The Enterprise Operating System and its role in the governance, viability and sustainability of enterprises

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Abstract. There is a lack of artifacts to handle the enterprise self, and consequently with its dynamic self-governing system, responsible for continuously assuring its viability and sustainability, in a fast changing environment. We need constructs to better model enterprises as self-observing systems, and not merely as observed systems. We introduce the concept of Enterprise Operating System (EOS), as the emerging enterprise´s control and governing system, which turns enterprises into autonomous, intelligent, viable and sustainable entities. Our assumption is that all organizations, being complex social-technical systems, evolve to higher complex levels, whereby at some point "organizational autonomous life" emerges as a reification, at a macro systemic level, of the social-technical network of its autonomous agents or its network nodes. This reification is precisely realized by the emergence of the EOS, which turns the enterprise into a kind of autopoietic system, with logical closure, characterized by its self-reference, identity assertion, and the emergence of its consciousness. The EOS should be able to compile in near real time its position and trajectory (integrating its functional, ontological and evolutionary views), to assess if is in line with its viable and sustainable states set and trigger/call for correction actions whenever needed. Our research goal is to develop a universal EOS (UEOS) model and a methodology, to design, diagnose and improve the EOS of any organization, supported by sound theory, grounded in Enterprise Engineering knowledge, General System Theory, Viable Systems Theory and other relevant complexity theories.

Keywords: Enterprise operating system, enterprise engineering, viable systems, sustainability, complexity, enterprise self-consciousness

1 Problem Statement

By Enterprise we mean any kind of social entity with a purposeful endeavor [16], such as a company, firm, corporation, organization and in general any king of formal or informal institution. Enterprises are complex social and purposeful systems, aiming to accomplish something. Key properties of any enterprise are its self-organizing and self-control capabilities, in view of its purpose. Enterprises are organized complex dynamic systems.

The enterprise´s self-organizing and self-controlling capabilities are constantly being challenged by increasingly complex, changing and uncertain environments. The pace of change is accelerating, with the rate of technological progress continuously rising in a hyper connected world, where systems and people, at a local and global levels, are communicating and exchanging information between themselves. To address the revolutionary and/or disruptive technological developments, the diffusion of traditional boundaries and the increased dynamics and extendeness of enterprises, successful enterprise change is an evident necessity [17]. More than ever, the ability to cope with continuous and unexpected change is critical for enterprises to survive and prosper.

Simultaneously, with the dramatic information and communication technologies (ICT) advances, which enable near-real time transparent and ubiquitous interaction between people and systems, the borders between humans and artificial systems as enterprise agents are becoming blurred. The increasingly capacity for enterprises to become truly sensing (powered by IoT), smarter (powered by AI), and acting systems (power by robotization), in fully integrated cyber-physical-social systems, make enterprises reach an higher level of complexity. Has highly-complex systems they emerge as autonomous, intelligent and adaptative systems or entities. Complexity is the attributed quality that is deliberately considered by an observer in its perception or conception of something that exercises unpredictable emergent behavior, i.e., behavior elaborated by the system itself in an endogenous manner. On other hand, a complex system is necessarily open to its environment. Therefore, being both, autonomous and open, complex systems are partially dependent of his environment, thus manifesting adaptive behavior, which implies intentional responses to what the system perceives as solicitations of the environment. This description of complex systems may be summarized in the following hypothesis: a complex system is an autonomous system, which is an intelligent system and therefore an adaptive system [20]. Enterprises, as highly-complex systems, are autonomous systems, manifesting intelligible intentional actions, in order to adapt and prevail in any changing and challenging environment. Hence, has complex and adaptative systems, enterprises are autonomous and intelligent entities, manifesting the ability to build (and intentional change) their projects of intervention in their environment, in order to assure its viability and sustainability. This implies the existence within each enterprise of a system with mechanisms to preserve its identity and integrity, ie, its viability and sustainability. Hence, mechanisms for regulating and stabilizing its internal milieu; for controlling and monitoring its resources and activities; for coordinating its subsystems activities ; for inquiring its large and uncertain environments and imagining , projecting and planning its future; and by defining its own projects, purposes and values. [21] [6]

We will call such a system, the Enterprise Operating System (EOS). We use the concept of EOS as a metaphor of a computers´ operating system. A modern computer consists of one or more processors, some main memory, disks, printers, a keyboard, a mouse, a display, network interfaces, and various other input/output devices. All in all, a complex system. If every application programmer had to understand how all these things work in detail, the code of increasingly powerful applications would be impossible to be ever written. Furthermore, managing all these components and using them optimally is an exceedingly challenging job. This is why computers are equipped with a layer of software called the operating system, whose job is to provide user programs with a simpler, cleaner and integrated model of the computer and to handle managing all its resources/devices . Thus, operating systems perform two basically functions: 1) providing application programmers (and application programs, naturally) a clean abstract and integrated set of functional resources instead of the messy hardware ones (the operating system as an extended machine, abstracting its complex structure as a single coherent and purposeful machine to its users); 2) managing these hardware resources (the operating system as a resource manager, managing all its internal devices or components). [28]

In the same way, any enterprise, as a socio technical system , which integrates a collection of independent and autonomous actors, should have its "operating system" for: 1) enables the enterprise to act as a single coherent and purposeful system, thus being viewed as a single and distinguished entity by its external users or systems, and connecting to them as a whole purposeful system; 2) managing, coordinating and integrating all its internal actors and/or "devices", in order to enable orchestrated, focused actions, to attain its shared goals and purposes, and preserve its integrity;

Computers, without their own essential operating systems, do not exist compromising its viability, i.e. they are "unable to maintain a separate existence", loosing entirely their identity and wholeness, being nothing more than a simple collection of devices, unable to respond as a single and coherent computing system. In the same sense, an enterprise, as an organizational entity, without its EOS, is no more than a ad-hoc collection of independent and uncoordinated active actors, unable to assure its collective integrity and identity and pursue a common purpose, hence ceasing to exist as a whole system.

Most of the enterprises are not aware of its essential EOS, being therefore unable to assess if all its components are in place and running correctly, if its EOS is assuring that the enterprise is following a viable and sustainable trajectory.

We want to develop a model and a methodology to design and/or diagnosis and improve the EOS of any organization. We assume the hypothesis that the EOS emerges, and materializes exactly when the enterprise becomes "alive" as an autonomous and intelligent entity. Hence, our assumption is that all organizations, being complex social-technical systems, evolve to higher complexity levels, whereby at some point "organizational autonomous life" emerges as a reification, at a macro systemic level, of the social-technical network of the autonomous agents that form the nodes of the enterprise network.]This reification is precisely realized by the emergence of the EOS, which turns the enterprise into a kind of autopoietic system [23] [32], enabling its logical closure, characterized by its self-reference and identity assertion mechanisms. The enterprise becomes then an autonomous and intelligent entity, manifesting intelligible or understandable behavior.

The EOS exists, in some form, in any "live" and viable enterprise. But, as mentioned above, the problem is that majority of enterprises are not aware of it, thus being not capable to distinguish its essential EOS, and/or diagnose its state of incompleteness, malfunctioning, or ineffectiveness. Being unaware of its EOS, enterprises put at risk their own existence.

Thus, to be aware if an enterprise has its EOS fully operational, we must answer our main research question: what are the necessary and sufficient topological and functional conditions of an EOS, in order to an enterprise becomes “alive” as an autonomous and intelligent entity, continuously adapting and assuring its viability and sustainability, in an ever changing environment? By autonomous, is meant to refer having a reasonable degree of freedom, as an embedded system, i.e., to act on its own initiative, having agency and purposeful intervention capacity, within and over its environment. By intelligent, is meant to refer having awareness of itself and of its environment, knowing who they are, how they do things, what they (and others) are doing things, and what should be done, at any particular moment. By viability is meant to refer being able to maintain a separate existence, and by sustainability is meant to refer producing a net contribution to the viability of the larger wholes into which they are embedded.

We assume that all enterprises, while being viable and sustainable systems, have their own idiosyncratic and embedded EOS, in some form. We assume too that there is an invariant universal EOS model (UEOS model), isomorphic to any enterprise specific EOS model, and with the necessary and sufficient components, relations and processes, of a well-functioning and fully operational EOS.

Using design science research approach [15], the goal of our research is to design and produce a model of the UEOS, and a methodology to use such UEOS model, for designing, diagnosing and improving any specific enterprise EOS.

Thus, another way to state our previous research questions is dividing it in two:1) what are the necessary and sufficient ontological and functional characterization of an universal enterprise operating system (UEOS) model, to enable its self-governing capabilities, in order to assure its permanent viability and sustainability, in an ever changing and uncertain environment?; 2) Which methodology, allows us to successful apply the UEOS model to any particular enterprise context, in order to design, diagnose and improve its specific EOS, by assuring that its particular EOS includes all of the UEOS´s required mechanisms and properties?

2 Methodology Approach

Our goal is to design and produce a model of the UEOS, and a methodology to use that UEOS model, for designing, diagnosing and improving a particular enterprise EOS. To produce and evaluate such artifacts we will apply the usual adopted methodology of the Enterprise Engineering and Information Systems research community: a design science research approach [18]

2.1 Design as a Search Process

We will follow the Design Science Iteration Research Process, as proposed in Figure1

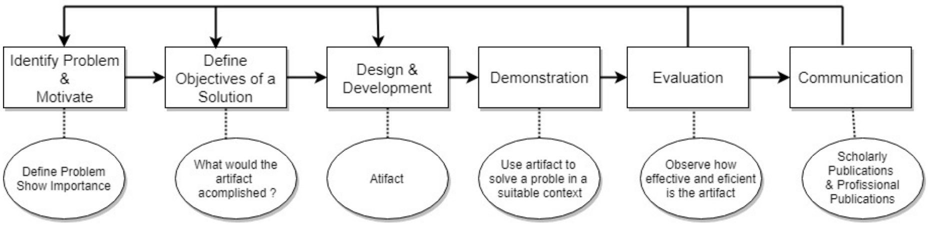

Fig. 1 – Design Research Process

This is an iteration process where we begin by: 1) identifying the problem and its relevance; 2) defining the objectives of a solution (specifying its requirements); 3) do the design and development of the artifact based on solid relevant knowledge (design and development phase); 4) demonstrate by using the produced artifacts to solve a problem in a suitable context (demonstrate the artifact utility); 5) and evaluate the effectiveness and efficiency of the usage of the artifacts (evaluate artifact in respect to the identified requirements) ; 5) iterating back to design whenever is necessary. Along all this process we will communicate intermediary and final results, through scholarly and professional publications.

To conceive, demonstrate and evaluate our artifact (the UEOS model and its application methodology), we will use Le Moigne´s [21] general system framework and holistic view, which states that any object should be defined in respect to its three poles or dimensional views: functional or physiologic (what the object does), ontological or analytical (what the object is), and genetic or morphogenetic (what the object was and will become). These three views, should be integrated in order to systemically define any general active object, by defining its functionalities, its structure and evolution, in its environment, and in respect to its purposes. Accordingly to the objective of an observer, we can find three different modes to capture an active object: conception mode, systemic analytic mode and simulation mode. Depending on the chosen mode, the sequence to address the different dimensions of the observed object changed, as depicted in figure 2.

	Purposes	Environment	Functionalities	Structure	Evolution
Conception	1	2	3	4	5
Analytical	4	3	5	1	2
Simulation	5	4	1	2	3

Fig. 2 – The three modes to capture a system: conception mode, analytic mode and simulation mode (adapted from Le Moigne [21])

For demonstration we will use an observational method, proposing to do a case study to demonstrate the validity of our produced artifacts, by studying in depth its application in a real business environment; For further evaluation we will use descriptive methods, using informed argument based on existing solid knowledge, and constructing/simulating some scenarios to demonstrate and evaluate its utility in different contexts.

3 Related Work

The concept of EOS it is not new in literature, but the notion of EOS is typically related to software implementation [16] and a new generation of Enterprise Information Systems, that try to shift to a new paradigm of information systems development, characterized by continuous change, and by addressing some relevant issues of complexity, adaptability and evolution of new fully digital enterprises models [45]. Our approach has a more holistic view, considering not only the informational/technological but also the social character of enterprises, thus considering its decision, physical/operative and informational socio-technical subsystems, in an integrative way. Our EOS concept, having a broader scope, represents the essential enterprise governing and self-organizing system, responsible for its preservation, i.e. its viability and sustainability. In order to accomplish this, an EOS has to address and integrate the three dimensional views of any complex system or active object (functional/physiological, ontological/analytical and evolutional/morphogenetic) [21] .This broader EOS concept rises the need for research in fields leading with organized complex phenomena, in a more holistic and abstract way. Thus, we end up reviewing and identifying some related work in the research field of General System Theory, as the concept of systems is central to any discussion of enterprises, and in other systemic and holistic based approaches like Organizational Cybernetics, Enterprise Engineering and Complex Systems Theories. In the rest of this section we will review Beer´s Viable System Model (VSM), Le Moigne´s Nine Levels Model (NLM), some Enterprise Engineering relevant concepts and finally some complementary and important issues addressed by other Complexity Theories

3.1 Cybernetics and Beer´s Viable System Model

The concept of cybernetics as Norbert Wiener (known as the father of cybernetics) defined in his seminal book title, is “the study of control and communication in the animal and the machine”. Cybernetics have then an emphasis on coordination, regulation, control and communication, not only in engineered artificial systems, but also in natural systems such as organisms and societies, which set their own goals and have self-controlling mechanisms, rather being controlled by an external entities or their own creators [2]. Organizational cybernetics conceives management in terms of coping with the organized complexity character of enterprises, trying to answer the question, how an organization could be organized to enable its self-control, self-organizing and self-finalizing capabilities in order to persist in an ever changing environment. Stafford

Beer, developed a model for that purpose. From a first neurocybernetic approach, Beer define the organizational prerequisites for the viability of systems [5], and developed and operationalized a model, the Viable System Model (VSM) [5],[6],[7]. In the VSM, a set of functional subsystems is distinguished, which provide the `necessary and sufficient conditions' for the viability of any social-technical system or organization, i.e. for being able to maintain a separate existence in a particular sort of environment.

We can consider the following principles, when using a VSM approach to distinguished and model an enterprise as a viable system:

1. Principle of recursiveness – we should depict an organization as a viable system, that contains a set of viable systems, and that is contained within a set of viable systems;
2. An enterprise is viable if and only if exists a set of functional subsystems with a specific set of interrelationships, which provide the `necessary and sufficient conditions for the viability of any social-technical system as depicted in Figure 3;
3. Any incompleteness, malfunctioning, or ineffectiveness in this necessary and sufficient management functional system, weakens or threatens the viability of the organization.
4. The viability, cohesion and self-organization of an enterprise depend upon these functions being recursively working at all its levels. A recursive structure comprises autonomous wholes within autonomous units. A viable organization is made up of viable wholes and it is itself embedded in more comprehensive viable wholes.

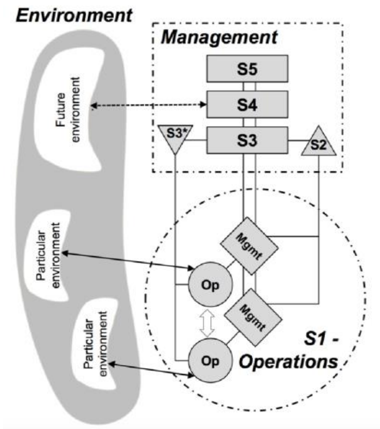

Fig. 3 – The Viable system Model

The needed "necessary and sufficient" functional subsystems and interrelation between then, as depicted in Figure 3, are the following:

-S1 (System One) – Operations: it is a logical necessity to identify: a) the operational elements of the viable system (that are themselves viable systems), distinguishing one or more operational units (S1-Operations) that develops the operational/productive activities of the the system; b) a meta-systemic controller (the Management metasystem), which governs the actions of every operational units; c) the viable system environment.

But operational units being viable systems themselves, they are characterized too by a particular environment, an operation unit and a management unit.

-S2 (System Two) – Regulation: As a consequence of the existence of more than one (autonomous) operational unit, there is a logical necessity for the existence of a coordinator subsystem for meta-systemic activities / interactions, responsible for damping inter-unit oscillations;

-S3 (System Three) – Control: to being aware of all that is going in on inside the enterprise, now, it is needed a control system with a synoptic systemic viewpoint from which surveys the total activity of the operational units of the enterprise. There is then a logical necessity for the existence of a control management system, which allows to govern, in an integral way, all of the operational and meta-systemic activiies which constitute the “here and now of the organization. This control system is realized by the subsystem S3 (the command system, which ensure the coherence of system-1), and S3* (the audit/inquiry system, that has directly and unfettered access to the operations of system-1);

-S4 (System 4) - Intelligence: the systems S1+S2+S3 enables the viable system capability to handle with its own internal regulation, conducing to stabilization of its inside and now. However, this is not enough. In order to a viable system be able to thrive within its ever changing environment, assuring its adaptability to its larger environment and unknown future, a new system is logically needed, the system 4 (S4). S4 is the system that allows to deal with the “outside and then” of the enterprise, is the intelligent subsystem able to design ways of foreseeing, anticipating and exploring the unknown future environment;

-S5 (system 5) – policy: Finally, there is a need of a system 5, a self-finalizing system, to supply logical closure to the viable system, and monitor the S3-S4 homeostat, i.e., monitor the balance it must possess as a whole, when confronting the interests of “here and now” (carried out by S3), and the interests of “outside and then”, i.e. its future designs (carried out by S4). Logical closure is “what makes the system complete, self-sufficient, and turns the system back into itself, to satisfy the criteria of viability at its own level of recursion. Closure means self-reference: the assertion of its identity” [6][7]

VSM theory also considers a set of rules for the viable system [6], including a law of cohesion, the recursivity theorem, and a set of organizational principles and axioms. Those principles and axioms are related to the required variety and information capacity, in (and between) its components and communication channels, in respect to the law of requisite variety [2], and a continuously need for the system to settle down in homeostatic equilibriums. Hence, these set of rules should be respected in order to a system be viable. Considering the central role of our EOS concept to assure its viability, we raise the hypothesis that the UEOS should also respect this set of rules for the viable system.

Although Beers´s organizational cybernetics and its VSM contributes with very interesting concepts to cope with systems viability, it is a black-box approach, lacking of a constructional/ ontological perspective , which is essential to cope with effective enterprise design and purposeful transformation/ evolution.

3.2 Le Moigne´s General System Theory and the Nine Level Model

General Systems Theory appears with Von Bertalanffy´s seminal work [7], where he claim the need for a general theory of complex systems, under the guidance of open system concept.

Le Moigne´s [21] defines a general system as something (presumably identifiable), which in an environment, towards some purpose, does something on something, transforming it over time. In other words is a structure that is functioning and transforming the world toward a purpose in a given environment.

Therefore, a perceived phenomenon must be defined due to three poles or perspectives. First, the functional perspective, the action of a system in its environment. Secondly, the ontological perspective, the static representation of object and its composition. Thirdly, the evolutionary or historical perspective, the phenomenon's transformations in time toward some goals (also named the morphogenetic or genetic/teleological perspective). [21]

Concerning the system functional perspective, Le Moigne developed the Nine Levels Model (NLM), a more elaborated version of the denominated Decision-Information-Operation-System Model (DIOS model). The functional DIOS model, is comprised of: the Decision System (DS), the Information-Memorization System (IS) and the Operation System (OS). In this case, the DS makes decisions for the whole system, the IS memorizes information and acts as a coupling or communication between the DS and the OS, while the OS does the work in the system.

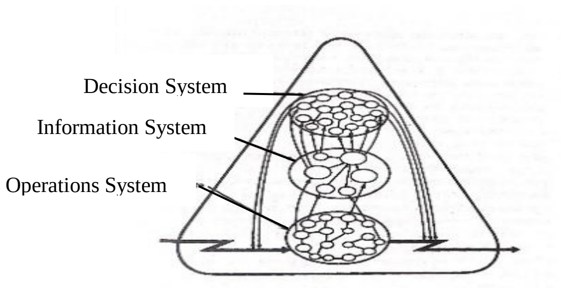

Fig. 4 – DIOS Model (adapted from [21])

In its more elaborate version of the DIOS model, the NLM, Le Moigne expresses all nine levels of Boulding's proposition [8], where an observer should distinguish the following:

1. a system or object in a certain environment ;
2. the object as an active entity, identifying what the system does. At this level we have the emergence of activity;
3. the object as an active regulated object. The object manifests some regularities in its activity, hence its regulation mechanism, which governs the operational system activities, is identified. This level manifest the emergence of operational level self-regulation trough feedback processors and circuits;

4. the information flows for the regulation. This level manifest the emergence of information in the object representation, representing the object as an active, regulated and informed object;
5. an information-memorizing system, which memorizes information and mediates the communication (acting as a coupling), between the higher levels (the DS) , and the lower levels (the OS), as depicted in figure 4;
6. a decision system for its behavior control. At his level we have emergence of decision capabilities. A teleological hypothesis about the decision processors internal logic, should be made: its behavior is not random but goal seeking. The object decide its activity. The decision / selection is made in relation to purpose / goal seeking states. The inputs of this decision/control system are representation and decision information , while the outputs are decision information;
7. a coordination system, which coordinates its decisions to act. At this level, emerges the self-coordination capabilities of the object, trough the establishment of allowed connection and interaction choreography between its parts;
8. a imagination system, which imagines and conceives new possible decisions or forms of action. At this level, the object intelligence and its self-organizing capabilities emerges;
9. a self-finalizing system which gives closure to the system. At this level the active system is capable not only to seek goals, but as the ability to set their own purposes and projects, and assert its identity. The system is characterized by being the interface between a finalizing or purposeful internal will, and the environment [32]. At this level emerges the object consciousness. And, since “consciousness is intentionality, therefore fatally free” (Jean Paul Sartre), eventually, in this level, emerges what we call the object free will;

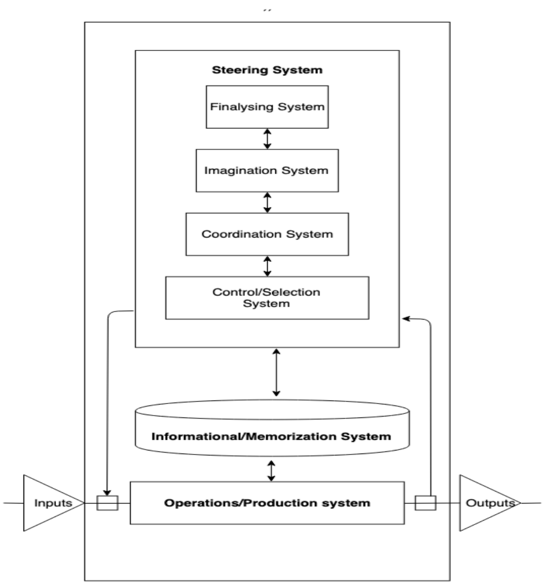

Fig. 5 - NLM (adapted from [21])

As previously stated, Le Moigne´s NLM is a system functional perspective, hence a black-box approach. To completely describe any active object or system, and effectively deal with its purposeful design and transformation, we also need a white-box approach, or ontological perspective. We can find interesting concepts and constructs, in Le Moigne´s general system theory body of knowledge [14][21] [22] , to deal with systems ontological and evolutionary perspectives. However since this constructs are supposed to be applied to any kind of system they are very abstract. Therefore, to address the also needed ontological /constructional perspective for the development of our UEOS concept, we decided to explore Enterprise Engineering body of knowledge (with more precise and adequate constructs to capture social-technical realities).

3.3 Enterprise Engineering

Enterprise engineering (EE) is a new holistic approach to address enterprise changes, of all sizes and in all kinds of enterprises. Because of its holistic, systemic, approach, it resembles systems engineering. But it differs from it in an important aspect: enterprise engineering aims to do for enterprises (which are basically conceived as social systems) what systems engineering aims to do for technical systems [10]

To model an active object or system (as enterprises), we need always to address two phenomena: one cinematic, i.e, modeling the form and related processes,, thus the different states of a stabilized object form; other dynamic , i.e, modeling the temporal evolution between the different forms of the object [21]. EE have been developing very helpful constructs to capture enterprises systems ontological and functional dimensional views (the cinematic process of enterprises), although usually as static time frames or instantaneous pictures. However, EE has not been successful to fully capture enterprises evolution and its self-transformation capabilities (its dynamic process), because there is a lack of EE constructs to deal with these phenomena. To capture the enterprise structural transformation process itself, and its historical dynamical view, we need to model enterprises as (self) observing systems and not merely as observed systems. We must not forget that organization´s agents are an integral part who are shaped and shape the organization themselves, and that change is a continuous process trough time which could not only rely on punctual intervention methods [22].

Moreover, the cinematic process of enterprises is neither fully captured. The pre-designed or prescribed organization is well captured, but not the enacted organization (with the apparently lack of concepts and method in Enterprise Engineering, for a continuous and timely update of models of organizational reality).

However, we should note that we found in the EE literature some relevant efforts to deal with these lack of concepts. In [13] Guerreiro implements an ontological solution (founded in business transaction concept which is rigorously defined by DEMO - Ψ-theory [11]) for the control of the run-time business transactions, in order to guarantees that the prescribed business transactions are followed in the operation by performing a continuously cycle of observation, decision and action. Control action actuates with a change in the business transaction models prescription to avoid the recurrence of unintended operations or a a change in the control rules if the deviation from prescription is recognized as being innovative. Another interesting contribution is GOD theory [3] . where the author propose a precise and integrate modeling of three aspects which he considered to be part of functional perspectives of enterprises: : 1) viability – characterized by specifications of vital norms of operations that ensure viability of the enterprise, dysfunctions and their causing exceptions; 2) change – characterized by specification of the organizational engineering process responsible for Generation, Operation and Discontinuation of organizational artifacts (OA), 3) architecture – characterized by specification of design rules that guide the referred engineering process, restricting the shape of their end results (OA). These modeling is accomplish by extending the DEMO-theory to specify the (re)Generation, Operationalization and Design of ontological artifacts, as a consequence of the handling of unknown exceptions causing dysfunctions that compromise the viability of an organization.

Although in [11] and [3], the authors made relevant contributions to cope with important aspects of enterprises change, and the alignment of the enacted enterprise with the prescribed enterprise, the proposed constructs cope only partial with the enterprises change phenomena. This constructs address the control, change and learning process caused by reaction to unexpected events , unknown environmental conditions and/or uncertain internal actors behavior. But they do not address the enterprise process of actively imagining the future and (self) transforming accordingly to it, or reflecting on its nature and purpose and changing accordingly its action upon on its environment, and/or the relation/ transactions with its higher order systems. Hence, we still need to go further and fill some gaps, like developing ontological constructs to capture the needed mechanisms and structure, to realize the VSMs system 4 and system 5 functionalities.

Other EE concept relevant to our research is the organizational self-awareness (OSA) concept [29][31]. OSA is also defined in [3] "as the continuous effort of minimizing the gap that exists between the understandings shared among all organizational members about the organization, the formal representations of those understandings, and the real and concrete organization", by integrating individual, partial and frequently incoherent views of the organization self into a unique and shared view. Moreover, the authors in [3] argues that "since organizational reality is constantly changing it is not only necessary to have a shared view of the organization as up-to-date and coherent as possible, but also a shared record of the history of changes of the organizational self".

Organizational self-awareness has an individual and an organizational dimension [31] : "the individual dimension refers to the capacity that individual members of the organization have of answering questions such as; who am I in this organization?, how are things done here? what is the organization -as a whole- doing now?; the organizational dimension refers to the combination of human or automated agents, resources and procedures that provides organizations with the necessary intelligence for dealing with questions such as; who are my members?, how do they do things?, what are they doing now?". An organization is self-aware when these two dimensions are aligned.

Applying the recursivity hypothesis (as in Viable System Model) we can postulate that:

- The enterprise, as a large distributed network of active agents that are continuously interacting and producing behavior, has an organizational dimension of self-awareness, in relation to their individual agent members (its network active nodes);
-The enterprise as an autonomous and active intelligent entity or (organizational) agent, has an individual dimension of self-awareness, in relation to its larger wholes or entities where the enterprise are embedded.

Thus, we have self-awareness when the organizational dimension of an enterprise (macro perspective) is aligned with the individual dimension of its lower recursion level agents (micro perspective). But beyond self-awareness, what about the self-alignment between the enterprise´s self-awareness individual dimension, in respect to its higher recursions levels entities, and its self -awareness organizational dimension, in respect to its lower recursive level agents network ? We believe that when this self-alignment happens, the enterprise´s self-consciousness emerges. Thus, consciousness emerges when different higher and lower recursion levels awareness are aligned and integrated in an whole entity. Note that there is not only a problem of integration within the self of an enterprise of the different vertical recursion levels, i.e. the alignment between its members views, the enterprise self, and one specific higher order system view (where the enterprise is embedded). There is too the problem of integration within the self of an enterprise of the different dimensions of recursions, i.e., between the different wholes and respective purposes where the enterprise is embedded (as the integration or coherence of different actor roles, within an actor self-identity).

The OSA concept developed within EE research field is quite relevant to our research, because is what supports the development of the higher concept of enterprise consciousness, which in turns enables its agency, autonomy and intelligible behavior. However coping with the enterprise consciousness concept requires developing tools to capture its logical closure, what makes the enterprise complete, self-sufficient, closing into itself, to satisfy the criteria of viability at its own level of recursion and asserts its identity.

We believe the EOS concept addressed by our research will contribute to better capture in an integrated way, some phenomena which are not well captured with existent EE tools, as the logical closure of enterprise systems and the emergence of its self-consciousness, the enacted enterprise, and its dynamic or its self-transformation and evolutional process , for continuously assuring its viability and sustainability.

3.4 Complexity Theories and Complex Adaptive Systems

As a result of strong critiques to the traditional mechanistic paradigm of organizational theory, and with increasingly pace of change and uncertainty of enterprises environment demanding for more adaptive structures, applying complexity theories to studying enterprises as complex systems is becoming relevant. Complexity theories address the emergence of order in dynamic non-linear systems operating at the edge of chaos [1]. Order in such systems is seen as manifesting itself in a largely unpredictable fashion, in which patterns of behavior emerge in irregular but similar forms through a process of self-organization, which is governed by a small number of simple order-generating rules.

Although relevant to our research, particularly to address the evolutionary or system dynamics perspective of enterprises, a more deeper presentation of complexity theories is out of the scope of this particular paper. In [1], [9],[26] could be found some interesting reviews from different perspectives, all addressing the relevant research fields and concepts in complexity studies, such as Dissipative Structures [25] , Chaos Theory [18] [19] and Complex Adaptative Systems[27].We will just briefly address here one significantly relevant concept for our research, the concept of bounded instability or "edge of chaos". "Bounded instability", means systems are constantly poised at the edge between order and chaos, in the "edge of chaos". It is argued that the important capabilities of a system to adapt and evolve , in order to survive, are only fully operational when a complex system operates at the edge of chaos. If the system become too stable , with too much order, they became rigid and died. If they become too chaotic and unstable, they may get out of control and self destroy. What allows a system to remain at the edge of chaos, is the system´s order-generating-rules. Even in the most complex systems, the emergence of order manifests itself through the operation of a limited and simple order-generating rules, which permit limited chaos while providing relative order. The concept of order-generating rules explains how complex, non linear, self-organizing systems manage to maintain themselves at the edge of chaos, even under changing environmental conditions [26].

4 Current State of Research

Current research is still in a very initial phase. We have been examining different theories in the research fields of enterprise engineering, organizational cybernetics, general systems theory, complexity theories and complex adaptive systems, as highlighted in section 3. This initial review led us to better define our research problem and its relevance (as highlighted in section 1), and to identify Le Moigne´s General System Theory and Beer´s VSM, as the most adequate and sound bodies of knowledge to contribute to a first functional approach for design the UEOS model. Although, inspired in different theories, (NLM based on the systems complexity levels theory [14], and VSM based on human neurophysiology system [4]), these two models have clearly similarities. In figure 4 we compare the NLM and VSM. NLM is a version of Le Moigne´s DIOS model (Decision-Information-Operation System). This could well compared with the VSM cybernetic typical model, i.e., the DOS model (Decision-Operation-System), which is comprised of two subsystems, the decision system (feedback and control system) and the operation system (feed forward system).

In figure 6, we can find the correspondence between NLM´s components and VSM´s components.

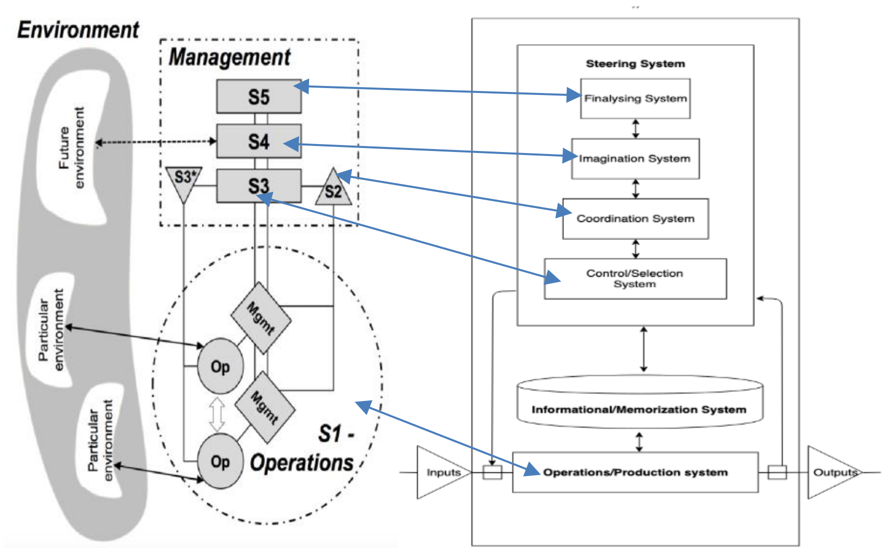

Fig. 6 – Correspondence between the VSM (Cybernetic DOS model) and NLM Systemic Le Moigne´s DIOS model)

The most relevant difference when comparing NLM with VSM, is the explicit presence of the memorization and information levels at the NLM logical breaks. Accordingly to Le Moigne [21], the cybernetic model (the DOS) reduces complex systems to automats, due to the cybernetic command-control relation that imposes the will of the DS on the OS. In Le Moigne´s systemic conception such a relation between DS and OS is mediated and expressed in the memorization system, thus of a complex nature. Moreover, the cybernetic system lacks memory, reducing complexity to a simple thermostat, while the memory of the DIOS expresses the potentiality of a system to accounts for its history and evolution. We agree with the need to address and explicit a memory system, because of the extremely important role of information and memory in complex systems, as enterprises. Moreover to account for the historical and evolutionary perspective only an object with memory could intelligibly evolve, while being able to conserve its identity. Thus, we consider essential to integrate an explicit information and memory system, mediating and/or coupling the operation system and the decision system in our UEOS model (as in the NLM). In figure 7 we propose an integrated functional model for discussion, modeling an enterprise as an autonomous and intelligent entity, i.e. as an organizational intelligent entity (OIE), by integrating NLM and VSM components. As considered in VSM and NLM, we also assume the recursive hypothesis (every OIE is composed by OIEs and are embedded in other OIEs).

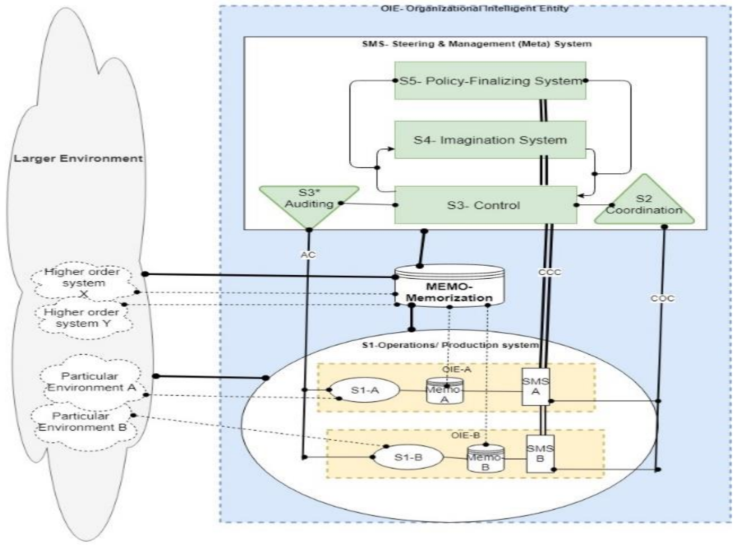

Fig.7 – Proposed model of an enterprise as an organizational intelligent entity

This model integrates the components with direct correspondence, as depicted in figure 7, namely: S5-Finalizing System, S4- Imagination system, S3- Control system, S2-Coordination System and S1- Operations system. We also consider the explicitation of the S3*- auditing system of VSM. Considering the central role of memory in NLM, as a requirement for an intelligent complex entity, we considered a memory system mediating the DS (decision system) and OS (operating system).

From this proposed integrated model of an organizational intelligent entity (OIE), we propose as being part of (or controlled by) the UEOS, the following items:

- The SMS – all Steering & Management (meta)System components
- The MEMO – the memorization/information system (including its connections to the SMS, to its lower order members´ memo systems, and to its higher order entities´ memo systems. In other words, the MEMO system of the system in focus (the enterprise) is a distributed system: by integrating its agents´ memo systems, and by being itself a component of the memory of its higher order systems (or wholes where the system is embedded).
- The connections/channels between the system environment and its Operational/Production system,
- The internal main meta-systemic communications channels, namely the control and command channel (CCC), the Coordination Channel (COC), and the auditing channel (AC)
- The higher-end mechanisms to balance the "inside and now" activity (S3) and the "outside and future" (S4) of the enterprise, monitored by its finalizing system (S5).

In figure 8 we present a simplified and rudimentary UEOS functional model

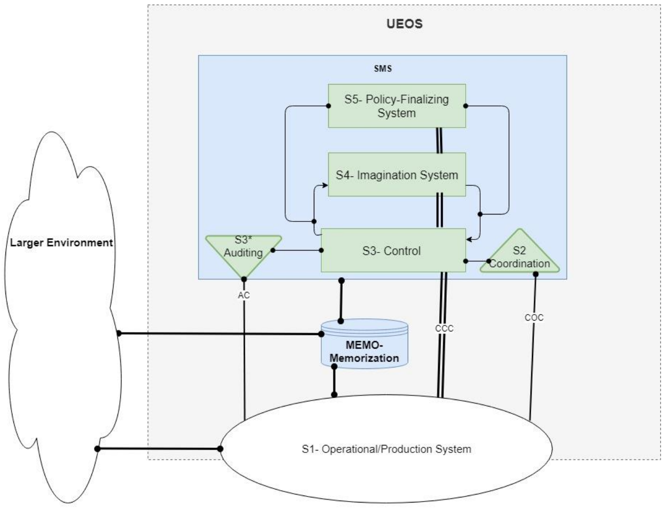

Fig 8 - A UEOS first rudimentary functional model

We should also note that SMS is a meta-systemic component of the organizational intelligent entity, while operational/productive intelligent entities are at a lower recursion level. Thus, the channels between SMS components and production systems (S1) components are channels between the system in focus EOS, and its lower recursion level individual production systems EOSs. In short words, the EOS is a distributed and recursive system.

Another issue addressed in this initial research phase is the role of the EOS assuring that the enterprise is contained in the "edge of chaos " to fully enable its adaptation and evolution capabilities, and the role of EOS responding to a highly changing environments or disruptive events, by a kind of simultaneous process of stabilization and overcoming, production and conservation [24].We still need to extend our first rudimentary functional UEOS model presented above to cope with these issues. Deeper investigation in complexity theories concepts will be made to address this requirement.

5. Future Plans

We intent to investigate deeper the concepts we reviewed so far, and get additional feedback from the research communities, to progress with our rudimentary functional UEOS model, to a sound, complete and coherent final UEOS model, while trying to address all above mentioned questions. We believe enterprise engineering research community could contribute significantly to help us progressing from a more abstract and functional (black-box) model, underpin by cybernetics and general system theory, to a constructional/white-box model, adequate to capture real social-technical contexts, underpin by EE sounded body of knowledge, .

Following our proposed research methodology, after defining our problem and our objective (see section 1), we are presently in the design and development phase, of our design science iteration research process (see section 2). We need to enhance our first rudimentary functional UEOS model, and after defining the teleological UEOS terms, its functions and purposes (the what), we will need to design and define its ontological / constructional terms (the how). Finally we will need to implement it, put it functioning, and then evolving to also capture its evolutionary/dynamic perspective. For that purpose we intent to: 1) investigate deeper and finalize a first complete and coherent functional and ontological model of UEOS; 2) test the model, while developing a methodology to use it, in a real context, through a case study in a local hotel group enterprise; 3) evaluate the UEOS model and methodology in other contexts, trough complementary case studies, and/or constructing a set of detailed scenarios;

6. Conclusion

We believe enterprise engineering has not developed yet sufficient and useful artifacts to cope with enterprises self (as self-observing systems and not merely as observed systems), and with its self-organizing and evolution capabilities, in fast changing environments. To contribute to fill this gap we introduce the EOS concept, defined as its essential self-governing system responsible for its viability and sustainability. Our research goal will be to design a universal EOS (UEOS) model and a methodology, to help in designing, diagnosing and improving any specific EOS. Our research is still in its initial phase. Comprehensive review of viable systems, Le Moigne general system theory and his nine level model(NLM), and some enterprise engineering and complexity theories relevant concepts has been done. A first rudimentary functional model of a UEOS is proposed. Although deeper investigation of mentioned concepts is already planned, it will be valuable to get additional feedback from the enterprise engineering community about which areas to focus on in order to deal with the issues that have arisen during our initial research phase, and to help evolving our first functional rudimentary UEOS model, into a complete and coherent one, addressing the functional, ontological and evolutionary perspectives of any EOS.

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