10	0.71	0.29
F5	0.08	0.79	0.21
F6	0.08	0.78	0.22
F7	0.05	0.74	0.26
F8	0.04	0.79	0.21
F9	0.03	0.63	0.38
F10	0.02	0.63	0.37
Composite Weight		0.75	0.25

3.3. Importance – Performance Analysis (IPA)

Identifying the areas that need to be developed to integrate air to sea transportation in Sri Lanka is very important. Importance performance analysis (IPA) can be used to categorize influencing factors based on the interaction of importance and performance. Martilla and James (1977) first introduced IPA to investigate the service quality of an automobile dealer based on the importance and performance of its facilities. IPA is found to be commonly used in service related fields for evaluating service performance and prioritize corrective action. IPA can be used in the current framework to prioritize future action required on influencing factors conditional to the interaction of its importance and current performance. This study measured the performance of each factor using the subjective rating of industry experts. In the detailed questionnaire survey of industry experts, they were asked to indicate the current performance of air-maritime integration of Sri Lanka with respect to each influencing factor on a 0-10 Likert scale. Performance of a factor was calculated by taking the mean performance rating given by 10 industry experts. Mean performance values were rescaled between 0 to 1 to be used for the IPA analysis. Relative importance values were obtained from the AHP analysis. AHP produces weights representing the part worth of each criteria and summed over all the criteria equals to one. Therefore, the ratios of weights among the criteria are more meaningful than the nominal value. Hence the AHP weights were normalised with respect to the highest weighted among the 10 factors. This transformation produces a scale between 0 to 1.

IPA analysis defines four types of interactions between the two variables based on the quadrants formed by splitting the X and Y axis into high and low categories. Locations where the X and Y axis are split act as reference points defining high and low values. 0.5 was chosen on both axis as the crosshair point to form the quadrants (Silva, 2011). Figure 7 shows the IPA matrix. Then interaction within each quadrant can be defined as follows:

Quadrant-1(QI) (High Importance/Low Performance) is labelled “concentrate Here”. Attributes that fall into this quadrant represent key areas that need to be improved with top priority.
Quadrant-2(QII)(High Importance/High Performance) is labelled “Keep up the good work”. All attributes that fall into this quadrant are the strengths and pillars of the organizations. These factors are related to the image of the organization.
Quadrant-3(QIII) (Low Importance/Low Performance) is labelled “Low Priority”. Thus, any of the attributes that fall into this quadrant are not important and pose no threat to the organizations.
Quadrant-4(QIV) (Low Importance/High Performance) is labelled as “Possible Overkill”. It denotes attributes that may be given less priority in allocating scares resources; they should allocate more resources to deal with attributes that reside in quadrant 1.

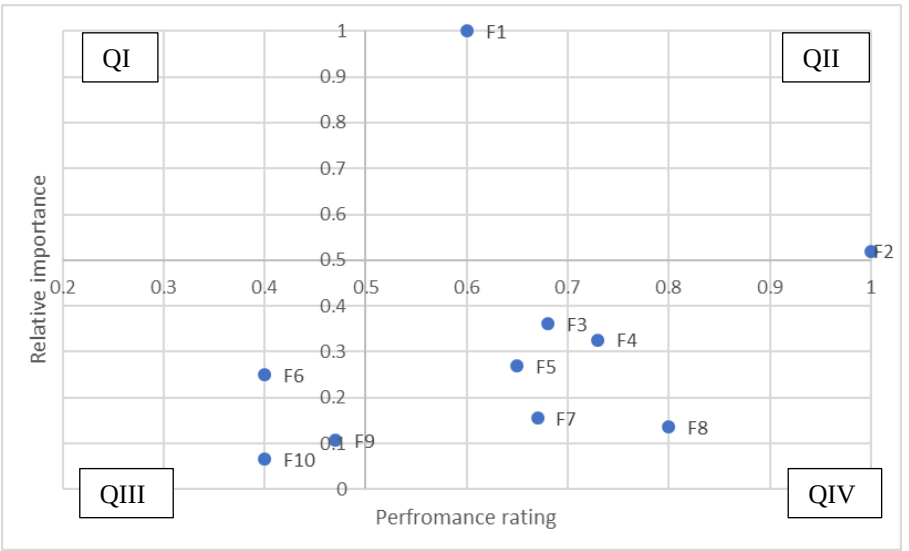

Fig. 7.IPA matrix

3.4. *Evaluation of the influencing factors.*

3.4.1. Worldwide connectivity:

According to the IPA analysis this factor has been fallen in to the II quadrant, means this factor is important and performing well. According to the AHP analysis, the most important factor for integration of air - Maritime transportation is worldwide connectivity. According to expert rating Sri Lanka's performance in this regard is 0.67. Since this value is closer to 0.5, it is an indication that the actual performance needs improvement. Flight / ship frequency and number of airline / shipping line operating at our terminals are important to increase the efficiency of cargo movements.

3.4.2. Central location

IPA analysis shows that the performance of this factor also falls in to the II quadrant. The performance of this factor is rated 100% as Sir Lanka is Located in a highly strategic location in the Indian Ocean. According to AHP analysis, central location is the second most important factor for air-maritime integration. Sri Lanka is situated near India which has a relatively larger economy. India is rapidly increasing its production capacity and an emerging producer of global commodities. Currently most of Indian cargo transhipments happen through Colombo seaport to other destinations. More over China is one of the biggest supplier in the world. Europe and Middle East are the main markets of China. Sri Lanka is thus located in between supply and demand regions.

Located near a main shipping line and air route is another good opportunity to success the air-maritime integration. Sri Lanka is located near one of the busiest international maritime routes in the world. Since there is no any country below Sri Lanka it is another good opportunity to attract air lines. Hence, there is high possibility to integrate an air to sea transportation and get the maximum benefits from it.

Kra-Canal establishment in Thailand may become a reality as part of China's Belt & Road Initiative (BRI). The project will create the connection between South Chinese Sea on the East in the Gulf of Thailand and the Andaman Sea in the west by passing through Sothern Thailand. The canal will be 135Km long 400m wide and 30m depth. This will be benefited for shipping lines by reducing nearly 1200 NM distance from their travel journey. Sri Lanka will gain more benefits and it is a great opportunity to become the next main shipping hub in Asian region. (Verley, 2015). Figure 8 shows the existing and proposed shipping route.

Fig. 8. Proposed Kra Canal in Thailand

Acquiring Hambanthota port and developing Hambanthota as main industrial zone by China as the biggest investor will give us a chance to enter the new industries and opportunities.

USA's pentagon 2008 'Joint Operation Environment Report" has mentioned that Kra Canal and Hambanthota ports were part of China's shipping lane strategy (Peries, 2017). Most of the cargo which is coming from India and Bangladesh to Far East will be diverted to Hambanthota. Since the perfomance of world wide connectivity and

centralized location in Sri Lanka will be increased in near future. This will be a great opportunity to integrate air and sea transport modes and get the maximum benefits by smoothing the supply chain process in Sri Lanka.

3.4.3. Infrastructure capacity, Ground handling and Clearing government procedures, effective land transportation

All four factors relate to effective and efficient transition between maritime and air models. These factors may be more important for substation type integration than complementary as the lag in transition directly affects the lead time. All four factors have been rated with similar relative importance. However, their importance values are closer to 0.5 compared to other less important factors. Except for land transportation other three factors are included in quadrant -4, indicating they are better in performance. In terms of infrastructure capacity, Sri Lanka is already having two international airports and two major ports in the country. Capacities of all these ports are envisaged to be upgraded in the future. Sri Lanka has room for improvement in Ground handling and government procedures. Investment in high skilled workforce and new technology is key for improving ground handling performance. Even though Sri Lanka has good intercity highway connectivity, important nodes providing access to major ports such as the capital city Colombo is highly congested.

Furthermore, some changes that can be done to improve the efficiency and accuracy of the clearing procedures : Reducing transactional costs, Increasing transparency and predictability of the procedure, Improve publication and administration of policies related to trade, Streamline rules and procedures for imports and exports, Increase usage of ICT (Information Communication Technology) for trade, Eliminating irregular payments, Extending pre-arrival processing to more products, Setting up of a single window and fully automating the trading system.

3.4.4. Economic activities, Land availability in the region, Ownership or authority power, Influence of policy makers

According to AHP analysis above factors were grouped as the set of least important factors compared to other influences on the integration. All the four factors can be related to strategic or policy level considerations for affecting air-maritime integration. In terms of performance, economic activity and ownership and authority power Sri Lanka has been rated above average. Sri Lanka is currently striving towards export-oriented production industries. The Western Region Megapolis initiative of Sri Lanka envisages to develop the country's western province as an economic hub to boost the development in several folds. Included in the master plan are several industrial zones including an aero-city. Sri Lanka's ports and air-ports are governed by authorities directly under the preview of the government. However, successive governments in Sri Lanka has leased out port operations to foreign operators. Hence the operational goals of the key infrastructure such as ports may not be easily aligned with government policy initiatives towards air-maritime integrated logistics. Thus, the performance in ownership and authoritative power is relatively less.

4. Limitations

1. Research has been done based on Sri Lankan context.

2. Further studies are required to check the validity in other economic contexts.

5. Conclusions and Recommendations

Through the literature review and discussions with the experts the factors that need to develop for air-sea integration are identified. In order to further extract the important factors, the opinion of the industry experts was taken. AHP analysis was selected as the suitable method to analyze the factors as the exact numerical value allocation for these data types is not possible. AHP allowed the synthesis of the opinion of the panel of experts for methodically comparing the identified influencing factors and the two methods of integration. The analysis showed that complementary method is the most suitable for Sri Lanka given the performance of the influencing factors. Worldwide connectivity and centralized location were identified as the most important factors affecting the potential for successfully implementing air-maritime integrated logistics. Finally, IPA analysis was used to interact derived

relative importance with the current performance of each factor. This analysis allowed to classify the factors to four quadrants and identify possible future actions required for improvement.

Furthermore, the industries which can be benefited from air-sea integration are identified through the research. For Sri Lanka textile and textile articles, electrical machinery, equipment and parts, products of the chemical or allied industries (Pharmaceuticals), Tourism can be aligned with air-maritime integrated logistics.

The results derived using the proposed framework is mainly based on subjective inputs. Thus, the variations of the results need to be considered when arriving at conclusions. Reliability of the AHP results can be improved by expanding the panel of respondents to the survey. Furthermore, the panel was entirely comprised of local experts. Thus, the results can be biased based on their exposure to global practices. Evaluation of the performance and choosing the crosshair points in the IPA can be improved by using objective performance measurement criteria.

By further improving the analysis procedure, this can be used for any other scenario in the world for evaluating the potential for air-sea integration.

Moreover the factors which have been considered here are mainly related to the current situation in Sri Lanka. If we are to use this methodology for other larger economic zones like Hong Kong, Singapore, USA, we may need to consider new factors related to their economic contexts. Factors may be valid, but the importance will change according to the economic zones. From this we may be able to generalize the factors and importance by finding more results.

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