Data & Knowledge Engineering xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Data & Knowledge Engineering

journal homepage: www.elsevier.com/locate/datak

An agent-based model for analyzing the impact of business interoperability on the performance of cooperative industrial networks

Izunildo Cabral *, Antonio Grilo, António Gonçalves-Coelho, António Mourão

UNIDEMI, Departamento de Engenharia Mecânica e Industrial, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2829-516, Caparica, Portugal

ARTICLE INFO

Article history:
Received 15 March 2015
Received in revised form 19 July 2015
Accepted 24 August 2015
Available online xxxx

Keywords:
Business interoperability
Construction cooperative networks
Agent-based simulation
Empirical studies
Business intelligence

ABSTRACT

This paper presents an approach for analyzing the impact of business interoperability on the performance of cooperative industrial networks. The analysis of the impact is grounded on the agent-based simulation method. A theoretical agent-based model is proposed to simulate the manner in which companies interoperate in cooperative industrial networks and how the distance between the actual and the required level of business interoperability in different dyad relationships can affect the performance of these companies. To test the applicability of the proposed theoretical agent-based model, a case study regarding a dam construction project is presented. The objective of the case study is to analyze the impact of the introduction of a Radio Frequency Identification system and a cooperative information system platform, first on the business interoperability performance and then on the operational performance of a the companies involved in the dam construction project. The application of the theoretical agent-based simulation model to this case study supports our assumption that indeed, agent-based simulation is appropriate for achieving the objective set. Regarding to the case study results, the main benefits of the introduction of the cooperative information systems platform are the reduction of the time needed to analyze the slump and compression test results, which can be reduced up to 98%.

1. Introduction

A growing body of literature has begun to recognize that in today's competitive economy, companies increasingly need to operate in cooperative industrial networks in order to achieve competitive advantages and/or achieve synergistic results (e.g. [17,43,45,72]). However, due to the fact that over the years most companies created their own applications and designed their own set of services [43], focusing their attention to the effectiveness and efficiency of separate business functions [66], a major issue when it comes to operate in cooperative industrial networks is the existence of business interoperability problems such as conflicting interests, misaligned business processes, linguistic barriers, lack of trust, different cultures or methods of work, different legal bases, multiple sources of data, various data formats, heterogeneity of Information and Communication Technology (ICT) solutions from different vendors, syntactic and semantic heterogeneity of information (see: [89]). Moving beyond machines and systems to people and business processes [43], business interoperability is becoming one of the major disciplines that is enabling companies to improve cooperation and communication in the most effective way [72]. Business interoperability can be defined as "*the ability of companies and systems within those companies to communicate and interact effectively*" [53]. Previous works, e.g. Loukis and Charalabidis [61], Gallaher et al. [37] and Brunnermeier and Martin [13] already acknowledged that business interoperability affects the performance of

* Corresponding author.
E-mail address: i.cabral@campus.fct.unl.pt (I. Cabral).

http://dx.doi.org/10.1016/j.datak.2015.08.001
0169-023X/

companies that work together. Although the significance of these studies, the literature reveals that there is still missing a methodology that can be used as a reference for analyzing the impact of business interoperability on the performance of companies, mainly in the context of complex cooperative industrial networks. Those studies addressed the problem of the impact of business interoperability by analyzing the companies individually, i.e. no specific connections are supposed to exist among the various companies in the network. In other words, the unit of analysis was defined at the organizational level rather than at the dyadic relationships level. As emphasized by Johnston [55] (cited in [79], p. 175), focusing on any one single company cannot provide a significant understanding of the processes of business. Håkansson and Snehota [49] go further and advocate that the performance and effectiveness of companies operating in a network, by whatever criteria these are assessed, become dependent not only on how well the company itself performs in interaction with its direct counterparts, but also on how these counterparts in turn manage their relationships with third parties. Popova and Sharpanskykh [74] reinforce this by asserting that the viability and success of an organization depend not only on how effectively the organization manages its internal activities but also on how well its behavior fits with the environmental conditions in which the organization is situated. These rationales support our choice for adopting the network approach as the theoretical framework behind this research, rather than the business relationship perspective (see Section 2.2.2). In short, those studies did not explore the network effect, which is to say that they did not explain how an impact of business interoperability on one or more dyad relationships affects the performance of the network of companies that the two companies in the dyads belong to. In other words, questions remain on how the impact of business interoperability spreads over the network. Another relevant limitation of those works is that the methodologies employed cannot be used to predict the performance a new interoperable cooperative industrial network, before its implementation. In other words, they do not provide any explanation how to predict the future behavior of the new designed interoperable cooperative industrial network. Therefore, as a new contribution for overcoming those research gaps, this paper grounds on the context of cooperative industrial networks to propose a model that enables the analysis of the impact of business interoperability on the performance of companies, considering dyad relationships as unit of analysis, taking into account the network effect, and how the interoperable networks evolve over time. In the attempt to achieve the research goal, the following research question (RQ) and proposition (P) were formulated:

- RQ: How can we analyze the impact of business interoperability on the performance of companies, in the context of complex cooperative industrial networks?
- P: Agent-based simulation provides an effective set of tools for analyzing the impact of business interoperability on the performance of companies, in the context of complex cooperative industrial networks.

The rationale for choosing agent-based simulation (ABS) as the modeling method is explained in detail in Section 4.2. The remainder of this paper is structured as follows: In Section 2, we review the literature on business relationship perspective, business networks, network effects and construction networks. In Section 3, we introduce the concept of business interoperability and present related work. In Section 4, we present the proposed theoretical ABS model and the rationale for choosing ABS as the appropriate method for supporting the analysis of the impact. In Section 5, we demonstrate the applicability of the proposed theoretical ABS model through a case study regarding a construction cooperative network. Finally, Section 6 draws the general conclusions, and discusses the limitations of the study as well as the directions for future work.

2. Business relationships and networks

2.1. The business relationship perspective

A business relationship can be defined as a process where two companies or other types of organizations "form strong and extensive social, economic, service and technical ties over time, with the intent of lowering total costs and/or increasing value, thereby achieving mutual benefit" [2] (cited in Ritter et al. [79], p. 176). Business relationships can occur at the dyad level (e.g. a single supplier and buyer relationship) or at the network level (e.g. a set of relationships among upstream and downstream companies in a Supply Chain (SC)) (see [78]). The core of the business relationship perspective is that the traditional economics perspective of free markets, pure competition (companies compete as isolated systems against each other), with unconnected and adversarial single transactions, basically coordinated by price mechanisms, is not considered adequate to explain inter-company phenomena [40]. In other words, the relationship perspective advocates that business relationships are mainly complex and rich social constructs between people in companies, which evolve over time (see e.g. [40,46]). The implications of this perspective are twofold: Firstly, the unit of analysis is a dyad (i.e. one-to-one linkage) rather than the focal organization. Secondly, in order to understand the processes of business, one needs to analyze the structure, and processes dynamics of the business relationship in which such processes of business will be embedded [40]. Although recognizing the importance of these implications, in this research we advocate that the relationship perspective is not enough to explain the business interoperability phenomena in a context of complex industrial networks because of its limitation to a dyad. Therefore, we grounded on the Industrial Marketing and Purchasing (IMP) network approach (see e.g. [46,49]) in order to capture and understand the complex and dynamic nature of industrial networks (see Section 2.2.2).

2.2. Business networks

2.2.1. What are business networks?

Network is a general term for physical infrastructure or patterns of interaction that can be represented as a set of points connected by a set of linkages [57]. The term is widely used to describe a structure where a number of nodes are related to each other by specific

Please cite this article as: I. Cabral, et al., An agent-based model for analyzing the impact of business interoperability on the performance of cooperative industrial networks, Data Knowl. Eng. (2015), http://dx.doi.org/10.1016/j.datak.2015.08.001