Performance evaluation of interoperability in peer-to-peer processes

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Abstract

By ensuring interoperability; the correct interpretation of the communication within an organization will be ensured, as also the organizations that interact with each other. Regarding to the benefits obtained, the significate diminution of defective products will be ensured, as the costs of reprocesses, elimination of orders with different characteristics to the required due to a bad interpretation of the order…etc. Simultaneously, the functioning of this type of program in an organization also means an investment, which is what is wanted to be evaluated in this project; the cost-benefit analysis of the usefulness of this kind of programs in an enterprise. The paper first discuss the theory as the actual studies that have been made about interoperability, then studies it in one study case that later will be modified in order to compare both scenarios. By making an evaluation of this type of program, there will be a justification made or developing judgement about the utilization of a software that offers and ensures the interoperability between the different processes mentioned before.

Introduction

Nowadays, globalization demands each time to more enterprises in the different sectors for being able to be more competitive in the market. Thus, these enterprises should look for ways to maximize the productivity, and reduce unnecessary economical costs throughout theirs processes. These demands do not exclude type or size of the organization. Between these, there are included big manufacturing enterprises, such as Airbus and Toyota, that, because of their respective growth, they should ensure their way for the supplying of all the raw material of the different parts needed for the production of their final product. The above, regarding to the assurance of the fulfillment of their orders with the quality assurance.

Airbus, as a manufacturing company of the aeronautical sector, by the third trimester of 2016, has reported net revenues for €1.811 millions, corresponding to its divisions of commercial aeronautics, choppers, and defense and space aeronautics. These revenues represent a big proportion of the European economy, since Airbus keeps operations mainly in European countries; such as France, Germany, United Kingdom, Spain, etc. In the other hand, Toyota, which has reported for the first semester, a net revenue of ¥946.1 billions, which is an equivalent of €7 937.8 millions, due to its global operations.

These two manufacturing enterprises of massive production represent large quantities of investment, and have in common the possession of a big and complex supply chain. Because of being a big and complex supply chain, they must ensure as most as possible the interoperability within their operations. The interoperability previously mentioned refers to the capacity that an operator, software, process, resource, department, or organization has for communicating with other entity in other location without featuring any problem in the interpretation.

Within the processes of these two big enterprises, a bad management of information where there is no insurance of the interoperability within its operations, can become to represent high quantities of money, although the inconvenient could be fixed in a fraction of time; since the price of a product of these enterprises can be around €150 000 for Toyota, or €391 000 000 for Airbus.

That is to say, the minimum failure within some component of the supply chain, would represent big economical loses for the organization. The deficiency of interoperability within operations or a

bad communication issue during the process, represents unnecessary economical costs. These costs can be reprocessing costs, costs of the time attending the issue, wasted resources…etc. For example, assuming that 1 of each 1 000 administrative or manufacturing operations presents a problem of this type; in economic terms, it would be €150 in losses for a Toyota unit, and €391 000 in an Airbus unit. The sum of these amounts of losses at the end of a year, where it have been already made a large amount of operations, brings negative results in big proportions.

The problem of interoperability requires to be treated in any kind of enterprise; in big enterprises, as explained before, as well as in smaller enterprises. This, since if a waste is kept from the beginning of the development of an organization, in the long term, it will represent considerable losses of resources.

Actually, there are computational innovative systems that ensures the interoperability within processes. There has not been absolute certain of the real contribution these programs will be giving to the organization in economical, or in productivity terms, in exchange of its investment as its acquisition means another investment for the enterprise.

In the search for solutions to this aspect, several authors have agreed that there is a need to study deeply the insurance of the interoperability. It is needed to demonstrate through performance indexes the changes and results a software of this kind would be making. Hence, it is desired to make the necessary to evaluate deeply the benefits and implications of the acquisition and functioning of a computational program of this kind, where it ensures the interoperability within the processes of an organization.

Between the actions to do in order to evaluate interoperability, this paper will begin introducing the background of interoperability, and later the design of a study case of a process, which consists in the painting process of airplanes. This study case will be compared in two scenarios; one with the behavior of the organizations with the existence of interoperability and with what it includes, and the other with the absence of interoperability.

What is interoperability?

In [1] the authors define interoperability as the capacity of two or more systems or components to communicate, exchange information, and use this information effortless. In other words, is the capacity different operations have to communicate with each other; between or within organizations. Also, the resources interacting can be computer programs, human resource…etc.

On the other hand, Vernadat [2] explains its focus, from Industrial Engineering area, where the enterprise integration and interoperability are seen from a more global point of view, using theoretical investigations, administratives, and supporting different informatics sciences to approach interoperability problem, from its functional, informational, technical, and organizational aspects.

Furthermore, the difference between enterprise integration and interoperability is explained; where interoperability is a component of enterprise integration. Enterprise integration aims to remove all barriers between departments, personnel, systems…etc; looking forward to create a scenery where the system or enterprise offers more capacity as a whole, than as the sum of all its components. On the other side, interoperability is one characteristic of enterprise integration, where it can be seen the integration level the enterprise has:

- Complete Integration: components cannot be differentiated.
- Closely coupled Integration: components can be differentiated, but one modification affects the whole system.
- Weakly coupled Integration: the components are independent, but these interact with each other; interoperability is present here.

Interoperability background

Interoperability has unleashed several investigations in different areas where it stands out; such as industrial engineering, software engineering and sciences of management. For industrial engineering, there is as search to solve interoperability problems through the different aspects, such as informative, functional, technical and organizational aspects.

The researches that have been done about interoperability in organizations have explained the impact that communications have in an organization, by which it deserves to be continuously studied as a benefit for a more competitive organization. The global market, which each time is more demanding and challenging for the different organizations, demands a strong communication (clear and understandable), in both, within the organization, and in the cooperation with other organizations.

Issues of Enterprise Interoperability

For the evaluation of the information quality that will be made, an investigation of the criteria to use was made; where Vernadat [2] discusses the different aspects of the problems that are present in the enterprise interoperability; which are divided in technical issues, semantic issues, and organizational issues:

Technical Issues:

Technical issues are also called syntactical aspects of interoperability, these face problems with the programs, due to a high presence of heterogeneity. For which, it is required that vendors develop systems that are more open, reliable, scalable, secure and fast-responding to changes through the time. One proposal Vernadat [2] is the development of web services, that are really agile to cope with reactivity requirements.

Semantic Issues:

This type of issue looks for making sure that two entities interpret common or shared information in a consistent way, where it is required that systems are developed in a way that is possible to interpret the meaning of data, information or knowledge in a clear way.

In the same way, it faces with the heterogeneity of information, where the same concepts have different interpretations. In this way, it is proposed a deeper study of interoperability, in order to improve it.

Organizational Issues:

In the organizational aspects, it looks for interoperability within and between the organizations. It faces the presence of different human and organizational structures, different business process organizations and manages approaches, different senses of value creation networks, different business goals, different legal bases, legislations, culture or methods of work, different decision-

making approaches…etc. Those mentioned before, are the challenges to face in order to ensure the interoperability between organizations.

A proposal of Vernadat [2], is to coordinate business processes of cooperating business entities, define synchronization steps and messages, and define coordination and collaboration mechanisms for inter-organizational processes.

In the same way, other issues that are present are mentioned; such as trust management, security issues, confidentiality issues, legal issues, and linguistic issues; which are also included in the classification above.

Interoperability Challenges

As it has been mentioned before, several investigations have been made around interoperability, where it has been demonstrated theoretically that its assurance will benefit in many ways an organization. However, in the checked studies, the authors in [3] ensure that efforts have been made to develop interoperability solutions, but there is still no satisfactory implementation in an organization. These authors also indicate that organizations understand the interest to take into account interoperability, but do not take risk in implementing it. The decision of these organizations is based in the fact that there are no cases, where evidence, or an estimation made of the contribution and the productivity gain that can be achieved, with an investment of this type.

Because of the above mentioned, is why interoperability performance measurement is being studied. This measurement would estimate the real effects that interoperability has in the organizations. Besides that, there would be an estimation of how much the factors such as costs, times and quality are affected; depending on interoperability level.

Interoperability Service Utility (ISU)

For a best comprehension of the way the current situation is going to be evaluated, where it will follow the basic dynamic of the functioning of a program for interoperability assurance, where a syntactic and semantic analysis described before in this chapter take place; the important aspects will be mentioned:

- The function of the program is to transform information from an entity, into information described with the format of the receiving entity; in order to ensure a correct interpretation.
- When ISU processes the information, it classifies it in the way it is showed in figure 1.

Information Exchanged	**Syntactic Analysis**	**Semantic Analysis**			**State**
		Terminological	**Representational**	**Structural**	
Documents and Data	✓	✓	✓	✓	Excellent
	✓	✓	✓		Satisfactory
	✓	✓			Good
	✓				Acceptable
	●				Limited
					Unacceptable

Figure 1. Information Qualification.
Source: [3]

- Initially, the syntactic state of the information is evaluated. The information is classified as Unacceptable, when syntax cannot be identified; Limited, when syntax can be recognized, but keeps errors that can be corrected; and Acceptable, when there are no syntax errors, but no syntactic analysis is made, due to competences deficiencies.
- Next, there takes place the semantic analysis. The quality of information is classified as Good, when only the terminological analysis is successfully made; Satisfactory, when terminological and representational analysis are made with success; and Excellent, when terminological, representational and structural analysis are successfully made.
- The analysis is made in the order described above; where structural analysis cannot be made if representational analysis has not been made, and representational analysis cannot be made if terminological analysis has not been made.
- Finally, the program transforms all this classified information, but the classified as "Unacceptable", since this information is returned to the remittent for its improvement.

Study case

As it has been mentioned before, by ensuring interoperability, the organizations will save some costs that influence economically in them. Thus, they transform themselves in more competitive organizations. A simulation model is made in Arena Simulation Software, where the current interoperability situation can be observed, without the use of any type of tool to ensure interoperability.

For the simulation, as it has been mentioned before, a case study is made where the studied process is the existent interaction between the producer and its process, and between the producer and its supplier; as in the same way, the supplier influences in the producer process.

For the study case, the process of painting an airplane is studied; where it is called "Producer" to the process of painting the airplane in its assembly, and "Supplier" to the specialized paint for airplanes supplier.

In this case, as mentioned before, interoperability is analyzed in the "Producer" process, as the interoperability with the "Supplier". Hence, the analysis aims more to the quality of exchanged information in each area. Based in theory and engineering experience, the six different classifications of the information are defined, as the different probabilities as explained in table 1.

Table 1. Probabilities Classification of the Information

Producer	Supplier	Classification	Type of Information
25%	2%	6	Excellent
30%	8%	5	Satisfactory
25%	10%	4	Good
10%	25%	3	Acceptable
8%	30%	2	Limited
2%	25%	1	Unacceptable

Source: Personal Collection

In table 1, the probability of having an excellent quality in the Producer process is higher than the Supplier, as this information is received inside the same organization and location. On the

other hand, the probability for the Supplier is lower, as the information is received from a different organization, and a different location; where the probability of interferences in the established communication is higher.

According to the different types of information, it works in the following way:

a) Excellent Information (6): This type of information does not contain errors, therefore, there are no consequences.
b) Satisfactory Information (5): This information can contain some type of error that can be hard to identify, or acceptable; but as it is minimum, it does not cause a consequence.
c) Good Information (4): Errors are showed, so that a partial reprocess might be made.
d) Acceptable Information (3): As Good information, in the same way there are errors, but this type of information requires of a more exhaustive reprocess.
e) Limited Information (2): This type of information does not show identifiable error initially, but at the end of the process it will require of a total reprocess; in other words, go back and begin again from the initial process.
f) Unacceptable Information (1): This information contains errors in the understanding of the production order, therefore is fast detected at the beginning; when this type of information is presented, another production order might be asked with clearer information.

On the other hand, the following suppositions are taking into account for the simulation:

- Production orders arrives each 47 hours to Producer, and when Producer receives it, an order is sent to Supplier.
- Each replication represents one working month, where it is worked 35 hours per week, so that per month, the working time is 151.55 hours.
- The reprocess time for type 4 information is 14 hours, while for type 3 is 21 hours.
- The painting process made by Producer follows a triangular distribution, where the minimum is 27 hours, the mode is 28 hours, and the maximum is 29 hours per unit.
- The reprocess time for type 4 information of Supplier is 5 hours, while for type 5 is 7 hours.
- The process of Supplier has a duration that follows a triangular distribution; where the minimum is 13.5 hours, the mode is 14 hours, and the maximum is 14.5 hours per unit.
- The reception of the paint by Producer has a duration that follows a triangular distribution; where the minimum is 2.8 hours, the mode is 3 hours, and the maximum is 3.2 hours per unit.
- For both, Producer and Supplier, the reprocess time due to clarifying of the order is the same, and it follows a triangular distribution; where the minimum is 2.8 hours, the mode is 3 hours, and the maximum is 3.2 hours per unit.
- There are no products in inventory.
- The process of Producer requires 5 workers, which each of them earn the minimum salary of France. These workers would do the reprocess if it is needed, the reprocess takes place in the same location.
- The time that takes Supplier in the preparation and delivering of the paint, is taken as idle time for Producer, where it represents a cost for Producer.

After having run the two scenarios in the Arena Model, with the absence and presence of interoperability, we have the results showed in table 2.

Table 2. Performance Indexes Comparison of Interoperability Absence and With Interoperability

Performance Indexes	Current	Improvement proposal	Difference (%)
Time in System	64.106	46.515	27.441
Producer			
Quantity Orders Producer Reprocessed due to Information	0.075	0.000	100.000
Quantity Products Partially Reprocessed	1.200	0.000	100.000
Quantity Products Totally Reprocessed	0.300	0.000	100.000
Total Production	3.175	3.400	-7.087
Supplier			
Quantity Orders Supplier Reprocessed due to Information	1.625	0.000	100.000
Quantity Products Supplier Partially Reprocessed	2.175	0.000	100.000
Quantity Products Supplier Totally Reprocessed	1.175	0.000	100.000
Quantity Products Delivered by Supplier	4.100	4.050	1.220

Source: Data provided by Arena Software

As it can be observed in the table 2, the major part of the performance indexes show positive differences, but the total production, which is good; since is required a rise in the production. Regardless is almost the same production, this is being made in less time and there is one unit in process with more progress, than in the current situation. The confidence intervals in the case of the current situation and the improved, overlap, where the proposal interval moves to the left decreasing the probability area; hence the change in production during the simulation of the system is little.

The difference of the average time in system as going from 64.106 hours to 46.515 hours, represents 27.441% of time savings; which is due to the reduction of quantity orders producer reprocessed due to information, quantity products partially reprocessed, quantity products totally reprocessed, quantity of orders supplier reprocessed due to information, quantity of products supplier partially reprocessed, and the quantity of products supplier totally reprocessed that correspond to zero units. In this case, when comparing the location of both confidence intervals, the proposal intervals locates the lower and upper limits in the right side, since its value is higher. There is no overlap in anyplace with the current situation intervals; which indicates that a significate change took place. Hence, the productivity of the process is improved, by having processed a similar quantity of airplanes as in the current situation, but in a time 27.441% lower. For Supplier area and for Producer area, there is a difference with the proposal improvement of 100%, by not having any type of reprocesses. The above mentioned, is due to interoperability assurance that is now present in the organizations of the case study.

On the other hand, the quantity of products delivered by the supplier remains almost the same, where even that the width of the proposal confidence intervals is reduced, the probability area of its mean, is inside of the current situation confidence limits; which indicates that there is no

significant change in this index. This consistence is due to the probabilities initially assigned, the reprocesses done in Supplier area, affects in less proportion the time in system. The reprocess time in Producer area, represent the 50% and 75% of the painting process time, for information type 4 and 3, respectively; on the other side, the reprocess time in Supplier area represent 35% and 50% of the paint process, for information 4 and 3, respectively.

Thus, it can be concluded that implementing a system that ensures interoperability in an organization, is technically possible when observing in the simulation model, the benefits it represents in productivity, where the same quantity of airplanes is processed in less time. Also, besides the existence of systems engineers that are available to implement this system, the personnel will be motivated to its usage.

Conclusions

According to the previous analysis, where the implementation of a program for the assurance of interoperability in the organizations, the following conclusions were obtained:

- The performance indexes of Producer area, are in 0, which indicates an improvement of the process productivity.
- In Producer area, the total production counter varied 7.087% regarding the current situation, which means there is a little difference in the increase of the production, and the productivity has improved.
- The difference in the index of time in system shows the biggest change, by changing 27.441% regarding the current situation; where productivity has been improved, by producing the same quantity, or almost the same, but in a time 27.441% lower.
- In both areas, Producer and Supplier, what regards to reprocesses, has been improved 100%, as the counter that identify the reprocess are in 0.
- This simulation has not been validated in a real-life case, where real times and other data closer to the reality can be obtained. The case study was intended to be the most real as possible for the evaluation. It is desired to continue studying the effects of interoperability in an organization, by evaluating it in a real-life organization, with more accurate data.

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