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Nassim Zbib, Bernard Archimède, Philippe Charbonnaud. Impact Evaluation of Interoperability Decision Variables on P2P Collaboration Performances. 14th IFAC Symposium on Information Control Problems in Manufacturing, May 2012, Bucarest, Romania. pp.1252-1257, 10.3182/20120523-3-RO-2023.00206 . hal-04023707

HAL Id: hal-04023707

<https://hal.science/hal-04023707>

Submitted on 10 Mar 2023

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To link to this article: DOI: 10.3182/20120523-3-RO-2023.00206
<http://dx.doi.org/10.3182/20120523-3-RO-2023.00206>

To cite this version:

Zbib , Nassim and Archimede , Bernard and Charbonnaud , Philippe *Impact Evaluation of Interoperability Decision Variables on P2P Collaboration Performances*. (2012) In: 14th IFAC Symposium on Information Control Problems in Manufacturing, 23-25 May 2012, Bucharest, Romania.

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Impact Evaluation of Interoperability Decision Variables on P2P Collaboration Performances

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Abstract: This article deals with the impact evaluation of interoperability decision variables on performance indicators of business processes. The case of partner companies is studied to show the interest of an Interoperability Service Utility (ISU) on business processes in a peer to peer (P2P) collaboration. Information described in the format and the ontology of a broadcasting entity is transformed by ISU into information with the format and the ontology of the receiving entity depending on the available resources of interoperation. These resources can be human operators with defined skill level or software modules of transformation in predefined languages. A design methodology of a global simulation model for estimating the impact of interoperability decision variables on performance indicators of business processes is proposed. Its implementation in an industrial case of collaboration shows its efficiency and its interest to motivate an investment in the technologies of enterprise interoperability.

Keywords: Enterprise interoperability, interoperability management, concurrent processes, event-based simulation, performance evaluation.

1. INTRODUCTION

The multi-site manufacturing leads to modifications not only in the organization and the internal functioning of companies but also in the collaboration methods which lean largely on heterogeneous information exchanges between the partner' applications. The productivity improvement of enterprise networks requires a better understanding of the exchanged information and thus has to pay a particular attention on interoperability problems.

In the literature, interoperability is defined by Konstantas *et al.* (2005) as being the capacity of two or several systems or components to communicate together, to exchange information and to use this information exchanged effortlessly for the users of these systems, IEEE (1990), Baina *et al.* (2005). Many researches, concerning interoperability service utility (ISU) were mainly initialized in iSURF (Interoperability Service Utility for across Collaborative Supply Chain Planning Multiple Domains) Kabak *et al.* (2009) and COIN¹ (enterprise COllaboration and INteroperability). In spite of efforts deployed to develop interoperability solutions, there is still no satisfactory and suitable implementation in the enterprises. In the case of supply chains dominated by OEMs (Original Equipment Manufacturers), the interoperability problem is *de facto*

adjusted because OEMs recommend strongly their software and methods to subcontractors ranked 1. This lack of interoperability is expensive for subcontractors; they have to implement software solutions of all OEMs with which they collaborate.

By concern of independence for the subcontractors between their information system and those of OEMs, and of cost reduction, the international association BoostAeroSpace wants to disseminate the results of SEINE project (Standards for the extended digital innovative enterprise). It was developed interoperable standards and connectors for introducing best practices and facilitating digital exchanges within the supply chain. However, standardization is sometimes considered as a brake in innovation and competition. Poplewell *et al.* (2008) outline the approach to be followed in SYNERGY research project which proposes the delivery of collaboration knowledge services through interoperability service utilities. Zhang *et al.* (2008) propose an interactive framework which is used to establish interoperability between two SaaS applications for automotive supply chain management and detailed ISU specification. ISTA3 project (Interoperability of 3rd generation for subcontractors in Aeronautics) developed prototype solutions, customizable, reusable, flexible, evolutionary and low-cost for SMEs (Small and medium-sized enterprises) called ISUs. These last ones are more generic than connectors and lean on services, ontology

¹ COIN Home Page, <http://www.coin-ip.eu/>

techniques, as well as on enterprise modeling. In the former approach based on connectors, the problems of transformation and performance of the exchanged information are supposed to be not changed any more. It is not the case considered in ISTA3 project. Indeed, ontologies and resources of interoperation are evolving with the time. Transformations may have a consequence on the requests for resending, on delays during the release of business activities or on the risks of malfunction during their execution. Although the industrialists understand the interest to take into account interoperability, nevertheless most of them are reluctant at the idea of its implementing because they have a lot of difficulty for estimating the contribution and the productivity gain that they can achieve.

The objective of this paper is to propose a methodology and tools to estimate by simulation the impact of the decision variables of interoperability on business processes in the case of an ISU implementation. In this paper, Section 2 focuses on interoperability management of collaborative activities. Section 3 presents the ISU simulation model (ISU-SM). Section 4 describes the design steps for elaborating a global simulation model. Section 5 deals with a case study on P2P collaboration showing the effectiveness of the impact evaluation approach.

2. INTEROPERABILITY MANAGEMENT OF COLLABORATIVE ACTIVITIES

2.1 Interoperability measurement

Numerous researches were led on interoperability evaluation of enterprise applications. They concern mainly the measurement of the potential interoperability and in lesser proportions the measurement of the interoperability performance. The potential interoperability measurement estimates the maturity of a system to avoid the barriers of interoperability during the interaction between partners. Kosanke (2005) proposes a classification IEC 62390 in five levels of interoperability to qualify the communication between the components of enterprise information systems, by leaning on a study of the compatibility and the degree of cooperation of electronic components within a system. The approach LISI (Levels of Information Systems Interoperability) C4ISR (1998) allows, by means of a reference model in five levels of maturity, to estimate the degree of potential interoperability between independent systems by the comparison of their profiles of interoperability, elaborated by studying the technological interconnection of applications and systems. Less spread than the approach LISI, the model LCIM (Levels of Conceptual Interoperability Model) Tolk *et al.* (2003) proposes a more abstract alternative for the classification methods of the interoperability by basing itself on the conceptual study of the quality and some documentation of the interfaces relative to the data exchanged between the interoperating systems. As regards the measurement of the interoperability compatibility, some works were led in particular by Daclin who proposes the measurement model of the interoperability degree of an enterprise, EIDM (Enterprise Interoperability Degree

Measurement) Daclin *et al.* (2006), respecting the identified and applicable barriers of interoperability only when partners or systems wishing to interoperate are well known.

Some works on the interoperability performance evaluation during the phase of collaboration were led in particular by Blanc (2005). Interoperability can be seen as an enterprise performance, Blanc (2005) proposes a typology of the necessary tools to measure the interoperability of a collaboration between several companies and "generic rules of interoperability" applicable to the modeling graphs of enterprise. The typology has for objective to offer a visual support for helping the determination of the level of the relations between the various enterprises, to identify the interoperability level between the concerned enterprises. The modeling of company by means of graph allows highlighting interoperability problems, to characterize and to measure the interoperability, by considering it as dependent on classic performances of cost, quality and delay. This study concerned the interoperability measurement for information exchanges, for product exchanges, and "effortlessly". This last one is based on a questionnaire limited to the calculation of interoperability level, and to the effort level quantification for obtaining the semantic interoperability. For all the methods presented previously, the interoperability evaluation means mainly positioning the company on a valuable scale defined beforehand.

If it is important today to know the capacities of a company to be globally inter-operated with a particular partner or to know the values of the indicators of interoperation delay, cost and quality in phase of collaboration with a partner, these evaluations do not seem sufficient to suppress all the business manager's hesitations to invest in more interoperable solutions. It is thus necessary to design a global model of the collaboration to estimate by simulation the impact of the interoperation variables evolution on the business processes.

2.2 Assumptions

It is assumed that the collaboration activity will consist of two tasks: the former on interoperation and the latter on business.

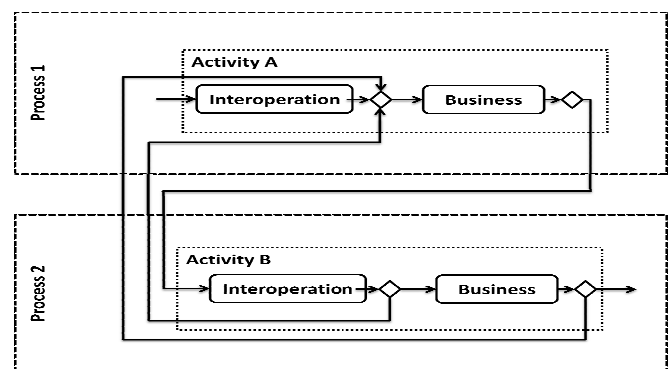


Fig. 1. Model of collaboration activity

An ISU is required to make it possible to administrate interoperation resources. These resources can be human

operators with a defined level of qualification or software modules of transformation of predefined languages. The role of an ISU is to transform information from an entity, described with the format and the ontology of the broadcasting entity, into information described with the format and the receiving entity ontology. The respective ontology of the broadcasting and receiving entities can evolve with the time, independently some of the others, and has differences with regard to the known ontology for interoperation resources.

3. INTEROPERABILITY SERVICE UTILITY SIMULATION MODEL

3.1 ISU-SM definition

An ISU-SM is defined by a 3-uplets $\langle G, RI, T \rangle$ where G is a valued state graph, RI is a finite set of interoperation resources and T is the time. $G = \langle S \cup \{S_s, S_p\}, AC \rangle$,

where S is a finite set of ordered states

– $S = \{s_0, s_1, \dots, s_n\}$ with $s_k < s_{k+1}, \forall k = 0, 1, \dots, n$.

– S_s and S_p are two additional states such as

$\forall k = 0, \dots, n, S_s < s_k$ and $s_k < S_p$

– AC is a set of interoperation activities

$AC = \{(s_u, s_v), \in S \times S \mid s_u < s_v\}$.

The competency CP , the duration DU , the cost CO and the risk RK have to weight the interoperation activities which depend on the chosen interoperation resources valued by the four following mappings:

– CP represents the interoperation resource competency

$CP: RI \times AC \times T \rightarrow \mathbb{R}$.

– DU is the duration of interoperation activities $DU: RI \times AC \times T \rightarrow \mathbb{R}$.

– CO is the cost of interoperation activities $CO: RI \times AC \times T \rightarrow \mathbb{R}$.

– RK is the risk to end the interoperation in a state $RK: S \rightarrow \mathbb{R}$.

The interoperation path is the set of states $S_s, s_0, \dots, s_n, S_p$,

where $s_k < s_{k+1} \forall k = 0, 1, \dots, n$.

The state evolution is done by an interoperation mapping which is based on a compromise between the values given by the four previous mappings.

The definition of the states of an ISU-SM arises from the analysis of information exchanged between heterogeneous cooperation activities. It is derived from the analysis of the syntactical and semantic problems of the received documents and from the detectable heterogeneousness between the formats and the ontologies associated to the activities in relation. The number of states depends on the capacity and skills of interoperation resources. More their syntactical, semantic analyses and heterogeneousness are fine more the number of states raises. In a synthesis proposed by Ishak *et al.* (2008), the problems of syntactic and semantic heterogeneousness were classified. The semantic heterogeneousness is decomposed into structural, terminological and representational heterogeneousness.

Based on this synthesis, a classification in six states of the exchanged information can be proposed (*see Fig. 2.*).

Information exchanged	Syntactic analysis	Semantic analysis			State
		Terminological	Representational	Structural	
Documents & data	O	O	O	O	Excellent
	O	O	O	?	Satisfactory
	O	O	?	?	Good
	O	?	?	?	Acceptable
	N	?	?	?	Limit
	?	?	?	?	Inacceptable

Fig. 2. State classification of information exchanged.

The state of the received information is "Unacceptable" if the syntax cannot be identified. The state is denoted "Limit" when the syntax is recognized whilst it presents certain errors that can be corrected. The state is "Acceptable" when there is no syntax error but its semantic analysis cannot be realized for lack of competence. During the semantic analysis three aspects can be verified according to the skills, in a progressive way and in a defined order. It is proceeded firstly to a terminological analysis. The representational analysis is achieved if the terminological analysis is satisfactory. Finally, a structural analysis is done when the representational analysis is possible. The state of the received information is considered "Excellent" if three analyses are successfully realized. It is considered "Good" if only the terminological analysis is successfully realized. The state is considered "Satisfactory" if the first two semantic analyses are successfully achieved. With the exception of the information received in a state "Inacceptable", all the others can be the object of a transformation.

The associated ISU-SM is organized around five states. The elements of the state "Inacceptable" are sent back to the broadcasting entity for improvement and reemission.

3.2 Risks associated to transformation activities

The ontology of the activities in collaboration evolving with the time can pull a loss of alignment with the ontology used during the elaboration or during the training of the interoperation resources of the ISU-SM. With the exception of those received in the state "Inacceptable", all the received documents can undergo two types of transformation further to the upstream reconciliation concerning the stake in conformity with regard to the ontology of the broadcasting activity and to the reconciliation swallow which concerns the ontological transformations to put in accordance with the ontology of the receiving activity.

This loss of alignment can pull during the semantic reconciliations a link between concepts positioned at more or less taken away distances and thus cause interpretation problems. In every transformation, the resources of interoperation take certain risk of transformed refusal of documents due to a problem of interpretation by the activity "business" concerned. Values of the risks (rk) depend on the ease of understanding of the received document and on the impact of documents transformed on the activity business.

3.3 ISU-SM integration in a collaborative activity

The collaborative activity begins with an interoperation stage, the leading part of which is to put in conformity the received information. It ends by the realization of the business stage. The interoperation stage requires firstly an analysis of the information received to identify its origin and state. It continues with a transformation done by the module ISU-SM if the received information issued from the activity of upstream collaboration and its state are considered suitable considering the current competence of the ISU-SM. At the opposite, information is sent back to the activity of upstream collaboration for being improved.

The information resulting from an activity of collaboration situated downstream corresponds to data or documents produced by the described activity but evaluated in a not suitable state by the activity of collaboration downstream or having caused a defect of realization at the business stage. This information is sent to the business stage so that they are improved by the module "Improving information" and sent back to the activity of collaboration downstream. The transformed elements stemming from the module ISU-SM are sent to the module "Running the jobs" where they begin the associated process. If this last one is achieved correctly, the results are sent to the module "Improving information" so that it generates new elements of information in accordance

with the format and the ontology of the business process. If the associated process does not achieve correctly, elements of information are sent back to the activity of collaboration upstream so that they are improved.

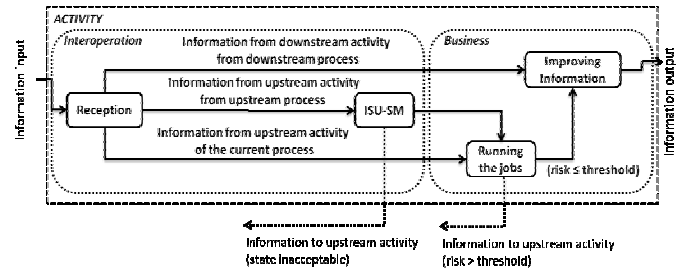


Fig. 3. Collaborative activity integrating an ISU-SM.

The implementation of a collaborative activity requires the use of two thresholds of state and risk which can be randomly assigned or fixed according to the competences of the ISU-SM. The state threshold allows selecting upon their arrival in the activity during the stage of documents or data analysis which must be sent back or managed towards the ISU-SM. The risk threshold allows identifying documents or data treated by the ISU-SM and which can bring to a successful conclusion the business process.

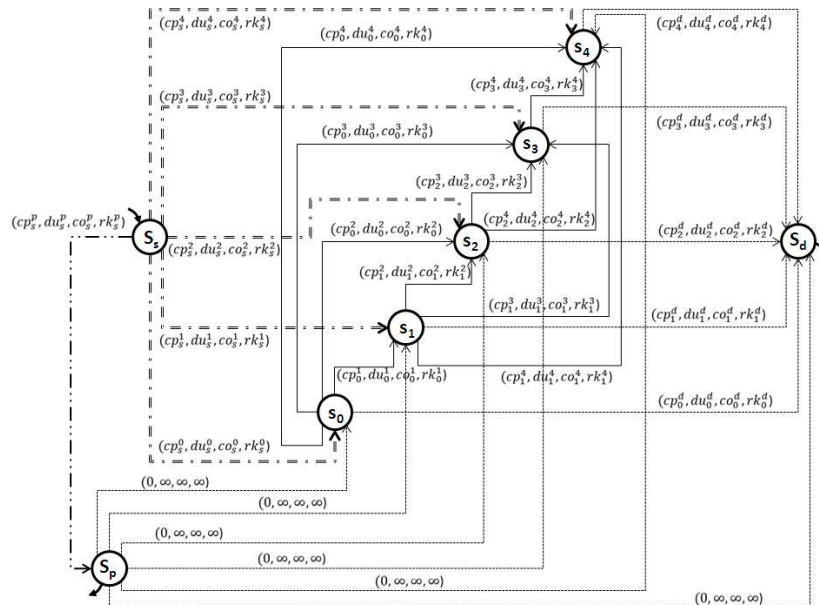


Fig. 4. State graph describing the behavior of an ISU-SM.

4. DESIGN STEPS OF A GLOBAL SIMULATION MODEL

The proposed methodology, based on six steps, aims at designing a global simulation model to estimate the impact of the evolution of the interoperation decision variables on business processes in P2P collaboration. During the first step, the realization of a high-level modeling of both partner companies is made to identify their processes and their

business activities, the resources required by these last ones, performance indicators and their objectives, business decision variables impacting these processes as well as their domains of variation. The second step consists in identifying, from both models obtained in the previous step, the collaboration model grouping together the interoperating activities and their resources, the performance indicators of interoperation with the associated objectives, the decision variables of interoperation as well as their domain of variation. The third step concerns the identification of the links between the

business decision variables and the interoperation decision variables. The fourth step has for objective to apply the model transformation mechanisms to generate the BPM models (Business Processing Modelling) of business processes of the partners drawn from the high-level modeling. The fifth step concerns the transformation of BPM models into simulation models and the generation of the simulation model of the interoperation activities. This step is realized from the interoperation activities identified in step 2 and from the generic simulation models of interoperation. This step ends by an implementation of business and interoperation decision variables as well as performance indicators. The last step consists in merging three models of simulation built in the previous steps in a global model of simulation and in establishing the connections between the interoperation and business variables.

5. CASE STUDY

ISU-SM was studied within the framework of a national project ISTA3 on the third generation interoperability. A case of collaboration extracted from this project is going to show the interest of the proposed approach.

5.1 P2P collaborative manufacturing activities

Two types of actors are participating to this collaboration: the assessors of the work realized in production and two employees of the service quality who collect, analyze and validate the results. After the manufacturing of Unitarian parts or small series, the evaluations are transmitted to the service quality which has to validate the results and dispatch them for exploitation by other services. Data and documents exchanged between assessors and the service quality are an Excel file or a paper document.

The data received in the form of Excel file can present certain abnormalities such as missing mentions, problems of code error, etc. The paper document can present a lack of legibility. Some of these abnormalities can be corrected either directly by the service quality, or after a phone contact of assessor concerned. In case of abnormalities not corrigible detected by the service quality, the document provided with an explanatory mention is sent back to the assessor concerned for correction. The data received under paper form are integrated one by one by the service quality. Those received in the form of Excel file can be submitted to a procedure of global and automatic integration in the information system when they do not present abnormality. Every assessor has his own practices which are more or less difficult to change. For each of them, a level of hesitation is defined describing the difficulty to change his behavior. In order to incite him to privilege the sending of Excel files, steps of raising awareness are made. The hesitation level of an assessor i evolve with the time according to n the number of steps of raising awareness followed, according to the formula $NR_i(n) = \alpha_0 * e^{-\beta * n} + \alpha_1$ where α_0 is the level of hesitation of the assessor i before any approach of raising awareness, α_1 the lower limit of the level of hesitation of the assessor i , beyond which the steps of raising awareness have no more effect, and β is a coefficient linked to the speed of

susceptibility of the assessor i . The values α_0, α_1 et β are allocated in a random way to every assessor. For every possible value of the number of steps of raising awareness n , a level of persuasion is defined to identify the assessors who changed behavior according to the relation $NP_i^k(n) = k(1 - e^{-\frac{n}{\tau}})$, where k is the level of maximum persuasion which can be reached and τ the rate of persuasion. More the rate is low more the speed of persuasion is raised. For a number of steps of raising awareness n , every assessor i having a level of hesitation $NR_i(n) \leq NP_i^k(n)$ is an assessor whose behavior evolved.

The performance indicators of interoperation measure the time number when a document is sent back to the assessor before the complete integration of the evaluations in the information system, as well as the interoperation time necessary before a document can be collected by the employees. Performance indicators of the service quality inform on the time of cycle so that a document is ready to be passed on to the other services. Performance indicators of the assessors are: the number of requests for correction done by the service quality, the time spent for the correction of documents. The business processes associated to the model (See Figure 7) highlight the activities of collaboration "Edit the evaluations" for assessors and "Collect the evaluations" for the service quality.

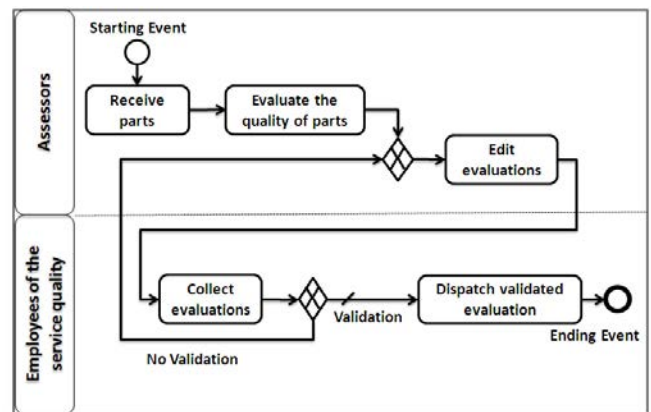


Fig. 7. P2P collaboration processes.

5.2 Simulation model

In the studied configuration, 300 products were estimated by 200 assessors. The sharing of loads of production and evaluation between the assessors, the quantities by product, the number of abnormalities in Excel files, as well as the number of corrections realized after the return of a file of evaluations by the concerned assessor, are attributed in a random way. During the activity "Collect evaluations" both employees of the service quality make firstly a phase of analysis, corresponding to the phase of interoperation, in which they estimate the state of the document, realize the possible corrections or send back the document to the concerned assessor. Both employees are the resources of interoperation. The model was executed on 5 benchmarks identified by a couple (k, τ) of parameters defined previously:

A=(8.82,11.46); B=(14.48,8.06); C=(9.86,7.13);
 D=(9.62,20.96); E=(14.11,23.09).

5.3 Results and impact evaluation

The obtained results show an important decrease of the various indicators of interoperation and businesses as the number of steps of raising awareness increases. Whatever is the benchmark, the number of reemissions, the time of interoperation and the number of improvement are more

important when the number of steps of raising awareness is low. They decrease with the increase of the number of steps of raising awareness. That confirms globally the interest for setting up interoperable solutions. These results require to be however put in perspective with regard to the costs of the steps of raising awareness.

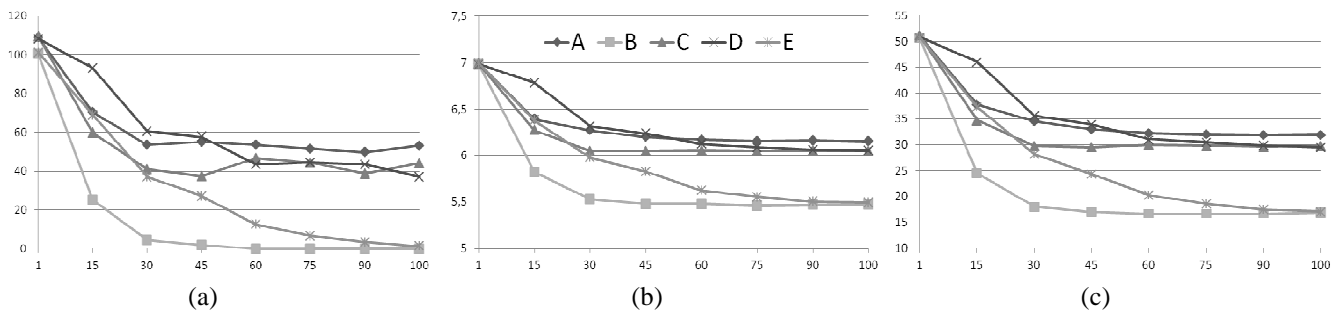


Fig. 9. Simulation results (a) Number of re-emission (b) Number of improvement (c) Time of interoperation.

6. CONCLUSIONS

In this paper, an ISU simulation model was presented in order to evaluate the impact of the interoperability decision variables on the business process in P2P collaboration. A methodology was proposed to build a global simulation model. It was applied to a case study issued from a manufacturing industrial benchmark. This approach will make it possible to configure an ISU for reaching or preserving a given maturity level of interoperation.

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