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Causal mechanism in transport collaboration

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ABSTRACT

The changing climate in supply chain management, driven by technological trends, increased competition, demand pressure, globalization and outsourcing has led companies to be more receptive to forming coalitions while taking a broader strategic view of the marketplace. The structure of a transport coalition is an important issue influencing the life cycle of such relationships. This structure is a set of consensual relationships that connect key operating criteria for the coalition. The structure can change over time. This structural change is causal and its extreme situation might cause deterioration of the coalition. This work proposes a systematic way of analyzing the causal inference mechanism between the operating collaborative criteria and their categories in transport collaboration using a fuzzy cognitive map based approach. The findings address the decision making on the level of collaborative integration of coalition by the detection thresholds according to "go", "go with conditions" and "no-go" signals. This approach is supported with the application to a "real world" case of a multi-echelon heterarchical transport network through a series of simulation experiments.

1. Introduction

Transport management is a highly leveraged function for value creation meaning that even small improvements in business processes can drive large increases in profitability and cost reduction (Stank & Goldsby, 2000). Therefore the transport industry has seen a recent emergence of strategic collaborative initiatives (Cruijssen, Dullaert, & Fleuren, 2007; Fugate, Davis-Sramek, & Goldsby, 2009). Studies have shown that there is a notable realization of collaborative actions in the business of freight transport with particular increases in the use of intermodal shipments and the improvement of carrier tracking and shipment consolidation (Graham, 2011). Transport collaboration can be considered to be a strategic asset for optimizing the supply chain and improving the competitiveness of companies (Kayikci & Zsifkovits, 2012). Therefore, transport users, transport service providers and/or technology providers establish *coalition communities* in order to reap benefits from joint operational processes. Since every coalition has unique aspects, there is no "*one size fits all approach*" for building a transport collaboration. That being said, the *structure* of a collaboration should contain the combination of automated and adaptive *technologies*, business *processes* and proactive *human collaboration* in socio-technical systems (Gaurav, 2004; Ritter, Lyons, & Swindler, 2007). Success for a transport coalition is achieved when the above-mentioned combination is strategically aligned for every coalition partner. The structure of transport collaboration can change over time. This change in the structure is causal (Dickerson & Kosko, 1998). The analysis of *causal mechanisms* among critical criteria is crucial as it might provide early signals about the level of collaborative integration of a coalition. These signals are mainly used for decision making and prediction. In previous work, we investigated thirty-seven operating criteria within five main categories for transport collaboration structures. This work utilizes those criteria and is aimed at answering the following research question: *How would a given pair of criteria in transport collaboration structure be causally interrelated. In other word, how would every change in the pair of criteria affect the transport collaboration structure under a set of scenario conditions?* To address these concerns, a Fuzzy Cognitive Map (FCM) based model is proposed, which can give early signals for the possible future condition of coalition by detecting "go", "go with conditions" and "no-go". These signals can be interpreted as the level of collaborative integration respectively as "full-integration", "partly integration" and "no integration". The FCM approach is especially useful for solving unstructured problems in soft knowledge-based issues (e.g. organizational theory, intra-organizational relations, and transport network), where different decision criteria are causally interrelated and fundamentally "fuzzy" (Kosko, 1986). FCM can be seen as descriptive models which can explain the ways coalition partners actually do derive explanations of the past, make predictions of the future, and choose policies in the present (Schwenk, 1988), from those aspects FCM is also applicable for the scenario development (Glykas, 2010; Jetter & Schweinfort, 2011; Van Vilet, Kok, & Veldkamp, 2010). In an FCM-based model, we utilized a pair-wise

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scenario matrix in the FCM iterative process to compare every pair of given criteria using simulation experiments. The form of extended FCM gives fuzzily intersected zones to observe the causal mechanism among a system set. These zones can infer the intensity of change in the structure. This research is based on the empirical findings of transport collaboration practices in a "real-world" coalition and the required data for the approach was collected in advance from a questionnaire. The findings of this research show how the change among two criteria can affect the transport collaboration structure and the result can be divided into smaller fuzzy sets or sub-domains in order to observe the change in the structure. This paper assumed that the coalition has a high level of collaborative integration. The result of this study provides a structured understanding of the system perceptions for the coalition partners. Therefore, it contributes to the simplification of the decision making process for a coalition by scenario development based on the FCM-based model.

2. Criteria and categories in transport collaboration structure

Today, the most frequently identified underlying inefficiencies encountered by transport managers are poor capacity utilization, empty backhaul, high transport costs, low profit margins and the sometimes harsh environmental impact of transport logistics. Transport collaboration has grown in popularity as a sustainable strategy over the last few years to cope with such industry consequences. Transport collaboration refers to innovative approaches with socio-technical systems applied to collaborative transport planning and execution encompassing platform-based, automated, adaptive technologies, supporting business processes and proactive human collaboration (Gaurav, 2004; Ritter et al., 2007). Coalition communities in transport collaboration occur across a variety of levels and business functions between two organizations (bi-lateral) or in a network of multiple organizations (multi-lateral) that is driven in three planes: vertically, horizontally, and laterally. These can vary with the level of collaborative integration from a very superficial transactional relationship to a highly integrated relationship among coalition partners (Kayikci & Zsifkovits, 2012). This may not only involve exploiting synergies between participants, but also conducts the allocation of benefits fairly among them. Transport collaboration typically requires a consolidation of capacities across different business units where the centralization of transport management allows the allocation of the resources more efficiently. Transport collaboration models are powered by advanced software systems and the Internet which allow companies to expand collaborative transport networks on a large scale. In effect companies are forming web-based and more traditional partnerships to reduce the transportation and inventory costs while raising the bar on customer service. Transport users and transport service providers enter into relationships to fill perceived needs; one of which is for scarce resources. Each partner contributes necessary resources with the expectation of receiving valued returns (Fugate et al., 2009). A coalition's partners must decide together on the selection of the proper collaborative infrastructure and systems. Bringing together the right partners and selecting the right process and technology for collaboration are as critical as defining the supporting structure at the right time. Close collaboration is always desirable to align the involved parties and then enhance the value of the transport network's combined activities (Kayikci & Zsifkovits, 2012). However, many collaborative transport initiatives fail to deliver the value expected from them (Kampstra, Ashayeri, & Gattorna, 2006; Lambert & Knemeyer, 2004) and come to an end with separation and failure (Graham, 2011). This results in a misalignment of transport collaboration structure and results in poor decision making and wrong actions being taken.

Structure is an important issue influencing the level of collaborative integration of coalition; it can be seen as a collection of criteria and the set of interactive relationships that connects these criteria. After elucidating the importance of transport collaboration structure, in previous work we investigated thirty-seven criteria with five main categories based on their attributes (as seen in Table 1). These criteria and categories are used as fuzzy logic toolkit in this research. These categories were: (1) *Technical perspective*: contains Information and Communication Technology (ICT) capabilities which facilitate data integration and exchange across supply chain. (2) *Risk perspective:* refers to the possible risk areas in management of transport collaboration associated with strategic restructuring activities like transport chain, skill set, control risk and so on., (3) *Financial perspective:* gives a reflection of financial performance ensuring financial integrity within distinct organizations are in place for reducing costs and increasing overall efficiency. (4) *Organizational perspective:* indicates the organizational alignment that involves readiness of integration, co-ordination and collaboration across organizations (5) *Operational perspective:* comprise the effective resource (asset) utilization and customer service, efficient transport costs and environmental sustainability.

3. Research methodology

Causal inference is a central aim of both experimental as well as observational studies in the social sciences. It is a big challenge to infer counterfactual conditions from observed data by accounting for what would have happened versus what actually happened. The term of causal mechanism is the causal process through which the effect of a treatment on an outcome comes about (Imai, Dustin, & Teppei, 2013). This causal process draws the connection between different criteria. Causal effect is the findings that change in one criterion leads to change in another criterion. FCM is a powerful technique for representing models of causal inference among pairs of criteria. This paper formally analyzes the causal mechanism of transport collaboration by proposing a FCM-based model. Intuitively, FCM is a fuzzy digraph with feedback (Kosko, 1986) that represents a causal system with uncertain and incomplete causal information. The human experience and knowledge on the complex systems is embedded in the structure of FCMs and the corresponding causal inference processes. FCM combines simple actions to model human knowledge and dynamic behavior for decision making process (Dickerson & Kosko, 1994; Jetter & Schweinfort, 2011). FCM is developed by the number of decision makers who know the system and its behavior under different circumstances in such a way that the accumulated experience and knowledge are integrated in a causal relationship among the system components (Kosko, 1992). FCM analyzes the causal interference (i.e. positive, negative or zero) between given criteria and the degree of influence (x) of this interference expressed in linguistic terms. However, there are other semi-quantitative and qualitative modeling methods available besides FCM; Ozesmi and Ozesmi (2004) and Van Vilet et al. (2010) mentioned that FCM addresses the following characteristics. These are our reasons for choosing FCM instead of other methods:

- It is easy to understand (as all decision makers should be able to understand the basics)
- Has a high level of integration (needed for the complex issues related to transport)
- Can be performed over a relatively short time
- Gives a system description.
- It is also useful for extension activities to educate decision makers, if there are any misperceptions.