Computers in Industry 63 (2012) 844–857

Contents lists available at SciVerse ScienceDirect

Computers in Industry

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

# A contribution of system theory to sustainable enterprise interoperability science base

Yves Ducq [a,*], David Chen [a], Guy Doumeingts [b]

[a] University of Bordeaux, IMS/LAPS/GRAI – UMR N° 5218 CNRS, 351 cours de la Libération, 33405 Talence cedex, France
[b] INTEROP-Vlab, Bat A31, 351 cours de la Libération, 33405 Talence cedex, France

ARTICLE INFO

*Article history:*
Received 20 November 2011
Received in revised form 22 July 2012
Accepted 1 August 2012
Available online 16 September 2012

*Keywords:*
System theory
Organisational interoperability
Enterprise modelling
Evolution management

ABSTRACT

Even if the research domain related to interoperability has been developed for more than 10 years and particularly for the last 8 years, the different kinds of interoperability and the different problems to solve need to be consolidated in order to define a real science. Moreover, because of the continuous evolution of enterprises in supply chains, interoperability problems must continuously be considered and solved in order to reach a sustainable interoperability.

The objective of this prospective research paper is to discuss how system theory (ST), applied to system of systems, is able to support the development of sustainable enterprise interoperability science base. After an introduction which reminds the definition of enterprise interoperability and the development of this domain in Europe, the system theory concepts are introduced. Then, the requirements are described to support the determination of the necessary concepts to develop a science base for sustainable enterprise interoperability. This part also describes how the concepts of system theory meet the defined requirements. The fourth part presents a specific approach based on system theory in order to manage the evolution of interoperability in enterprises and to reach sustainable interoperability. Then last part illustrates this work with a concrete example showing how ST concepts are used in GRAI methodology for instance to represent business process and decision interoperability problems.



## 1. Introduction

Interoperability is defined as "the ability for a system or a product/service to work with other systems or products/services without special effort of the user" [1].

Enterprise interoperability (EI) is defined as "the ability of an Enterprise to interact with other Enterprises, not only on an Information Technology point of view, but also on organisational and semantic points of view. This interaction must be flexible and be developed at the lowest cost" [2].

This last definition was step by step elaborated through a serial of works and projects developed in the frame of the European Commission since 2000s.

Enterprise interoperability in fact appears long time ago when the economic world starts to exist: the enterprises have to interact in order to develop business.

The use of IT applications has supported the development of EI with a strong acceleration in the last 20 years.

But the economic environment has obliged Enterprise to develop EI solutions at a low cost and in a flexible way. It was recognised that 40% of the IT budget of enterprises was the consequence of the non interoperability of IT applications. This situation was the driver of an initiative launch in 2000s by the European Commission to create a working group in order to develop several research works to meet the new economic constraints (cost, flexibility, security).

Based on the suggestions of this expert group composed of the main stakeholders, the thematic network "IDEAS" (Interoperability Development of Enterprise Applications and Software) was launched within FP5 (July 2002–June 2003). The objective of this network was to elaborate a roadmap to develop a research program in EI. Two main initiatives were launched within FP6: ATHENA Integrated Project (IP) (Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications) [3] and INTEROP Network of Excellence (NoE) (Interoperability Research for Networked Enterprise Applications and Software) [4].

In the FP7, several projects were launched, among them the COIN FP7 Integrated Project (Collaboration and Interoperability for

* Corresponding author. Tel.: +33 5 4000 3714; fax: +33 5 4000 6644.
*E-mail addresses:* yves.ducq@ims-bordeaux.fr (Y. Ducq), david.chen@ims-bordeaux.fr (D. Chen), guy.doumeingts@interop-vlab.eu (G. Doumeingts).

0166-3615/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.compind.2012.08.005

networked enterprises) which developed an advanced integrated solution, made of a secure Generic Service Platform providing the European Industry (and mostly SMEs) with EI and EC (enterprise interoperability and collaboration) services, under innovative business models inspired by the SaaS-U paradigm (Software as a Service-Utility).

Through all these results developed since 2000s, the concepts of enterprise interoperability have been established, the domain has been defined, the problematic identified and some solutions proposed. A new scientific domain is born which must be promoted in order to allow the recognition of this new discipline, its understanding and its use by the stakeholders of the domain.

Moreover, in order to take into account the rapid evolution of enterprises inside supply chains, EI domain must be extended towards sustainable EI. This last concept aims to manage continuously the evolution of interoperability between partners through the continuous modelling, the continuous performance measurement and the continuous implementation of interoperable solutions.

This situation might be compared to the emergence of enterprise modelling (EM) at the beginning of 80s, when it was necessary to create a science base for EM. System theory was a good support to elaborate the theoretical concepts of EM. This research paper proposes to use a similar approach in order to contribute to the development of a science base in the domain of EI and sustainable EI. The European FP7 ENSEMBLE project which aims at developing a science base for enterprise interoperability has identified a list of relevant established sciences that potentially can contribute to enterprise interoperability development [5]. System science/general system theory is considered as one of the most relevant ones. In this paper, we start to investigate the basic concepts and principles of general system theory and its use in enterprise interoperability domain. Other system related approaches such as complex systems, system dynamics or systems engineering could be studied in the next stage of the research.

So, in the following part, the requirements to support the development of an EI science base will be detailed. Then, the concepts of system theory will be presented and their contribution to the EI science base will be discussed. In the fourth part of this paper, the evolution management approach based on system theory will be presented to reach a sustainable EI. Finally, a case study will be detailed to demonstrate the interest of system theory.

## 2. The system theory

The system theory is the result of the research works done by many authors among whose one can cite Von Bertalanfy [6], Simon [7], Boulding [8], Von Neuman [9], Le Moigne [10], Mesarovic et al. [11] and many others. These research works applied originally the same concepts (system theory concepts) in various disciplines: biology, physics, economy, organisation, computer sciences, cybernetics.

From all these works, several definitions are proposed below for a system and its related concepts.

A system is composed of a limited set of elements having attributes and relations between these elements. So, a system has a particular structure. It answers to the question WHAT?

The elements composing a system have the particularity to contribute to reach one or several common objectives. These are the objectives of the system. These objectives answer to the question WHY?

In order to reach these objectives, a system has several functions which are related to its structure. This answers to the question HOW?

Moreover, a system has a boundary. Sometime it is easier to determine the elements inside the system by determining the elements outside the system. The elements outside the system composed the environment of the system and enable to also the borders of the system. This environment answers to the question IN WHAT? But this environment has the ability to modify the system properties and to influence its evolution. This capacity of evolution is the last property of a system.

A modification of the borders and of the objectives of a system might lead to the modification of the different status of a system.

So, a system can be represented in Fig. 1.

But in the frame of new complex systems, the notion of system of systems is emphasised.

Indeed, few systems are running independently to their environment and this environment plays a more and more important role. Moreover, few companies are able to manufacture a product or a service in a whole (for economic reason they are focused on their core business) and they are obliged to look for partners in the frame of a network of companies. This network is in fact a network of systems which has the same properties than a single system, i.e. a structure, functionalities, objectives, an environment, and its own evolution. This leads to the concept of system of systems.

The concept of system of systems could be represented in Fig. 2.

Based on these definitions, the system theory aims to represent (to model) the realities of a system, concrete or abstract, highlighting at the same time the global and the detailed representations of this system. For instance, GRAI methodology (Graph with Results and Activities Interrelated) is based on the system theory, allowing to represent the controlled system (often called the Operative System, including the added value activities of the enterprise) and the control system at the global (GRAI grid, GRAI Nets and functional view) level and at a detailed level (GRAI Nets and business process views) and taking into account system objectives and environment. The explicit description of the control system enables to represent the elements which aim to reach the objectives [12–14].

This definition shows the importance to represent and to study the system at the global level (the level of the system of systems) and the detailed level, i.e. the level of each system. The first one allows to understand the whole system and to consider its whole objectives and structure and the second to understand each system separately in terms of practices and of control of these practices.

One of the main problems, in the running of system of systems, is then the interoperability problem. This interoperability problem can be then defined at different levels, contributing to the EI science base definition:

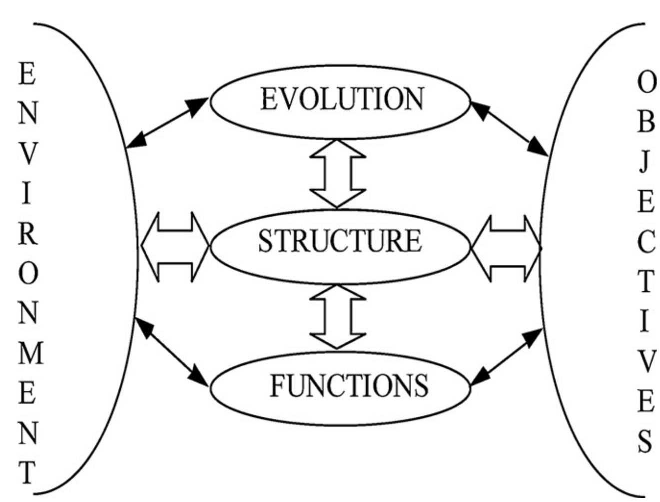


**Fig. 1.** The concepts of the system.