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Cargo allocation in Brazilian ports: An analysis through fuzzy logic and social networks

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ABSTRACT

Empirical and anecdotal evidence suggests Brazilian ports are running short in operational capacity for cargo handling and shipping movements. This paper focuses on the joint use of Fuzzy Logic (FL) reasoning and Social Network Analysis (SNA) to assess the cargo allocation pattern in Brazilian ports while shedding some light on policy-making directions and future research venues. Results suggest that cargo allocation patterns vary depending on the cargo type and product type. One can also infer that shippers prioritize distance in relation to other port allocation criteria. In the case of containerized cargo, this may be due to its higher value added compared to bulk cargo. Sensitivity analyses are also performed on the weights of port allocation criteria to explore opportunities for cargo relocation among ports in Brazil.

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1. Introduction

Ports constitute the major transportation mode for moving products around the world (Montes et al., 2012). In Brazil, port terminals handled over 90% of the total cargo throughput in 2014 for foreign trade, according to the Brazilian Ministry of Industry, Foreign Trade and Services (MDIC, 2015). In this context of huge cargo throughputs, competition for cargo allocation is widespread in seaport terminals (Alonso and Soriano, 2009; Tongzon, 2009; Álvarez-SanJaime et al., 2015). In fact, several factors must be considered simultaneously when choosing among port alternatives, making cargo allocation a complex decision. Criteria include (i) ground distance to the port and/or maritime distance to the destination (Malchow and Kanafani, 2004); (ii) port handling costs; (iii) port infrastructure; (iv) port customer service (Lirn et al., 2004); (v) port handling efficiency; (vi) carriers' frequency (Ugboma et al., 2006); (vii) port accessibility, (viii) regional centrality of port; and (ix) port connectivity (Yeo et al., 2011).

Multiple-criteria decision-making techniques such as FL improve the understanding of the inherent complexity of port allocation decisions while also taking into account the underlying countervailing forces or trade-offs embedded within each criterion. Broadly speaking, techniques such as FL allow representing each criterion within the ambit of the port allocation decision process by means of an inference system that ranks possible alternatives according to certain rules (McNeill and Thro, 1994). For instance, "give preference to a certain port to the detriment of the other if distance is low and service level is high" is a possible FL inference rule for ranking port allocation priorities.

Specifically, cargo allocation in ports has been examined through SNA, for example, in the work of Shan et al. (2013) in China. SNA helped in visualizing ports with a central role in Chinese economy either due to their centrality or due to their cargo scope. Although SNA was originally designed to map the relationship between individuals, the technique might also bring significant advantages when applied to ports by unveiling cargo allocation patterns among them (Ducruet and Zaidi, 2012; Kang and Woo, 2017). Broadly speaking, SNA delivers as a major byproduct a graph with lines connecting entities in the following ways: at the seaport level, ports that handle the same kind of products, and their respective throughputs (Scott, 2012).

Despite the wide use of FL and SNA for decision-making in logistics and transportation (e.g. Ducruet and Zaidi, 2012; Montes et al., 2012; He et al., 2012; Yeo et al., 2011), their joint use to assess cargo allocation patterns in seaports is innovative in the academic literature to the best of our knowledge. Additionally, in contrast with previous research, this study focuses on Brazilian ports, which are a relatively an understudied topic when compared to U.S., European, or Asian ports (Wanke and Barros, 2016). The distinctive aspect of the Brazilian port industry compared to other countries is related to the potential capacity shortfall that has been systematically reported either anecdotally (press) or empirically (academic papers) over the past fifteen years and that is further discussed in Section 2.

In this paper, a FL reasoning model that is also built upon some of the network measures that are used in the analysis of social networks is

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presented. Alonso et al. (2013) showed that SNA can also be successfully applied in the context of designing interpretable fuzzy systems. We apply this joint approach to emulate the way economic agents make decisions in Brazilian ports with respect to cargo allocation, subsequently comparing these inferred allocation patterns to actual cargo allocation. Considering that expansion of port capacity is a long-term project, the analysis of cargo allocation patterns in Brazilian ports may be helpful in shedding some light on possible alternative cargo handling routes, including designing short to middle-term measures to alleviate congestion and improve service levels.

Table 1
Summary of studies on port selection/cargo allocation criteria.

Authors (year)	Criteria analyzed	Locus and objectives of the study	Method and findings
Wanke et al. (2011)	Distance Queue time	US Analyze distribution of maritime shipments	Discrete choice model Location of the port is the most important criteria
Song and Yeo (2004)	Distance Support Services Port Infrastructure Throughput Volume	China Identify competitiveness from an outsider´s perspective	AHP Ports located in free-trade an industrial zones are more competitive
Lirn et al. (2004)	Distance Costs Port Infrastructure	World-wide container operations and port authorities Establish differences in perceptions as regards the most important criteria	AHP Perceptions were found to be similiar
Ugboma et al. (2006)	Distance Costs Port Infrastructure Shipping Line Frequency Port Efficiency	Nigeria Determine most important port selection criteria	AHP Efficiency, frequency of ship vists, and infrastructure are the three most important criteria
Guy and Urli (2006)	Distance Costs Support Services Port Infrastructure	US and Canada Assess whether the accepted rationale of port selection by shipping lines – based on the combined importance of quality of infrastructures, cost, service and geographical location – is useful to account for the selection behaviour observed	Multicriteria method based on different scenarios Findings suggest a trade-off between hinterland size and port cost/service
De Langen (2007)	Cultural aspects	Austria Evaluate port selection from the perspective of an inland country	Survey Shippers and forwarders share similar perspectives
Chang et al. (2008)	Costs Port Infrastructure Route Integration	Asia The objective is to identify the factors affecting shipping companies' port choice based on a survey to a sample of shipping companies.	Exploratory and confirmatory factor analysis Five factors were identified: advancement/convenience of port; physical/operational ability of port; operational condition of shipping lines; marketability; and port charge
Alonso and Soriano (2009)	Distance	Spain Study the port choice through revealed port selection instead of asking port stakeholders about the main factors in port selection.	Discrete choice model Location exerts a prominent impact in port choice
Tongzon (2009)	Distance Costs Support Services Port Infrastructure Shipping Line Frequency Port Efficiency Reputation	Southeast Asia Evaluate major factors influencing port choice from the freight forwarders perspective	Supply chain analytical framework Efficiency and shipping frequency are the most important factors
Jafari et al. (2013)	Distance Costs Support Servce Bureaucracy Time Transport Infrastructure to Port Technology Used in the Process Port Infrastrucutre Shipping Line Frequency Specialized Work Force	Iran Establish port ranking and competitiveness	ORESTE and Shannon entropy Cost, hinterland size, and accessibility are the most important criteria

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