A Simulation Approach to Select Interoperable Solutions in Supply Chain Dyads

Pedro Espadinha-Cruz and António Grilo

Abstract Business Interoperability has become an indisputable reality for companies that cooperate and struggle for competitiveness. Supply Chain Management is one kind of industrial cooperation which relies on large integration and coordination of processes. Though, supply chain operations are ruled and conditioned by interoperability factors, which until now misses a tool to identify and solve its problems. In this context, this article proposes a simulation approach to study the effects of interoperability solutions on the performance of supply chain dyads.

Keywords Business interoperability · SCM · Dyadic relationships · Simulation · Performance measurement

1 Introduction

Business interoperability (BI) is an organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop information technology (IT) supported business with the objective to create value [1]. In the context of supply chain management (SCM), business interoperability is an enabler that makes possible to execute the SC operations seamlessly, easing their alignment and the information flow, guaranteeing high performance and competitiveness [2]. However, lack of interoperability is an emerging issue in IT based cooperation [3]. Most of the existing research on interoperability areas concentrates in forms to classify and identify interoperability problems and barriers, and forms to measure and remove them.

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On our research, we aim at the research question "How to achieve high levels of interoperability in supply chain dyads?", addressing one-to-one relationships in supply chains. To approach this issue, we address three topics: characterization and analysis of interoperability problems; cooperation re-design; and the study of the interoperability impact in the dyad performance. The present article proposes a method to study of interoperability impact on the dyad performance (in terms of SCM and interoperability performance), as a support to decision making in the dyad design and in the selection of suitable information systems to eliminate or mitigate interoperability problems.

The article is structured as follows: section two makes a brief review on the key topics (business interoperability, supply chain operations and performance); section three describes the methodology for analyzing and re-designing the supply chain dyadic cooperation; section four presents a case study on an automotive supply chain dyad; and section five presents the conclusions.

2 Business Interoperability

2.1 Business Interoperability Decomposition

BI is a concept that evolved from the technical perspective of interoperability incorporating several aspects of organization interactions. Frameworks and researches like IDEAS [4], INTEROP Framework [5, 6], ATHENA Interoperability Framework (AIF) [7], ATHENA Business Interoperability Framework (BIF) [7] and European Interoperability Framework (EIF) [8, 9] traced the evolutionary path that led to the exiting notion of business interoperability. In previous work from [10], several kinds of interoperability that contribute to the current definition of business interoperability were identified and related (see Fig. 1). In level 1 three interoperability types were suggested to contribute singly to the BI definition. Interoperability types shown in level 2 can provide input to more than one type of interoperability at level 1.

The different perspectives of interoperability reflect the issues that one must attend to achieve higher levels of interoperability or, as it was defined by [12], achieve "optimal interoperability".

2.2 Business Interoperability Measurement and Performance Metrics

Interoperability measurement and quantification is a branch of research dedicated to interoperability quantification in a qualitative or quantitative manner. Qualitative approaches to interoperability measurements are associated with subjective criteria

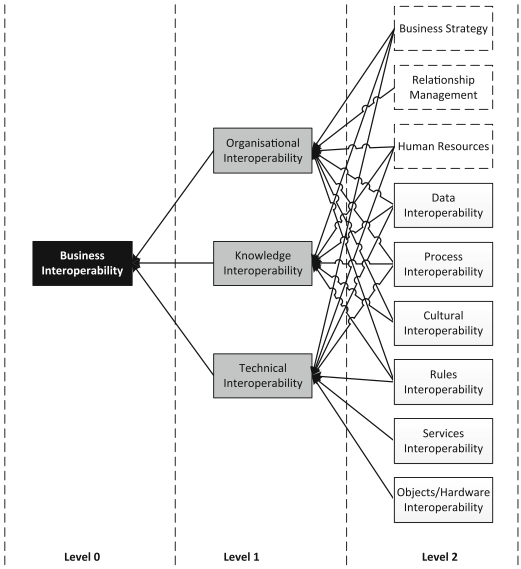


Fig. 1 Business interoperability components [10]

that permits to assign a certain level of interoperability (e.g. [13–15]), or a maturity level (e.g. [16, 17]), to a specific kind of interoperability.

On the other hand, quantitative approaches make an attempt to characterize the interoperations, proposing measurements (e.g. [18]) and scores [19] to convert interoperability issues into numeric values. The main problem with these approaches is that most of the numeric values that are obtained are as subjective as the interoperability issues that are analyzed.

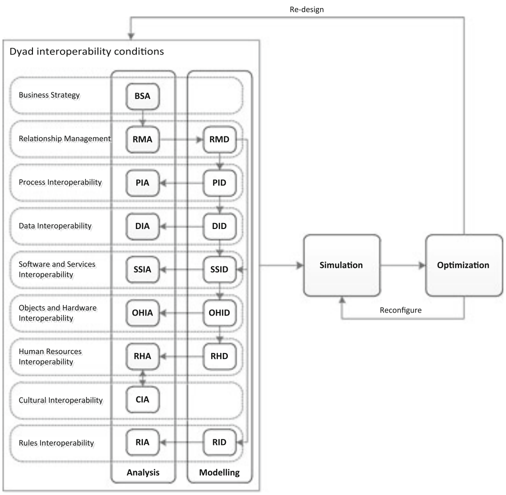
Another branch of interoperability quantitative assessment is dedicated to performance measuring. Approaches to performance measurement as [7, 20–22] suggest ways to measure the impact of interoperability on metrics such as costs, time and quality. However, it is not known a direct way of relating interoperability issues, or the companies' decisions, with the interoperability metrics [7, 20–22].

3 Methodology to Analyze and Re-Design Dyadic Cooperation

The proposed method to analyze and re-design the supply chain dyads is depicted by Fig. 2.

In this method, the first phase is to analyze and model the dyad interoperability conditions in terms of the business interoperability components that represent the "as-is" situation. On the second stage, one simulates the "as-is" model and one identifies the various scenarios that may lead to a more interoperable situation. In this matter, we propose two kinds of approach: an improvement of the current

Fig. 2 Methodology to analyze and re-design dyadic cooperation [10]



scenario by addressing the interoperability variables that one can change in order to reconfigure the relationship (for instance, the human resources quantity on a specific process); or the re-design of certain aspects of interoperability, such as the process design or the selection of another information system that permits improving the dyad performance. In the last stage (optimization stage), one finds which one of those scenarios has the best performance in terms of interoperability and in terms of supply chain performance.

3.1 Stages of Analysis and Decomposition

As mentioned in the previous section, the first step of the method is to determine the dyad interoperability conditions. This is achieved by interleaving the interoperability and the performance analyses, and modeling the interoperability components in a process that we call analysis and decomposition stages (see Fig. 2). The sequence of these stages has to do with the relationship between the business interoperability components. On the top of the method are the managerial and governance aspects, such as the business strategy and the management of the relationships that impact subsequent components. For instance, in business strategy analysis (BSA), the cooperation objectives are addressed and the dyad is analyzed to verify if these ones are clear-cut to both companies and if the individual aspects are aligned into a cooperation business strategy. Managerial and governance aspects have impact in operations. Process interoperability decomposition (PID) and process interoperability analysis (PIA) are ruled by the prior aspects of interoperability, thus constituting the focus of this method. All the following stages are associated to the operations taken place in the dyad. For instance, data interoperability decomposition (DID) and data interoperability analysis (DIA) are stages acting on the exchange of data between the firms that perform the processes. Issues like semantic alignment, communication paths and data quality are addressed in this stage in order to ensure that the data is properly interpreted, that there are sufficient contact points to exchange data, and that data is usable.

In terms of interoperability, the process resources are the information technology assets (software and systems interoperability, as well as objects and hardware interoperability) and the human resources. These resources enable processes and data exchange. As in the case of data interoperability, these resources are connected to the process interoperability.

3.2 Modeling and Measuring Interoperability Performance on Supply Chains

Modeling supply chain processes derives from the concept of process integration and coordination [23]. The supply chain operations reference model (SCOR) [24] makes a link between performance measures, best practices and software requirements to business process models [25]. However, the SCOR model does not show how to proceed to achieve interoperability. In the application of the method portrayed in Fig. 2 we propose a systematic representation of the interoperability perspectives of the dyad. In this one, we address the supply chain operations that take place between the two firms. For instance, in [11] a buyer-seller interface was designed. To achieve this design, a mapping has been done since the strategic objectives to the process design decisions using Axiomatic Design Theory [26] combined with Business Process Notation [27] and Design Structure Matrix [28]. This procedure allowed to decompose the SC operations and to address the interoperability issues inherent to each activity. The interoperability impact study and the selection of the appropriate design is the contribution of this article, and allows to demonstrate how the findings from [10] and [11] are modeled using computer simulation.

The course between an actual ("as is") to a desired more interoperable state ("to be") is supported by the decisions taken place during the re-design and reconfiguration activities of Fig. 2. These decisions are formulated according to the identified interoperability barriers and tested through simulation. Here, in this part of the methodology the performance measurement becomes an essential aspect to achieve an interoperable dyadic relationship. Supply chain performance metrics and interoperability metrics portray a relevant part to strive, both, for a competitive and interoperable supply chain dyad.

In the next section we present a case study that is currently being developed on an automotive supply chain. Here is addressed the interaction between two firms in the context of purchase and delivery operations. These two operations were decomposed into interoperability aspects, and the business processes were modeled in order to help in the design of a simulation model. To evaluate the two companies three performance metrics were selected: order lead-time [29–33], time of interoperation and conversion time [7, 20, 21, 34, 35].

4 Case Study: Automotive Supply Chain Dyad

The present case study was implemented in a dyad constituted by a 2nd tier rubber parts supplier (company A) and a 1st tier automotive engine gaskets supplier (company B). The application of this method was made through several interviews in both companies and by analyzing companies' documentation. The internal and interface processes are presented in Fig. 3.

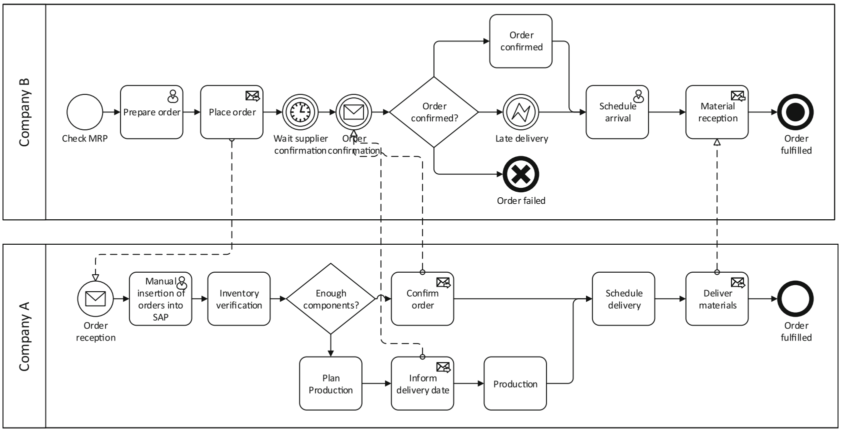


Fig. 3 Collaboration and internal activities business process model

The interoperability conditions for both are presented in Table 1.

Table 1 Interoperability conditions on the dyad

Interoperability aspect	Interoperability conditions
Business strategy	A contract was signed specifying the agreed lead-time of 7 days. The cooperation strategy was defined, but is not aligned with individual objectives
Relationship management	A long-term relationship was established
Human resources	Company A has 6 employees (5 responsible for inserting orders manually on SAP and 1 to validate orders) Company B has 2 employees to treat the orders
Process interoperability	In company A, 5 users insert manually orders into SAP. One HR verifies the inventory and confirms or calls for production. In company B, the ordering process is performed by 2 operators that check MRP data on SAP system and send the purchase orders to the supplier by e-mail and, then, wait for supplier response to validate the order and, then, wait for its fulfillment
Data interoperability	There are compatibility issues between the formats of the orders in both companies. Data must be treated manually in both cases
Software and systems interoperability	In both companies, SAP system and the E-mail system are not interoperable. This requires manual interaction between systems

The first improvement to test on the current approach for the collaboration is to study the use of the resources that enable cooperation. For simplification purposes, we only address the human resources quantity as variable to improve the "as-is" scenario. Other aspects featured on Fig. 1 should, if possible, be addressed in the performance analysis.

The results regarding the variation of human resources quantity are presented in Fig. 4.

Regarding order preparation from company B, currently there are 2 employees responsible for preparing, manually, the orders by accessing the Material Resource Plan on SAP system and send the needed orders by e-mail. On the "as-is" configuration, the average value of the order lead-time (OLT) is 163 h (7 days), which satisfies the agreed lead-time. Decreasing the number of employees to one permit reducing the OLT to 155 h (6 days) and the time of interoperation (TIP). However, the conversion time increases from 0,3 to 8,7 h for each order to be prepared. In counterpart, increasing the number of employees doesn't have effect on the metrics.

In respect to company A's activities, the number of employees on the manual insertion of orders on SAP could be decreased to a minimum of 3 in order to maintain the same OLT. Though, the minimum conversion time (Cv) is achieved with 4 employees.

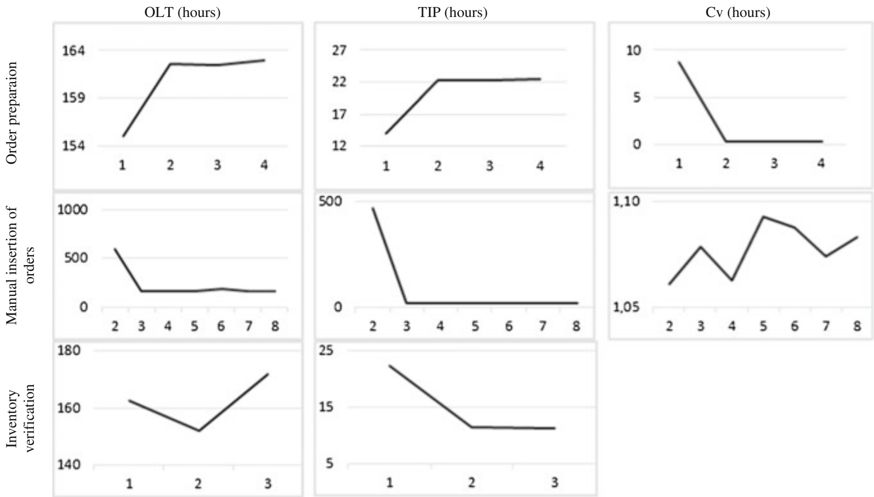


Fig. 4 Influence of human resources quantity on OLT, TIP and Cv for each process (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99 % and an error of 1,05 %)

Still in company A, increasing the employees to 2 permits to decrease the OLT to 152 h (6 days) and TIP to 11,54 h. This last improvement enhances the response time to the company B's requests. Instead of waiting 22 h to obtain the order confirmation, the increase of 1 employee permits to fulfill this in half of the time.

For this activity there are no Cv values because there is no conversion process involved.

The second improvement we propose is the implementation of an Electronic Data Interchange (EDI) system to replace the order placement communication path. This measure will enhance compatibility of data between the ICT and the order management system, reducing the time for order preparation in company B and eliminating the manual insertion process of company A. The obtained results are presented in Table 2.

Comparing the metrics for the “as-is” and the EDI implementation scenario, both OLT and TIP increase by 1 percent. In counterpart, there is a reduction of 76 % of the time to prepare the orders to send to company A.

In terms of human resources, the “as-is” scenario counts with 2 employees on company B and 6 employees (5 on manual insertion and 1 on inventory verification) on company A. The implementation of the EDI reduces the company A to 1 operator required to deal with company B’s orders.

Table 2 Comparison between “as-is” and the implementation of EDI scenario (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99 % and an error of 1,05 %)

Scenario	OLT (h)	TIP (h)	Cv (h)	Human resources (number of employees)
“as-is”	162.58	22.32	0.32	8
EDI implementation	163.44	22.59	0.08	3
Difference	+1 %	+1 %	−76 %	−5

In turn, the two compared solutions are based on the same interoperability conditions in terms of human resources quantity. From the first improvement, we had concluded that if we increase operators on the inventory verification activity we can decrease the lead-time in about 1 day. We can test the number of employees influence for the EDI implementation. The results are presented in Fig. 5.

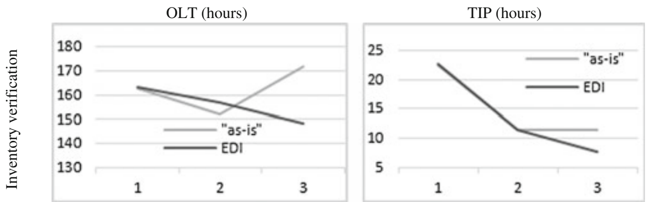


Fig. 5 Influence of human resources quantity on OLT and TIP for Inventory verification process for each scenario (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99 % and an error of 1,05 %)

If the companies decide to eliminate or mitigate the systems incompatibility (SAP and E-mail) by implementing an EDI, best results can be achieved if the number of employees on the inventory verification is increased to 3. However, if due to technical limitations the EDI implementation is not possible, the company A should add another employee to the inventory verification activity (by contracting a new employee) or remove one employee from manual insertion to inventory verification.

5 Conclusions

The presented research contributes to the development of an integrated framework to assess and re-design supply chain dyadic cooperation. It provides a method to study the interoperability impact on the performance of the dyad. This method allows one the test various scenarios without affecting the real system and providing the solution that may result in an improvement for the dyad.

Future work will concentrate on the integration of other interoperability aspects by implementing Design of Experiments and Taguchi methods. This will allow us to deal with the complexity of Business Interoperability by systematizing the influence of interoperability aspects on performance.

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