NOVA IMS Information Management School

MGI

Mestrado em Gestão de Informação
Master Program in Information Management

An Architecture for a Viable Information System

Application of "Viable System Model" in modern systems architecture for the creation of Viable Information System

Anton Selin

Dissertation presented as partial requirement for obtaining the Master's degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

AN ARCHITECTURE FOR A VIABLE INFORMATION SYSTEM

APPLICATION OF “VIABLE SYSTEM MODEL” IN MODERN SYSTEMS ARCHITECTURE FOR THE CREATION OF VIABLE INFORMATION SYSTEM

by

Anton Selin

Advisor: Vitor Duarte dos Santos

ACKNOWLEDGEMENTS

I would first like to thank my thesis advisor Dr. Vitor Duarte dos Santos of the Information Management School at Nova University. The door to Dr. Vitor's office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this dissertation to be my own work, but steered me in the right the direction whenever he thought I needed it.

Finally, I must express my very profound gratitude to my parents, my uncle and grandparents and to my girlfriend for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Anton Selin

LIST OF ABBREVIATIONS

A1 - VSM Rules: first axiom;
A2 - VSM Rules: second axiom;
A3 - VSM Rules: third axiom;
BPM - Business Process Management;
BPMS - Business Process Management System;
CBIS – Computer Based Information System;
CRM - Customer Relationship Management;
CRUD - Create, Read, Update, Delete;
FIS - Fuzzy Inference System;
IS – Information System;
JSON - JavaScript Object Notation;
LC - VSM Rules: Law of cohesion;
PO1 - VSM Rules: first organizational principle;
PO2 - VSM Rules: second organizational principle;
PO3 - VSM Rules: third organizational principle;
PO4 - VSM Rules: fourth organizational principle;
RA1 - VSM Rules: first aphorism;
RA2 - VSM Rules: second aphorism;
RST - VSM Rules: recursive system theorem;
TPS - Transaction Processing System;
VSM – Viable System Model;
XML - Extensible Mark-up Language;

PUBLICATIONS RESULTING FROM THIS DISSERTATION

Anton Selin, Vitor Duarte Santos: “Application of ‘Viable System Model’ and Soft System Methodologies in modern systems architecture for creation of viable information system”. (CAPSI 2016).

Anton Selin, Vitor Duarte Santos: “A Viable System Model in modern Information Systems”. (CISTI 2017).

SUBMISSIONS RESULTING FROM THIS DISSERTATION

Anton Selin, Vitor Duarte Santos: “An Architecture for Viable Information System”. (World CIST 2018).

Anton Selin, Vitor Duarte Santos: “New Perspective on modern Information Systems”. (Information Systems Research).

PRISES THIS DISSERTATION HAVE WON

Best Poster at CAPSI 2016.

FIGURES

TABLES

ABSTRACT

The idea of present work is born in the context of problems that nowadays organizations facing with their information systems. Modern information systems are monolithic, complex and not ready for the future challenges. But, at the same time, they are playing a key role in a chain of value delivery.

Such systems are not fitting perfectly into the businesses where they are employed (not providing all desired outcomes as they are expected by the creators and users of the system). There are three main areas where critical problems can arise in the process of information systems development: modelling, managing, and maintaining information systems. Once an architecture of the system is designed and implemented, the organization faces several problems in maintaining it.

It is important to notice that, most of the time, people do not approach ISs problems in a systemic thinking way, but instead in a reductionist way. Which means that no one trying to understand all the interactions between components of the system, which may lead to very interesting and useful findings when studied properly. But the information system it’s just a system, sometimes very complex and monolithic, but it’s still just a system.

In this work, Viable System Model will be used to help solve problems described above. The goal of this work is to apply VSM to the Information artifacts to take advantage of all benefits VSM offers. The main outcome from this work will be an architecture for Viable Information System. Systems thinking area will be taken as a basis for the development of the ideas presented in this dissertation.

We are proposing a new architecture for modern organizations to use, to take advantage of benefits that VSM must offer. Namely: understanding of complexity, resilience to change, survival to an external environment and ability to exist independently of its external environment.

Given that Information System is a system, and, so, obeys laws of general system theory, we could take advantage of using the “Viable System Model” architecture.

KEYWORDS

Information Systems Architecture, Viable System Model, Systems Thinking, Fuzzy Logic, Complex Problems.

INDEX

1. INTRODUCTION

1.1. BACKGROUND

We can observe that nowadays many information systems are big, monolithic, and embedded in every big organization. These organizations influence, directly or indirectly, our day to day life. For these organizations is extremely important to know each aspect of their information systems. One of the most important pieces is a need to know the behavior and all possible implications of changes could be performed toward information system. The world we are living in is changing rapidly and constantly, and changes to IS are impossible because they are constantly evolving. (Sridhar Nerur, 2005) The IS nowadays is playing a key role in chain of value delivery.

IS nowadays exists in a big variety. They are different from each other and normally are fitted to the needs of an environment (customized for a specific business) where they are implemented. Growing development speed of modern technologies makes very challenging performing modifications to the ISs. One of the reasons is due to its complexity, other is due to the implications that instabilities in the system may generate to the business.

Also, because of the complexities of the systems, nowadays it’s almost impossible to understand a system end to end. By the rule, we have different people responsible for different parts of the system. Because of that any changes that are made to an information system are preceded by meetings between different stakeholders. We can argue that normally these meetings are not perfect, not even well driven for several reasons like human factor, different points of view, a different understanding of the purpose of parts of the system, lack of knowledge, and so on... Which leads us to the logical conclusion, that well-done changes in modern ISs are timely and costly projects, which may not correspond to the needs of modern market requirements (John Leslie King, 1978).

Complex systems are characterized by large numbers of heterogeneous components with a high degree of interconnections, relationships, and dependencies. They exist in a dynamically changing environment that demands dynamically responding behaviour. In other words, these systems must adapt to their environment (Charles Herring, 2001).

Modern information systems had their begging during the second world war (Jackson M. C., 2003). After finishing the war, there was a need to rapid development which was strongly supported by areas like operational research, systems analysis, and systems engineering, these areas gave begging to the modern information systems. By its nature, these fields of study are very reductionist. This leads us to the conclusion that development of ISs using these methodologies, brought us to the state in which information systems exists today.

Inside of such systems is difficult to anticipate, and by consequence, to control all kind of behaviors that system may have, under different circumstances. Here, by behavior is meant a different kind of events: such as sending messages, updates to data records, communication within subsystems etc. And, by circumstances is meant inputs that systems may receive, and sets of estates that system may accumulate (Ackoff, 1971).

Ackoff argues that the ‘machine age’ associated with the industrial revolution began to give way to the ‘systems age’. The ‘systems age’ is characterized by increasingly rapid change, by interdependence, and by complex purposeful systems (Jackson M. , 1991). It requires much higher focus on learning and adaptation capabilities, if any kind of stability is to be achieved. This approach requires a big change in world view, and approaches that are used in modern IS field nowadays. IS problems approached using analysis, reductionism, a search for cause-effect relations and determinism is called machine-age thinking, and it was extremely popular in past century. In the modern world, it must be complemented with systems thinking strategies which are based on synthesis and expansionism, producer-product relation and existence of individual free will.

1.2. MOTIVATION

Companies have wondered about how to better understand their systems. Since the information systems appeared, several trials were made. Nowadays businesses have a missing "one single solution" which will allow them to work with information systems in an efficient way, without old reductionist fashion. A great solution comes when a problem is analyzed from the Information Systems perspective (Melville, 2010).

That why is very important to give organizations tools which will allow them to solve some, or all, of the problems that arise from information systems field. Namely, not understanding of complexity, normally complexity wouldn't be a problem, complexity, in the field of systems theory, just means that the system is large, has a big number of interconnected components, with more than one relationship between that component. But when complexity is not understood it cannot be managed (Ackoff, 1971). This will give companies possibility to concentrate better on an improvement of their businesses and, consequently, on an improvement of our lives.

Previously subject was approached by Joao Alvaro Carvalho in his paper: "Using the Viable System Model to Describe the role of Computer-Based Systems in Organizations" (Carvalho, 1998). The work of Joao Alvaro Carvalho was of great importance at the time, but given that in past 20 years technology changed into an almost new paradigm, the work needs to be updated referring the modern state of the art knowledge in information systems. Also, additional insights could be generated by using the systems thinking techniques when analyzing the modern systems, which will also do a big difference in terms of understandability of the work.

1.3. OBJECTIVES

The outcome of the dissertation will be of great importance for those who want to build understandable and predictable information systems, as well as will give a new perspective of how to think about IS field in systems thinking way.

This work is intended to help Managers of the companies, Information Systems Architects, Project Managers, and all interested in better understanding of their information systems.

The study will create a new knowledge of how Information Systems could be transformed (in a case when they are already implemented) or created in order to be viable.

The result of the investigation will have a practical application. The main outcome is the blueprint for the information system architecture.

A new perspective on how information systems should be constructed to face challenges of the present world, and of the future, will be provided. That will create a new state of the art for the field of information system architecture.

2. THEORETICAL FRAMEWORK

2.1. SYSTEMS THEORY

Popular definition of system is a regularly interacting or interdependent group of items forming a unified whole. We can see it in every aspect of the world surrounding us. The solar system, nervous system, political system, and so on, all of these concepts are set of items which are somehow connected to each other. This set of connections is what actually forms a system. In business, the organization is seen as a set of people and machines that interact in processes to achieve business goals.

First references to the systems were made by French physicist Sadi Carnot (Šesták, 2009), who first introduced a concept of system in the field of natural sciences in 1842. In 1850, the scientist Rudolf Clausius proposed the concept of the surroundings to the knowledge of systems. Following some years of studies, the concept of systems theory appeared in the scientific literature.

It is also important to outline the concept of systems thinking here, which is a cognitive process of studying and understanding systems of every kind. Systems thinking consists on set of methods which allow to see system as a whole. Sometimes it is considered to be an opposite to the reductionist approach where the system is divided into smaller pieces and then this smaller pieces are studied as separated entities. Systems thinking argues that simply the collection of parts is not equal to the whole because some new properties are only shown when the pieces are interacting with each other.

Some systems are very simple and easy to understand while others are very complex. But by being a system all of them are sharing something in common, those common properties among all systems are described in the work "General Systems Theory".

The systems theory is the concept which first was proposed by the biologist Ludwig von Bertalanffy, in his work of General Systems Theory and further was developed by Ross Ashby in his work Introduction to Cybernetics. Systems theory can be defined as the transdisciplinary study of the abstract organization of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the principles common to all complex entities and the (usually mathematical) models which can be used to describe them. (Bertalanffy & Rapoport, 1957)

In other words, general systems theory covers several methodologies which employ a systems approach to understand complex phenomenon and problems.

It plays very important role in the understanding of complex phenomena's. The main approach used by system theorist is to break the big and complex system into smaller pieces and then study the interactions between these small components to understand if something new is happening. The main rule of system theory states that "sum of the parts of the complex system is not the same as the whole system".

System theory gave beginning to many other fields and frameworks which are more specifically applied in different areas, such as: Applied Systems Thinking, Hard Systems Thinking, Systems Dynamics, Complexity Theory, Strategic Assumptions Surfacing and Testing, Interactive Planning, Soft Systems Methodology, Total Systems Intervention, Critical System Practice and some others (Kogetsidis, 2011).

2.2. INFORMATION SYSTEMS

Information Systems could be viewed as systems which are intended to process information. They always existed in our world in one way or another, because any phenomena that have as a purpose to transmit and structure information could be considered an information system. That would be logically correct to say that the library is also an information system.

Indeed, in this work by information system will be meant Computer Based Information System. CBIS is an information system in which the computer plays the central role. Such a system consists of the following elements: Hardware, Software, Data, Procedures, and People (Checkland, 1997).

In the modern world, we have many different types of information systems, some of them existed almost from IS beginning (transaction processing systems), others are more recent creations (artificial intelligence systems), some have already been extended and generally not used anymore (legacy systems such as Space Shuttle System). All this IS having different purposes, but at the end, all of them was implemented to process data, and it can use different Hardware, Software, Procedures and be intended for different people, so data is the main component that remains among all the types of Information System.

(Al-Mamary, Shamsuddin, & Aziati, 2014) separates information systems in the following graph:

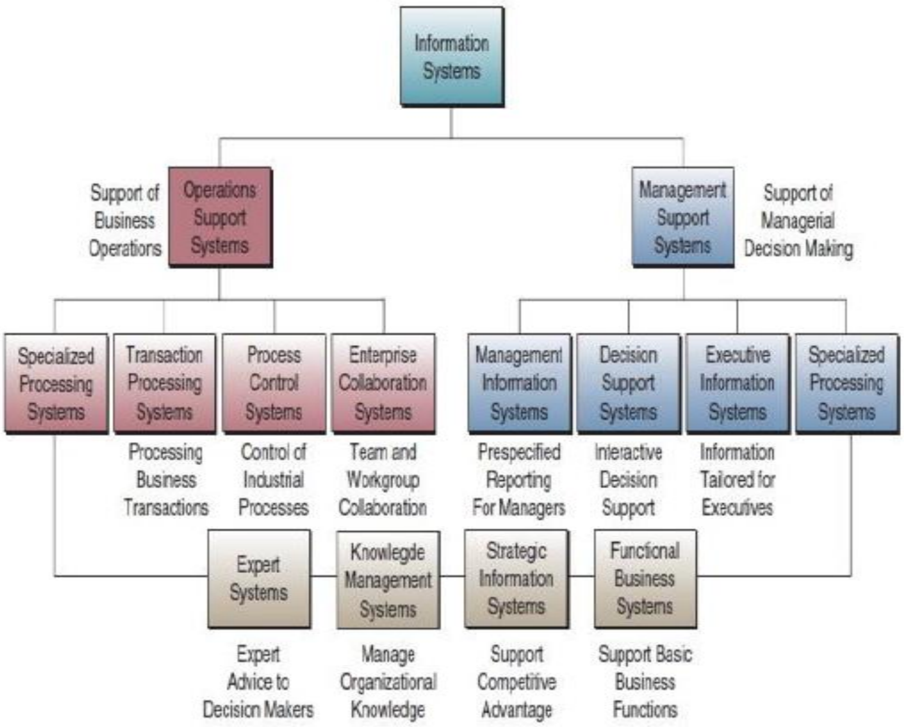

Figure 1 – Information Systems Hierarchy (adapted from: (Al-Mamary, Shamsuddin, & Aziati, 2014))

In this dissertation, a system is referred as Enterprise Information System, which will serve an entire organization, and not as a subsystem (which, viewed separately from context of parent system, could also be a system). The word subsystem will be used to point to specific computer based information system (Ackoff, 1971).

It is important to mention an attention that should be given to the architecture that is intended to be obtained with this work. The architecture referred here is the systems architecture but not the enterprise architecture. To better understand what is being said here we can refer to the Zachman Framework, which represents an Enterprise Architecture. A system referred to this work is a System Architecture which in Zachman framework is located at the Systems Model section (Inmon, 1997).

2.3. CHOOSING CBIS TAXONOMY

To discover a correct set of information systems, that will be used during the construction of Viable Information System Blueprint we will run through a process of classification. Classification is a method of categorization of things together so that they can be treated as if they were a single unit. In Information Systems, a category could be defined as an abstract concept that describes areas of commonality between different systems. That why it is important for this work to make a taxonomy which can be a support for the development of Viable Architecture.

As can be seen above, there is not a simple answer to the question of how to find a good information systems classification. Based on the classification structure, we can find any number of different categories of an information systems. At the same time, it is important to remember that different types of systems found in organizations were designed to deal with the specific problems and tasks of that organization. Based on that we can conclude that classification of Information systems into types rely on the division of responsibilities and tasks within organizational structure. Here is also important to mention the importance of classification in relation to what is being tried to achieve with this work. As we will see different components of Beer's Viable System Model have distinct responsibilities and distinct purpose (Beer, Brain of the firm: The managerial cybernetics of organization, 1972). So, we can argue that in addition to find a good taxonomy we also should take into consideration the responsibility of that system. We can define these responsibilities by answering the following questions: "what type of information the system deal with?", "what type of users the system is going to have?", "what is the time space that system deals with?", "what are the speed requirements for the data processing?", etc.

Viable System Model (VSM) was proposed by Staffor Beer. The VSM is a model of organizational structure that is based on the structure of the human nervous system.

Many companies have the hierarchical structure, meaning that responsibilities and information classes follows a hierarchy. And one of the most used approaches of systems classification in hierarchical structures is "pyramid model". The system in pyramid model mirrors the information, tasks, and responsibilities according to the levels of hierarchy found in the organization.

We can identify 3 main levels of decision taking in organizations. Strategic decisions, Tactical decisions, and Operational decisions.

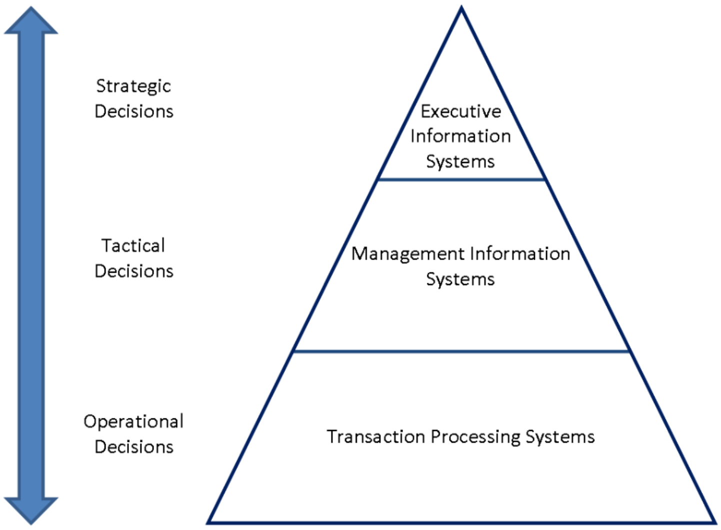

Figure 2 – Three level pyramid model (adapted from: http://www.chris-kimble.com/Courses/World_Med_MBA/Types-of-Information-System.html)

If we consider users of a system as main criteria to structure the classification it will signify that many of the other characteristics such as the nature of the task and informational requirements are taken by default.

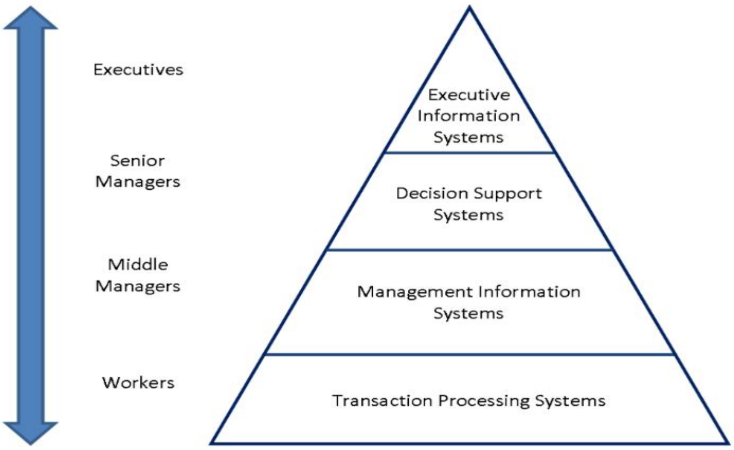

Figure 3 – Four level pyramid model (adapted from: http://www.chris-kimble.com/Courses/World_Med_MBA/Types-of-Information-System.html)

Similarly, by changing our criteria to different types of data/information/knowledge that reside in organizations we can create a five-level model:

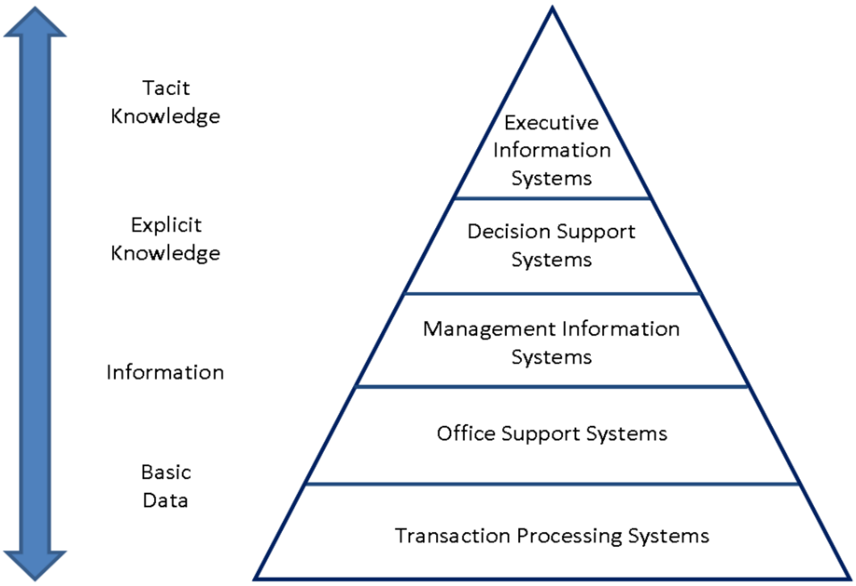

Figure 4 – Five level pyramid model (adapted from: http://www.chris-kimble.com/Courses/World_Med_MBA/Types-of-Information-System.html)

Probably this would be a better approach given the specific situation of our problem.

With five-level pyramid model, we are able compare differences among information systems in our model.

Transaction Processing Systems

The first system that we find in our graph is Transaction Processing System (TPS). TPS is operational-level system. These systems are the first line of interaction with company's external environment, which collect the key data required to support the management of operations. The process of data collection is usually done through automated or semi-automated tracking of low-level activities and basic transactions.

Functions of the TPS in terms of data processing requirements

Table 1 - Functions of Transaction Processing Systems

Inputs	Processing	Outputs
Transactions Events	Validation Sorting Listing Merging Updating Calculation	Lists Detail reports Action reports

Some examples of TPS: Payroll systems, Order processing systems, Reservation systems, Stock control systems, Systems for payments and funds transfers.

The role of TPS:

- Produce information for other systems;
- Cross boundaries (internal and external);
- Used by operational personnel + supervisory levels;
- Efficiency oriented.

Management Information Systems

For historical reasons, different types of Information Systems found in commercial organizations are referred to as "Management Information Systems". If we look at the pyramid model we will see that MISs are used by middle managers to help ensure that managers have enough information and action channels to guarantee a stability of a business for short to medium term.

The data collected from the TPS is normally structured into the meaningful information inside such systems. The managers should be able to evaluate an organizational performance (or at least performance of a specific department) with the data provided by MIS.

Functions of a MIS in terms of data processing requirements

Table 2 - Functions of Management Information Systems

Inputs	Processing	Outputs
Internal transactions Internal files Structured data	Sorting Merging Summarizing	Summary reports Action reports Detailed reports

Some examples of MIS: Sales management systems, Inventory control systems, Budgeting systems, Management Reporting Systems (MRS), Personnel (HRM) systems.

The role of MIS:

- Based on internal information flows;
- Support relatively structured decisions;
- Inflexible and have little analytical capacity;
- Used by lower and middle managerial levels;
- Deals with the past and present rather than the future.

Decision Support Systems

A Decision Support System (DSS) processes and analyses data to generate knowledge. Senior Management uses this system to integrate the knowledge into the organizational processes.

DSS systems are normally used to allow projections of the potential effects in the future of taking decisions today. Also, DSS helps to identify and manage ill structured problems in an organization.

Such systems may provide database access, data analysis tools, different simulation modules, and also supports integrations with other systems for data exchange purposes.

Data processing requirements functionality of DSS:

Table 3 - Functions of Decision Support Systems

Inputs	Processing	Outputs
Internal Transactions Internal Files External Information?	Modelling Simulation Analysis Summarizing	Summary reports Forecasts Graphs/Plots

Group Decision Support Systems, Computer Supported Co-operative work, Logistics systems, Financial Planning systems are all examples of DSS.

The role of DSS:

- Support ill- structured or semi-structured decisions;
- Have analytical and/or modelling capacity;
- Used by more senior managerial levels;
- Are concerned with predicting the future.

Executive Information Systems

At the top of the Pyramid constructed here we will find an Executive Information System (EIS). These are strategic-level systems, where we joint company's internal and external information (from the environment). Normally the information in the EIS is not well structured.

They serve senior management and executive board of a company during several tasks such as, analysis of the environment, identification of long-term trends, and planning and definition of the company direction.

Typically, EIS are custom-made. They consider the preferences, and needs of their users.

Functional requirements of Executive Information Systems:

Table 4 - Functions of Executive Information Systems

Inputs	Processing	Outputs
External Data Internal Files Pre-defined models	Summarizing Simulation "Drilling Down"	Summary reports Forecasts Graphs/Plots

Many EIS are highly customized for a specific client or group of clients, and normally are made individually according to the company needs. At the same time, we can observe the appearance of many software packages which are not designed or made to order but taken from existing offers. What happens is that these off-the-shelf packages offers a customizable module alongside the standard ones.

The role of EIS:

- Are concerned with ease of use;
- Are concerned with predicting the future;
- Are effectiveness oriented;
- Are highly flexible;
- Support unstructured decisions;
- Use internal and external data sources;
- Used only at the most senior management levels.

Besides the systems identified above, there are other types of systems which could be considered of high importance to this work. These systems are not related directly to the company hierarchy, but directly manages, measures and perform actions on the existing systems. This could be considered the support systems for existing systems.

The main purpose of such systems will be to measure the capabilities of the existing systems, measure the current utilization of existing systems and to perform actions to avoid critical situations happen.

Let's now list those systems which will support the main Viable Information System (VIS) modules.

Business Process Management Systems (BPMS)

BPMS is a system that comprised of systematic activities conducted to ensure the successful implementation of strategies and plans in an organization. It provides a tool to clarify how well a company is doing, in terms of processes, actions, and strategies, in order to achieve its objectives. (Zeglat, AlRawabdeh, AlMadi, & Shrafat, 2012).

Orchestration is often discussed as having an inherent intelligence or even implicitly autonomic control, but those are largely aspirations or analogies rather than technical descriptions. Orchestration is largely the effect of automation or systems deploying elements of control theory. (Erl., 2005)

Fuzzy Inference System

A Fuzzy Inference System (FIS) is a system that uses fuzzy set theory to map inputs to outputs. (Jang, 1993) This system is composed out of several components, which altogether allow to perform a pre-defined action based on input rule. Some of this input rules, as well as output actions, can be automatically adapted when the FIS is supported by Artificial Intelligence learning capabilities.

Simulation System

A simulation system in a work flow control system confirms whether or not prepared business process defining information is valid. (Patent No. US5887154 A, 1995) This types of systems allow simulating the outcome in a given business context under specific circumstances. The system takes a business model as a process workflow, then given a set of values for variables in the model the system simulates the behaviour. After the simulation, the results can be compared in order to understand whether the outcome is beneficial to the business or not.

Artificial Intelligence System

An artificial intelligence system is a system capable of accepting a statement, understanding the statement and making a response to the statement based upon at least a partial understanding of the statement. (Patent No. US4670848 A, 1985)

Given all written in this section, we can argue that we already have the taxonomy of CBISs well defined and all supporting components which will serve us as the main elements of the Viable Information System architecture. All these elements together will be placed on top of placeholders from Beer's VSM in order to achieve Viable Information System architecture.

2.4. Beers Model Sub Systems Overview

Stafford Beer was born in 25 of September of 1926. He was a British theorist, consultant and professor at the Manchester Business School. He is best known for his work in the fields of operational research and management cybernetics. One of the greatest outcomes of his work is a Viable System Model (VSM).

The VSM is a model of the organisational structure of any autonomous system capable of producing itself. The word "organisational" here is not being mentioned referring to the company or firm, but as a set of components logically organized between themselves.

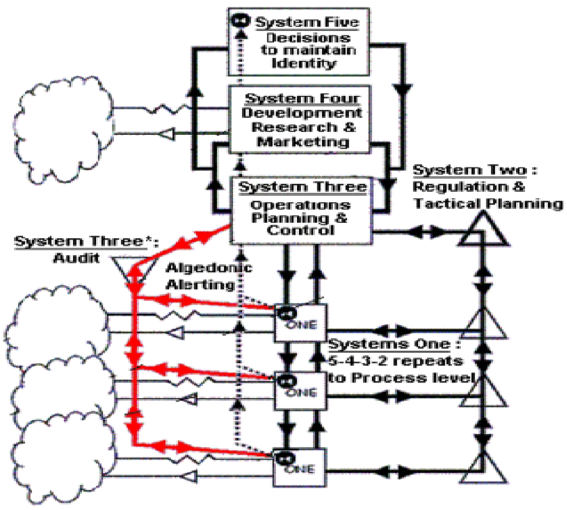

Figure 5 – Viable System Model (adapted from: (https://wiki2.org/en/Viable_system_model))

One of the primary features of viable systems that they can survive environmental changes through the process of adaptation. The Viable System Model give us an abstract architecture for a system that remains viable along its existence. It contains the description of system capable of autonomy that can be applied to any organization.

As we can see on the model above the VSM is composed out of 5 main components: 1 – Primary Activities, 2 – Information Channels, 3 – Structure and Control, 4 – Vision, 5 – Policy Decisions and 2 external components: 1 – Local external environment, 2 – Global external environment.

Primary Activities/Operations

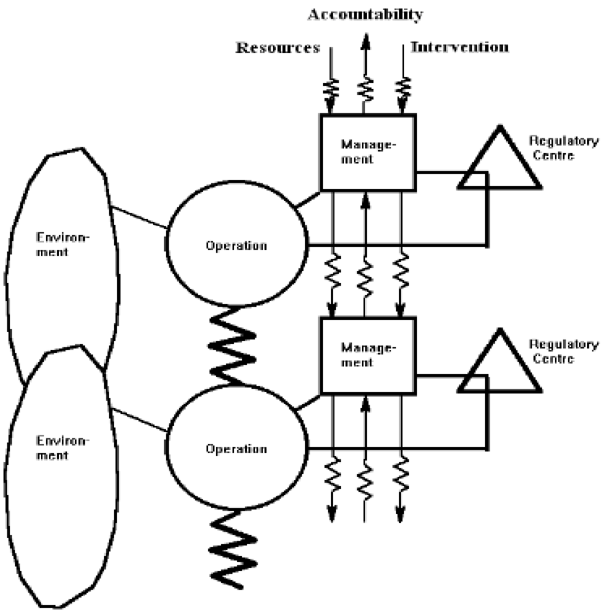

Figure 6 – VSM Operations (adapted from: (http://www.innovationlabs.com/summit/discovery 1/reading_materials/vsm.pdf))

Each Operational Unit (or Sub-System 1) should be a viable system by its nature due to the recursive nature of systems as described above (see “Recursive System Theorem”). System 1 units are concerned with performing a function that implements at least part of the key transformation of the organization. System 1 is concerned with operations. It comprises a collection of operational systems, each comprising an area of operational activity (Montangero, 1996).

Information Channels/Coordination

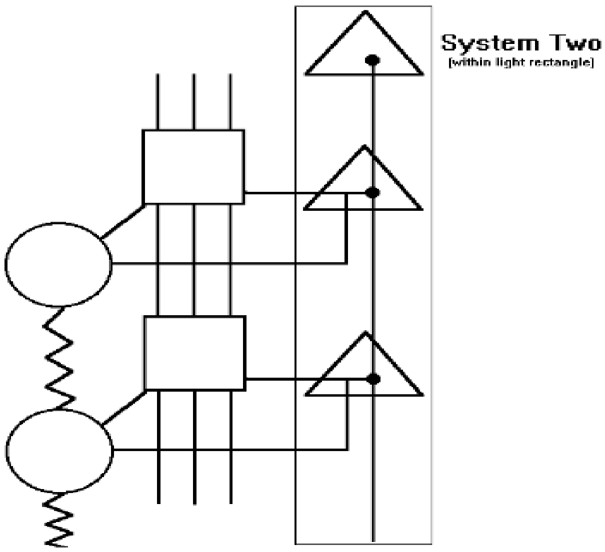

Figure 7 – VSM Coordination (adapted from: (http://www.innovationlabs.com/summit/discovery1 /reading_materials/vsm.pdf))

System 2 main concern is to allow the primary activities in system 1 to communicate with each other and to allow System 3 to monitor and coordinate the activities within System 1.

The overall organization has resources which are normally stored in one single place and are shared among different elements of the system, on demand. For that purpose, System 2 implements scheduling function which monitors availability of the resources that will be used by System 1.

System 2 is concerned with coordination. It provides a coordination service to system 1 without which System 1 would be potentially unstable (Kawalek & Wastell, 1999).

Structure and Control/Management

System 3 is a VSM sub system which establishes rules, resources, rights, and responsibilities of system 1 and provides an interface between systems 4 and 5. The structure itself reflects an overall view of processes inside System 1 elements. Managing operation level activities is the role of System 3. Its main goal is to guarantee that Systems 1 and 2 are finetuned to steer the organization towards its current objective.

The control is performed by “vertical command channels” as we can see on Figure 8.

But at the same time this control may not be truly effective if it doesn't have enough requisite variety. To allow the fine tuning of operational units, System 3 needs to have channels to be able to monitor directly all Systems 1. To do this, they may send task forces into the operations to carry out spot checks, audits, etc (Hilder, 1995).

This structure was considered by Beer to be the best to deal with requisite variety difference between systems 1 and 3. The module (sub system) responsible to execute these direct monitoring operations is referred to as System 3* (Three-Star).

Vision/Intelligence

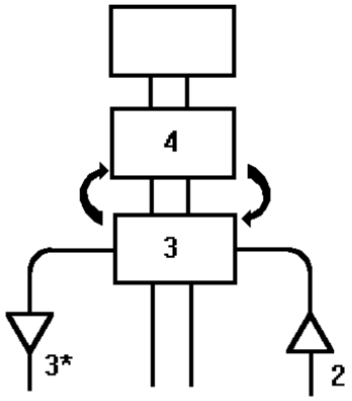

Figure 8 – VSM Intelligence (adapted from: (http://www.innovationlabs.com/summit/discovery1/reading_materials/vsm.pdf))

The Intelligence module of VSM is made up of structure that responsible for monitoring the environment and understand what changes are needed for the organization to remain viable.

The System 4 requires an understanding of the total environment of organization's operation to perform intelligence functions. In comparison Systems 1 concerns themselves only with a small part of this total environment.

The model of the whole organization as well as of its environment must be contained in the System 4, otherwise intelligent adaptation would not be possible. The quality of this internal model is crucial to the capability of the organization to adapt to change (Hilder, 1995).

Policy Decisions

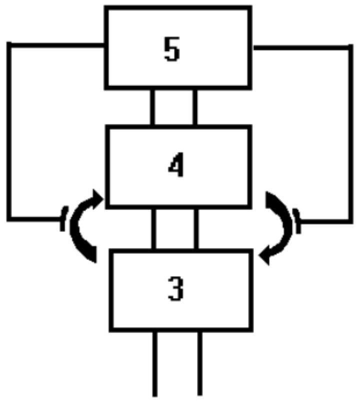

Figure 9 – VSM Policy Decisions
(adapted from:
(http://www.innovationlabs.com/summit/discovery1/reading_materials/vsm.pdf))

The effective organization needs to be based on some set of policies. System 5 takes policy decisions responsibilities and balances demands from different parts of organizational structure. It drives an organization as a unique element.

The presence of the environment in the model is necessary as the domain of action of the system and without it, there is no way in the model to contextualize or ground the internal interactions of the organization (Hilder, 1995). The local environment can be described as the limited domain in which Sub systems 1 operates. This environment is more well predictable and normally is not quickly expanded. The global environment is referred as the total environment, where all aspects are being considered.

Very interesting comment was made by Trevor Hilder in his work about an interpretation of Beer's VSM: "*It is interesting to note that, historically, practically all republics where the president has direct executive power, without the counterbalancing effect of an "upper house" and constitution, have collapsed into tyranny. This happened to the first French Republic, Bolshevik Russia, and Weimar Germany. This may be because organizations which do not clearly distinguish between System 3 and System 5 are inherently unstable.*" (Hilder, 1995).

System 5's main roles are to:

Supply logical closure to the viable system to monitor the System 3 - System 4 homeostat.

This axiom proposes a function that System 5 should perform to regulate any unstable variety, generated by the interactions between System 3 - System 4. In some cases, this function is extremely complex. On the other hand, if the homeostat element of systems 3-4 is working well, there may be little work for System 5.

A good practice for System 5 is to receive ok messages. The only problem may arise is if the System 5 enters the inactive/somnolent state, and fail to respond when action is needed. But all viable systems implement mechanisms that helps overcome this dangerous situation. This system is cited by Stafford Beer as the algedonic signalling element.

Viable Component Interfaces

In the work of Charles Herrings et al "The Viable System Architecture" (Charles Herring, 2001) which applies VSM to the software architecture we can find a specification of interfaces that the original VSM has. This interfaces should be considered of great importance and will be also specified here. These interfaces are as following:

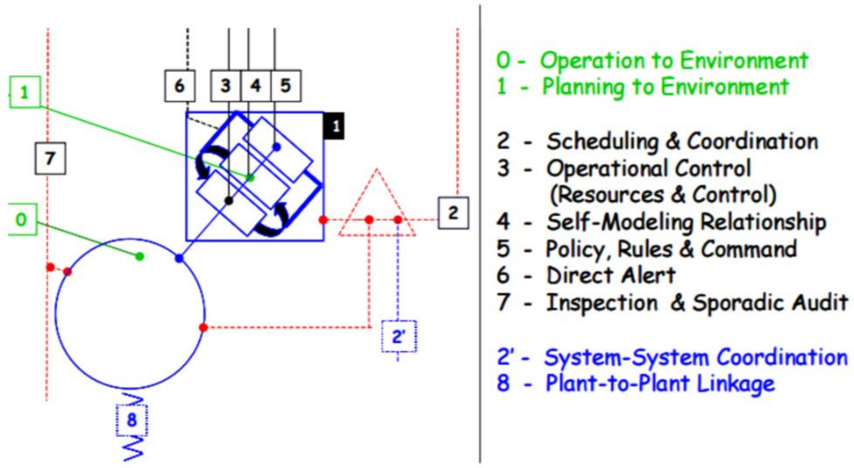

Figure 10 – Viable Component Interfaces (adapted from: (Charles Herring, 2001))

0. Direct Plant to Environmental coupling. Provides environmental information directly to the Plant and the Plant provides information to the Environment.

1. Planning's "view of the future" environment. This may be from historical data, data projections or simulations based on the current environment.

2. Provides for transmission of plans and schedules from the upper-level controller's scheduling system to the component. Also for coordination at the same level of recursion.

3. Commands and resources flow from the upper-level controller's Operations function to the component. Routine status reporting and requests for resources flow from component to upper-level controller.

4. This establishes the "modelling relationship" between components. The component transmits a model of itself for inclusion in the upper-level controller 's self-model for use by its Planning function.

5. Upper-level controller policies and rules are transmitted to the component's Executive via this interface.

6. This interface is used by the component to directly signal the upper-level controller's Executive (bypassing Operations and Planning) when needed, e.g. panic.

7. The sporadic audit interface permits the upper-level controller's Operations to monitor and verify the component's state.

8. This is the direct Plant-to-Plant connection. Plants may be chained together in production lines.

Algedonic Signals

Algedonic Signaling within Viable System Model monitors the signals passing from System 1 to System 3. If some emergency is identified, the signal is sent directly to System 5. This process goes through system 5 and requests urgent action by Systems 3 and 4.

Originally Viable System Model have derived from the architecture of the brain and nervous system. Systems 3-2-1 are identified with the ancient brain or autonomic nervous system. System 4 embodies cognition and conversation. System 5, the higher brain functions, include introspection and decision making (Beer, Brain of the firm: The managerial cybernetics of organization, 1972).

3. METHODOLOGY

In this chapter, we introduce the methodology process. Since the problem described here is a complex one (Ackoff, 1971), some strategy such as Systems Thinking Field should be considered in order to properly understand the problem, and be able to assure correct integration of subsystems (CBIS) into proposed architecture. The IS should be developed taking in consideration different perspectives such as an environment where the system going to be implemented as well as all responsible for the construction of the IS based on Viable Information System Architecture (Buttler, 2006).

3.1. INVESTIGATION STRATEGY

The foundation of successful investigation is a carefully conducted strategy. It allows the investigator to reduce mistakes and anticipate hurdles. Investigation strategy could be described as a function of planning an investigation thoroughly before beginning to collect evidence and interview subjects. (Henver, March, & Park, 2004)

The main goal to achieve with this work is: to construct a blueprint of architecture for information systems, that would take advantage of the benefits described in Beer's "Viable System Model".

Currently, three specific research steps can be identified. Which achievement should be performed accordingly to the order described below.

1. Find a taxonomy of the modern computer based information systems. Which will be used as artifacts and will be applied to the Viable System Model blueprint, to make an abstract description of the architecture, that we are trying to achieve. The result of this specific objective will be an abstract architecture, where generic parts of the Viable System Model are replaced by, more specific, CBIS artifacts.
2. After defining all subsystems from taxonomy chosen in the previous step, will be needed to make sure, that all subsystems are corresponding, by their nature, to the part of "Viable System Model". Despite VSM components are generic there are well-defined set of rules and goals that each component is intended to perform. This point will be achieved by studying interactions between subsystems (CBIS) identified to be suitable for the architecture. The main outcome of this specific objective is to have a final model of the architecture, assuring that all subsystems are properly chosen and all interactions between them are valid and feasible.
3. Validation of proposed architecture is the next step in the work and the most important one. After accomplishing construction of the architectural blueprint, it must be validated against possible errors. Since, architecture is foreseen to be complex, there is a great possibility that outcome from the previous steps may have conceptual errors, which could not be identified at the first glance. For that purpose, the most suitable solution found is to follow two techniques. One of them is to justify that all steps from design science framework are done correctly and corresponding to their original purpose. And the second is the several publications that have resulted from this work. These publications was reviewed by several experts from the area, who confirmed the validity of the architecture that is being proposed here. The main outcome of this specific objective is the final version of Viable Information System Architecture, that is assured, when properly implemented, to provide all benefits of the "Viable System Model".

To achieve such goals, our strategy for investigation was based on the design science framework proposed by Hevner. In the first step, we have choose a CBIS components which we placed on the parts of VSM. Then we found a proper way to validate the result. After that, we performed cyclical approach of placing new components onto the VSM blueprint. In each iteration, a set of predefined validations was applied. This process have continued until the best and most suitable result was achieved.

All the validations was done based on the requirements for the guidelines of design science proposed by Hevner in his framework. There are 7 main guidelines. For proposed model to be eligible it needs to comply with each of the following guidelines.

Table 5 - Design Science Guidelines adapted from (Henver, March, & Park, 2004)

Guideline	Description
Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.

Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

There are several manners to validate the new architecture. We can look at the validation of the work from two different perspectives: Information Systems Perspective and Contribution Perspective.

Validation of contribution perspective of research is the one where we should validate that the work that is being performed brings some new, valuable contribution to the field of investigation. That is not just a hack, meaning that we were doing something and then find out something new, without understanding whether is useful or not. But signify that a proper research was made with an already predicted result and that during the work results were achieved. This point is being assured by the work justification step, where we make a justification of why that work is useful for modern society and why the architecture proposed here will be solving a set of known problems of modern Information Systems Architecture field. The design science will allow us to build and follow the plan, according to well-defined steps from the paper of Hevner at al, and to guarantee that the research was performed correctly and that the solution being proposed at the end of research is actually a valid solution for the problems presented here.

From the information systems point of view, we will need to validate that the architectural solution that is being proposed in this work is actually feasible in terms of technology and whether it's make sense in the current state of the art of the field of ISs. By saying "make sense" is meant whether the solution is adequate in terms of speed, resources usage, a complexity of management and implementation, etc. A validation from IS perspective will be done via several publications in conferences and scientific journals.

3.2. Design science

The design science is the field of research where you create something new and then you examine the result of your creation. Design science helps researchers to develop exactly what they want. Sometimes happens that you shoot first, then call whatever you hit "the target". There is a little merit in randomly developing things in the vague hope you might develop something useful. The main goal of design science and what distinguishes it from simply futzing about, hoping to produce something useful, is a prediction. So, the planning of the work and careful prediction of the desired results is done in the first place. (Peffers, 2007)

The design research approach that is being handled in this work is based on the work "Design science in information systems research" of Hevner et. Al. from 2004, which traces a set of rules and defines a framework to perform a design science research in the field of information systems. In this work, author gives importance to two main paradigms which characterize every information system, which are behavioral-science paradigm and design-science paradigms.

The behavioral-science paradigm has as the main goal to include the idea of human presence during the system design. It means that the system should be designed with the idea in mind that it will be used by humans, and that not only machines but also humans are making a part of the system that is being designed or used.

The design-science paradigm enforces the idea that the result must be useful. As stated in the work “A justified theory that is not useful for the environment contributes as little to the IS literature as an artifact that solves a nonexistent problem.” (Henver, March, & Park, 2004)

Design science justification

There are 7 main guidelines for design science framework that has been chosen as validation principle for the proposed model.

1. Designing an artefact.

There is very clear that the outcome of this work is an artefact which comply with the first guideline requirement. In this case, it is a blueprint of architecture.

2. Problem relevance.

As stated in the justification of this work, the problems which Viable System Model is supposed to solve is of big relevance for companies. (Lyytinen, 1987)

3. Design Evaluation.

“IT artefacts can be evaluated in terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes.” (Henver, March, & Park, 2004)

In the work of Hevner we find several evaluation methods which are valid depending on the essence of the artefact being designed. From 5 methods proposed we may consider only 2 of them, given that other 3 needs to be performed in the real business environment, which is not possible at this stage of the work.

In between the Descriptive and Analytical methods, the Analytical is preferred. The Descriptive method uses information from the knowledge base (e.g., relevant research) to build a convincing argument for the artefacts utility. (Manson, 2006) It is also not possible in case of this work because there is no relevant research previously done, which satisfy our criteria. The analytical methods are 4: Static analysis, Architecture analysis, Optimization and Dynamic analysis. From this 4 the fittest for that work is the Architecture analysis.

Architecture analysis study fit of artefact that is being designed into technical IS architecture.

One of the steps of the work is being done exactly to achieve that step. We took careful actions and made proper research to make a model fit into modern technological architecture. That way we are assuring compliance with design science “Design Evaluation” principle.

4. Research Contributions.

After finishing the research, we conclude that: Viable Information System, when properly implemented, has all the benefits described and proved by Viable System Model. That is the main contribution of this work.

5. Research Rigor.

All methods, methodologies, and data used in this works are provided by scientifically approved sources. This work is strongly supported by scientific articles and studies, what gives it needed credibility to be considered a rigorous work.

6. Design as a Search Process.

The design is essentially a search process to discover an effective solution to a problem. (Henver, March, & Park, 2004) This search process is normally passing through the following steps. First, we identify what are the means, ends and laws are available in our domain. Next, we construct several design alternatives and compare them to the ideal solution.

In this work, the search process is already simplified since we already know what final design should look like, and the only steps needed to be taken are of understanding what means we have and apply them correctly to the Viable Model blueprint. The set of means available is represented by the ISs taxonomy described earlier in this work. And the result we can see in chapter 4 of the work.

7. Communication of Research.

First communication of the present work happened at the CAPSI conference of 2016. The work was communicated to the public (mostly technology oriented) in the format of a poster and had a great support. Also, the poster had won an award for best poster presented at the conference.

4. PROPOSED MODEL

Now that we have defined what is the Viable System Model, Systems Theory, Information Systems Artifacts, and what we believe is the correct Design Science approach to work with Information Systems, we can move forward to designing the blueprint.

It is clear the advantages that VSM can bring to the IS field if properly implemented. And since Information Systems are a part of Systems theory we can argue that the application of VSM to information systems architecture besides making sense, is also a very good fit.

Many modern companies lack the good information systems architecture, and spend many time and resources on maintaining their information system. With implementation of Viable Information System, we believe to reduce both time and resources employed in all IS maintenance phase.

4.1. TOWARDS A NEW VIEW APPLIED TO IS

All the rules for VSM were initially based on Ashby's law of requisite variety: the number of possible states of a system or of an element of a system. (Ashby, 1991)

The rules of viable system model is well defined in the book of Stafford Beer "Heart of Enterprise". These rules are not Information Systems rules, but instead are aphorisms, principles, axioms and other properties which may describe organizational environment (one more time is important to mention that the word organization is not being used to refer to the company or a firm, but as a way to describe a set of interrelated components). This rules will need to be adapted to the field of Information Systems.

The following section will be strongly based on the Beer's book "The heart of enterprise". (Beer, The heart of enterprise, 1979)

There are two aphorisms that allow observers to calculate Variety. They are "It is not necessary to enter the black box to understand the nature of the function it performs" and "It is not necessary to enter the black box to calculate the variety that it potentially may generate". We can name them RA1 and RA2 respectively. Those rules explain us that we need to care mostly about the inputs and outputs but not about the implementation itself. So, based on inputs and outputs we may understand what exactly a component is intended for, and what will be its variety.

Then the Beers work introduces to us four principles of organization, where principles are being considered as primary sources of an outcome. These Principles are:

1. "Managerial, operational and environmental varieties diffusing through an institutional system, tend to equate; they should be *designed* to do so with minimum damage to people and cost". This principle indicates us that we need to manage the variety of the interactions that are happening within the organization appropriately.
   Ex.: If we deal with the small environment we don't need to have a big amount of operations to handle interactions with that environment. And need even fewer components to manage these operations.

2. "The four directional channels carrying information between the management unit, the operation, and the environment must each have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating subsystem has to generate it in that time". Meaning that we should organize the channels in such way that they may always process all the flux that comes through each channel.
   Ex.: If we talk about the information systems, a web site, for example, this principle says that the server should always have more capacity than the incoming request may require. So, that the system is always alive and no processes are delayed.
3. "Wherever the information carried on a channel capable of distinguishing a given variety crosses a boundary, it undergoes transduction (converting energy from one form to another); the variety of the transducer must be at least equivalent to the variety of the channel". This principle indicates us that in each specific sub system of VSM there is a defined domain of actions and information. These domains may vary but the VSM must have a transduction capability which will transform the information appropriately so it may be communicated between sub systems.
4. "The operation of the first three principles must be cyclically maintained without delays". That principle indicates that all the tools and processes defined to maintain the described capabilities should be reevaluated in the defined periods of time, and necessary maintenance actions must be performed when necessary. This is being done to guarantee that the system still has working principles implemented correctly.

We will name these principles as PO1, PO2, PO3 and PO4 respectively.

Followed we have the rule of VSM which is described as "Recursive System Theorem", which states the following: "In a recursive organizational structure any viable system contains, and is contained in, a viable system". That means that the implementation of VSM should be structured in such way that its sub systems represent the VSM structure by itself. And as we already have seen this is being done in the systems of type 1. Each operational system by itself must have a VSM structure. We will annotate this rule as RST for the further references.

Then we have three axioms (axioms are statements 'worthy to believe') which are applied to the reality in which we implement the Viable System Model. These axioms are:

1. "The sum of horizontal variety disposed by *n* operational elements (systems one) equals the sum of the vertical variety disposed by the six vertical components of corporate cohesion. (The six are from Environment, System Three*, the System Ones, System Two, System Three and Algedonic alerts)".
2. Meaning that the domain of variety of local environment should be completely supported by the system, so no operations are missing and no data is integrated manually or passes outside of process.
3. "The variety disposed by System Three resulting from the operation of the First Axiom equals the variety disposed by System Four". Meaning that the intelligence function of VSM should be aware of all data available, that is being generated by the systems of type 1.
4. "The variety disposed by System Five equals the residual variety generated by the operation of the Second Axiom".

Since these are the axioms we should guarantee that all these 3 rules happening in any situation during the life of VSM. We will give the notation to these 3 axioms as following: A1, A2, and A3.

And the final rule that we find in the Beer's work is the law of cohesion for multiple recursions of the viable system, which states the following: "The System One variety accessible to System Three of recursion *x* equals the variety disposed by the sum of the metasystems of recursion *y* for every recursive pair". We will designate this rule as LC.

Now after we have seen all the rules that are applied to the Viable System Model, we need to translate them to the Information Systems reality, so further they may be applied to the Viable Information System Architecture.

Translating Viable System Model Rule into Information Systems World

Table 6 - Information Systems equivalent of VSM rules

VSM Rule	IS Equivalent
RA1	Good naming convention defined for all components of the Information System.
RA2	Good definition of process capability, in terms of inputs, outputs and volume of transactions.
PO1	Without exaggerated overheads of processing, each operation should be the minimum viable product, so we can reduce the complexity and control system in the proper way.
PO2	This rule has 2 faces in the world of IS. 1 is that the limits of data processed by each transmission channel should be adequate to the maximum amount of data it may carry on. 2 the physical servers should be prepared and slightly exceed the performance required by the data is being processed.
PO3	Each subsystem should have its own domain of operations it may perform. Each subsystem should expose an interface that can be used to transform data from other domains into the domain understandable for that subsystem.
PO4	The maintenance process should be defined and automatized. This process should run on the adequate schedule based on the nature of a system.
RST	The Viable System Architecture should be composed out of components which per se are viable.
A1	The system should be available for all the environment that IS deals with.
A2	Artificial intelligence and Business intelligence function must have access to all data that is being managed by system 3.

A3	The Viable Information System should provide functionality by which all inconsistencies between systems 3 and 4 can be managed.
LC	The number of operations supported by the system should be equivalent to the capacity of all software components that compose the system.

Requisite Variety

It is vital that all communication channels have requisite variety to handle transmissions (Hilder, 1995).

We can translate this as a need of effective communication of organizational policy to each management units, which, in turn should transform it into smaller and more concrete action steps and communicate them to the operational units.

The System 1 then should have effective channels of communication to its local environment. If we fail at any of those steps it will lead an organization to an ineffective action.

It is also important to mention that due to requisite variety nature channels must have higher capacity than the variety of all inputs it might receive.

That guide us to the Second Principle of Organization of Stafford Beer. This principle brings a time element into the concept. Messages should be exchange fast enough to hold on the rate of variety generated. In the opposite case, the system can turn into unstable state. The stability of the system is dynamic, not static (Hilder, 1995).

Also, it is important to mention that each element of self-organizing system has its own "language". If you consider an IT consulting company, the language used by engineers that designs a solutions and solve problems in client's systems is quite different to the language used by the sales and non-technical people at the sales meeting. The languages as well as the local environments in which they operate are likely to be mutually incomprehensive. The same applies to the language used in the VSM organization, as a whole, as compared to the local operational unit language. When a message/request crosses a boundary of a given sub system, it needs to be "translated" to continue to be understood by the whole system. A process is named "transduction". If the transducer does not have requisite variety, the message gets garbled or lost (Hilder, 1995).

The fourth principle of Organization (OP4) states that: "The operation of the first three principles must be cyclically maintained through time without hiatus or lags". (Beer, The heart of enterprise, 1979).

Beer underlines that organizations tend to divide their management activities into pre-defined intervals - month, quarter or year, for example.

We can notice that the real world doesn't follow the same approach. Management must be a continuous process to allow deal with the changes in the environment in real time. If we break our management activities in certain blocks of time, then it certainly will be a situation when the requisite variety will change in the middle of that time block, and so management will not be able to give a required answer promptly. This principle of organization explicitly refers to the need for communication and response to be fast enough to keep up with the rate of changes affecting the organization (Hilder, 1995).

System 1 units can deal with its local environment efficiently, only while it can deal with the variety from it, by attenuating the incoming variety and amplifying its own feedback variety.

In the same way, the System 3 unit can deal with all Operational Units variety effectively if it can handle the variety coming from it, by attenuating the incoming variety and amplifying its own variety back to it. Meaning that the state of equilibrium will be maintained in the system. If these requirements are not met, the system will become unstable, eventually leading to its collapse (Hilder, 1995).

4.2. CONSTRUCTION OF BLUE PRINT

Viable System Model is an autonomous system. Autonomous could be defined as having a freedom to govern itself or control its own affairs. As we saw the VSM implements features to govern itself and to perform control over its parts automatically based on the information it receives. And because of being autonomous it's not enough for the system to deal just with raw data. At some points of the processing of that data, it will be important to transform it into the information and create some knowledge based on that information. Also, during the implementation we must allow a system to be resilient enough to deal several changes that might come from outside of context of the system, as well as must provide a system with awareness of its internal state and bodies to take actions accordingly to events happening inside the system in order to maintain the system alive during the time. In other words, to make a system viable.

The following example gives a good insight to the concept described above: All the system has its maximum capacity, it might be a number of users, processing power, a quantity of data it may handle, or some other aspects. So, if the system just cares about processing information without paying any attention to its maximum capacity several problems may arise which could lead system to go down. To prevent such situation autonomous system must be aware of its maximum capacity at several levels and should be able to take actions necessary to avoid critical situations. It could be done through auto evaluation of its maximum capacity in some defined periods of time, and at the same time by measuring its current usage. Then, a set of rules must be defined, in order deal with the situations when the current usage of the system almost reaches the maximum capacity defined during the auto evaluation cycle. This rules must be specified by the users of the system. Also, a system must be flexible enough to allow dynamic amendments to that rules as well as the creation of new rules or deletion of old ones after the system goes live. By saying that, is also important to mentions that the system that going to be constructed using the Viable System Architecture should offer means to allow all described above to happen.

The main concern of Viable Information System is the information. The information will be provided to the system through its inputs (from external environment, and so only systems 1 and 4 deals with inputs), going to be processed by the system (important thing during processing are rules, error handling, and correct flow) and finally will be provided as the output of the system (also systems 1 and 4, but also is important to mention that system 4 will give kind of output to the system 5 in the terms of dashboarding).

Viable System Model has certain benefits with its architecture, such as being capable of auto adaptation for the changes in the external environment our being capable of auto regulation. But all the systems are built with purpose. In most cases, this purpose is related to the business.

In the book Beer mention that "Systems 4's job is essentially to realize a potential", it leads us to the conclusion that IS which will be assigned to the System 4 in the VSM should have the capability to deal with a performance management.

That means that the construction of Viable System Architecture should consider channels by which will be possible to achieve such measurements. This could be done through a definition of a set of applicational interfaces and System 1 elements should comply with them in order to be interconnected with a rest of the system.

Was defined the following rules for the intended architecture of viable information system.

1. All subsystems of type 1 must have recursive nature. They should implement a part of a key transformation of the organization. All systems of type 1 deals with primary operations of the business. All operations should be well-known and should obey the same interface. All of that done in order to be possible to perform generic operations over all sub-systems of type 1, which are namely: validation against pre-defined rules, logging, etc.;
2. There should be a generic logging available among all systems 1;
3. System 2 must enable a channel of communication between systems 1;
4. System 2 must allow system 3 to monitor and coordinate activities of systems 1;
5. System 2 must provide scheduling function and perform a coordination to systems 1;
6. System 3 must provide bodies to establish rules, resources, rights and responsibilities to the systems 1 (whose access will be scheduled and coordinated through the systems 2);
7. System 3 must provide an interface between systems 4 and 5;
8. System 3* must implement ways to send task forces to systems 1 to perform audits; The same system is responsible to send algedonic alerts to system 5 when necessary;
9. System 4 must have defined interfaces to communicate with the external environment;
10. System 4 must contain an updated model of whole organization and its environment;
11. System 5 should specify a domain of action to the whole System based on the model provided by system 4;
12. System 5 must implement Algedonic Alerting System;
13. System 5 must implement bodies to counterbalance systems 3-4 homeostasis when needed.

We may translate a model proposed by Stafford Beer to the information systems in following way:

Primary Activities/Operations

Systems of type 1 should be oriented to the operations execution. They must communicate with the external world. Also, must have interfaces to communicate with each other. Because normally the parts of the external world with which the system 1 is intended to communicate may overlap, and so it's necessary to communicate between systems also.

The most suitable Information System which going to be placed here is the Transaction Processing System. First, the TPS's are intended to be a primary point of data interaction with an external environment. It has capabilities of getting data from external users and to provide external users with data. It may update and delete the data when needed, so we may argue that TPS performs CRUD over the primary data. Also, TPS's has always its purpose, like for example cash register system, or CRM. So, we can argue that TPS will perform a small part of a transformation of organization (complying this way with the rule number 1 defined above).

Taking into consideration the importance of control over Primary Activities in Viable Systems we argue that system 1 must implement the same interface defined by the system of type 3. This interface will allow to collect the data among all systems of type 1 in a generic way as well as will allow adding new type 1 systems to the whole system on demand in the plug-in-play fashion.

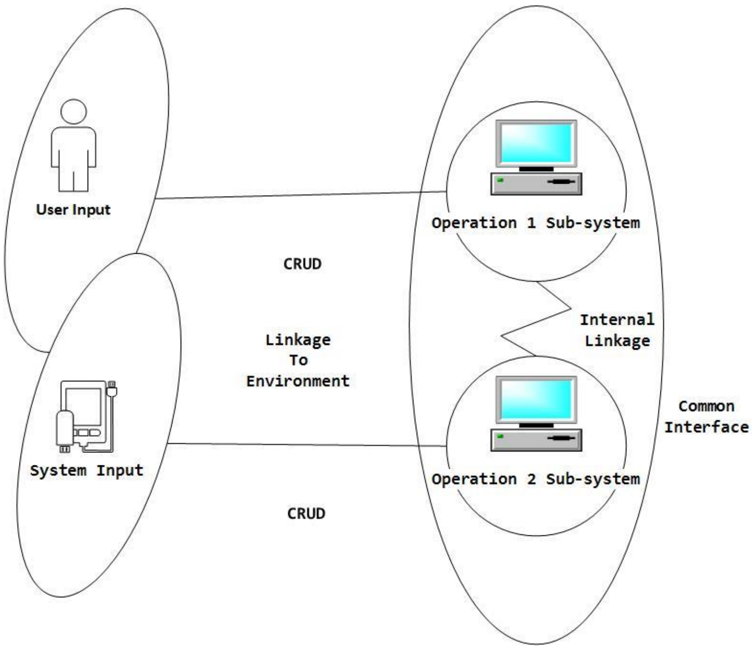

Figure 11 – Viable Information System Operations

As we can see on the Figure 11 TPS's are being represented by Operation 1 and Operation 2 sub-systems. Each of this system has the Linkage to its environment which should provide a capability to perform CRUD operations. The CRUD cycle describes the elemental functions of a persistent database. CRUD stands for Create, Read, Update and Delete. (Retrieve may occasionally be substituted for Read.) These functions are also descriptive of the data life cycle. The data interchanged with environment might be generated by the user or by the other system (Brandon Jr, 2002). All the CRUD operations should implement a common interface, which then will be used to create generalized logs. Also, sub systems 1 and 2 implement a linkage in between them. That is done because the external environment may overlap so there could be a necessity for the systems to interchange some information too.

Each of the Operation x Sub system exposes its own translator which translate its internal information types to the information understood by common interface. This is being done in order to have our TPS's plug-in-play like and decoupled from each other. In such architecture if Operation 1 sub-system wants to interchange data with Operation 2 sub-system it should use the translator to translate data to common format accepted by in interface, that comes from the domain, and then the Operation 2 sub-system will use the translator to translate the data that comes from common interface into its internal format.

This functionality should be performed by the orchestrator.

Information Channels/Coordination

Systems of type 2 are intended as adapters between a specific system and orchestrator. It is responsible for taking input information from system 1 and to validate weather the system 1 obey the rules of the business. Also, it communicates with orchestrator which in turn communicates with other systems.

This part will be composed out of several systems/components in order to achieve desired behavior. First, for each TPS, there will be a local management system, this system will be responsible to extract data from TPS and to summarize it in order to reduce a variety. Then the data will be provided to system 3 as an input.

Also, this element will have a presence of the Event scheduler which going to have a responsibility to schedule events to be performed by TPS when necessary.

Another component that should be implemented here is the Availability Manager. This system will be responsible to check the availability of resources.

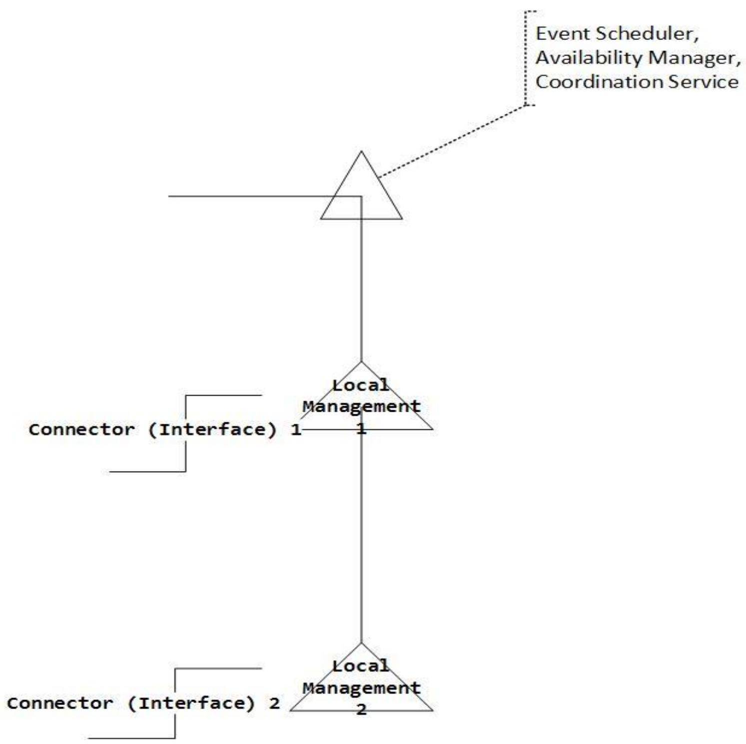

Figure 12 – Viable Information System Coordination

Finally, the coordination service should be implemented. Coordination service will execute a function of checking the correct execution of work flow and will guarantee that the same resource will not be allocated twice or so on.

As we can see on Figure 12 each System 1 will connect to its local management module, noted as Local Management 1 and Local Management 2. The main purpose of the connector is to serve as the reducer, in order to summarize the information that will be managed by the Local Management Module. This will allow us to manage correctly the requisite variety of the system, which in this case is information.

All Local Management systems should be connected to the scheduling system, which will allow to schedule events to be processed inside TPS.

Structure and Control/Management

Systems of type 3 are where we create rules. Also, serves as the joining peace between all operational subsystems (of type 1). In this case, the good choice would be the orchestrator, combined with Domain Database.

The orchestrator would combine the data from several TPS and allow this TPS to communicate with each other.

The Domain Database will establish the limits for each TPS which could be considered as the organizational rules.

The Systems 1 will consume that limits from system 3, and system 3 will receive such limits from system 4.

System of type 3* is the system which performs audit. As was already defined, the TPS's located in the system 1, must have log of the CRUD operations, under the same interface. This will allow the system to have access to the generalized logs. The audit will be performed over the logs in the predefined time intervals. Such audits will allow guaranteeing that the system is doing what is intended to do, and no suspicious actions have happened. This system will consume the domain rules from the Domain

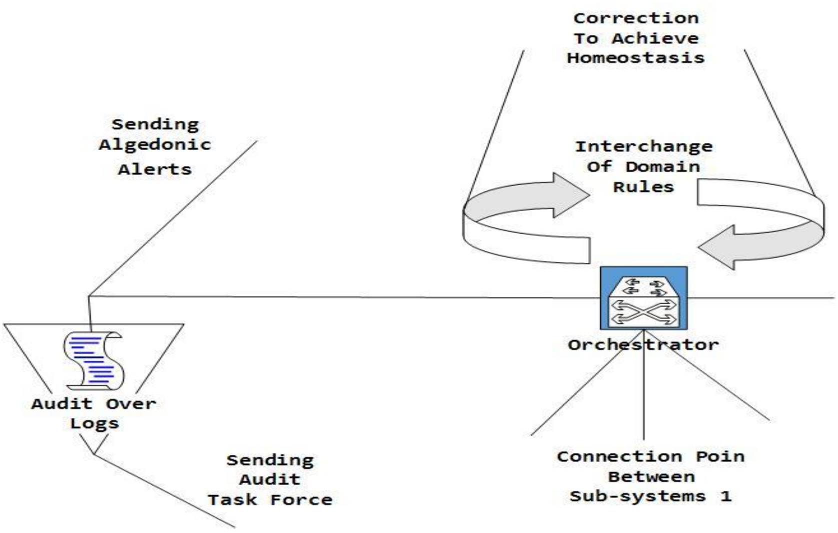

Figure 13 – Viable Information System Management

Database, generate the automatic test based on those rules and run this tests over the generic logs of all systems 1 to identify whether something is wrong. If some wrong behavior is detected the algedonic alert will be sent to the system 5 by the channels exposed by system 5. Also, such system will be able to execute the checking tasks directly in the systems of type 1.

Let's take a closer look at the Figure 13, which represents the proposed components to cover System 3 from VSM. Let's first look at the orchestrator. It will be the peace which going to serve as a connection point between all systems 1. If some of the TPS's needs to talk to another TPS, it will do it through the orchestrator, which contains o model capable of translate datatypes among all the TPS contained in the system.

Another important thing here is that this element will provide a Domain Database. This domain database will contain limits and rules for the data that circulates in the system. This rules will be consumed by Local Management systems in order to impose those rules to the Systems 1. Also, this rules will be inserted into the Business Model contained in system 4. In the return, the only way to update those business rules would be through the system 4's simulation module, which may at some point decide that rules must be updated. As specified in the VSM rules the system 5 must have the capability to step in when the homeostasis between system 3 and 4 is impaired (in danger). This action will consist of sending amendments to the rules that is provided to and retrieved from system 4.

Vision/Intelligence

Intelligence module is also composed out of a set of information systems for the company. An important remark is that inside a sub-system of type 1, which is also VSM, because of being recursive, the system 4 will be a unit oriented for the performance of that specific operational unit, which results will be used by local management of that specific sub system.

One of the main purposes of the system is that it should be able to communicate with the external environment. This will be done using the web services. Through this web services must be possible to integrate external data to the system. It can be done by using the web generalized data formats, such as JSON, or XML.

Another subsystem that is going to be included here is the business modelling and business simulation tool. This will allow business to perform periodic simulations of its business model, as well as have the complete image of business processes (domain) of a system itself as well as of its environment.

This system will also permit the artificial intelligence to be applied here. Based on the data that comes from the systems 1, through the orchestrator, the system can analyze this data using artificial intelligence systems and then provide meaningful input to the simulation module to see if the results of the artificial intelligence are correct and if they fit well within the business model.

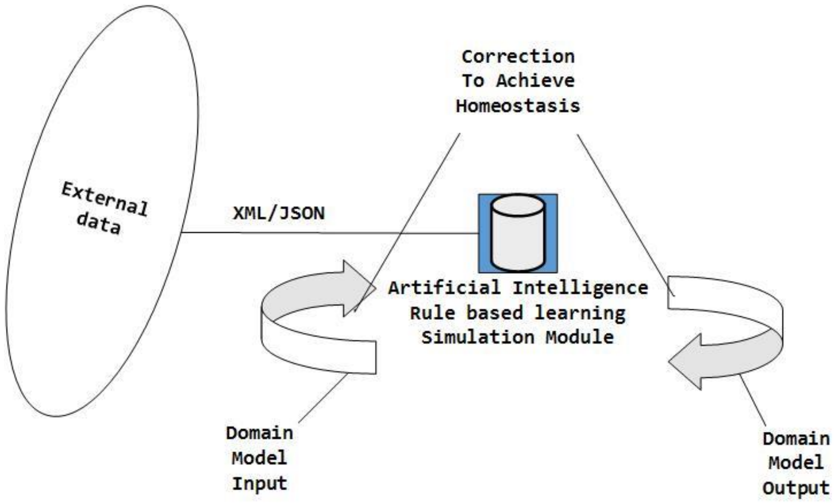

Figure 14 – Viable Information System Intelligence

Figure 14 demonstrates the design that the intelligence part of the Viable System Architecture should have. The process here is quite simple, and has as a main goal to foreseen changes and improve TPSs functionality to be prepared for those changes. The process approached by the System 4 is the following: First the System 3 provides the current domain model to the system 4. After system 4 gets the external data which represents possible future events. After that the artificial intelligence techniques apply external data to the current data and bring input to the business simulation system. The business simulates the state proposed by artificial intelligence and if that happens to be better than the current one the Domain model gets update with new rules.

Policy Decisions

The system of type 5 is the policy steering system. This system will be composed out of several specific elements. One of them will be Fuzzy Inference System which going to be able to attend the necessity of changing the system workflow and model when needed. This model is contained in system 4. The system 5 should understand how the model could be transformed by using the system which speaks some business understandable language, such as BPEL. Also, the fuzzy inference system will be responsible for receiving the communication from other systems (algedonic alerts) and react to that alerts appropriately.

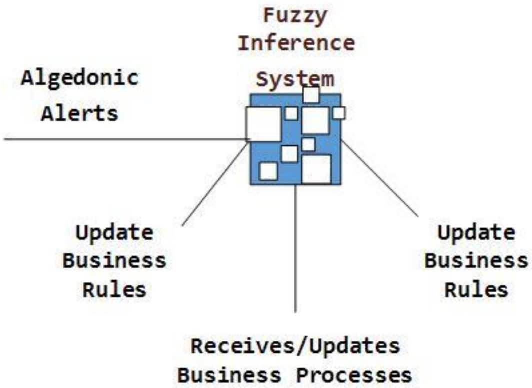

Figure 15 – Viable Information System Policy Decision

The Figure 15 shows us interfaces that Fuzzy Inference System should expose. One of these interfaces offers the possibility to update business rules now as they were inserted/retrieved to/from the system 4. This actions should be taken as a reaction to the algedonic alert received. To provide an example of such functionality lets imagine the cash registering machine which is connected to the transaction processing system. Let's suppose that the system has a limit of 10 characters for username field who is making payment. Suppose that during the audit task force the system noticed that one of the user's payment requests was rejected because of the username field exceeded the limit in the payment request received. That meant that the algedonic alert will be sent to the system 5, and system 5 will figure out how to update the username max length in order to accept those payments in the future. In other words, the system will adapt itself to external changes.

Another functionality that is being assured by the system 5 is the possibility to update business processes when needed.

We argue that transforming VSM as described above will bring as the outcome the desired Viable Information System Blueprint, let's see how we can do that.

Table 7 - VSM components to IS artifacts mapping

VSM Component	Main Characteristics	IS Proposed
System 1	Operations	Transaction Processing System
System 2	Coordination	Event scheduler and Availability manager, Coordination service

System 3/3*	Management	Shared databases, Domain database (contains rules such as value limits, dates of executions, etc..), Audit System, Performance Auto-Evaluation System, Logging System.
System 4	Intelligence	Business Intelligence System, Simulation System, Machine Learning / Rules Based Learning, Artificial Intelligence
System 5	Policy	Interfaces Definition System. Algedonic Alerting System.

Original diagram:

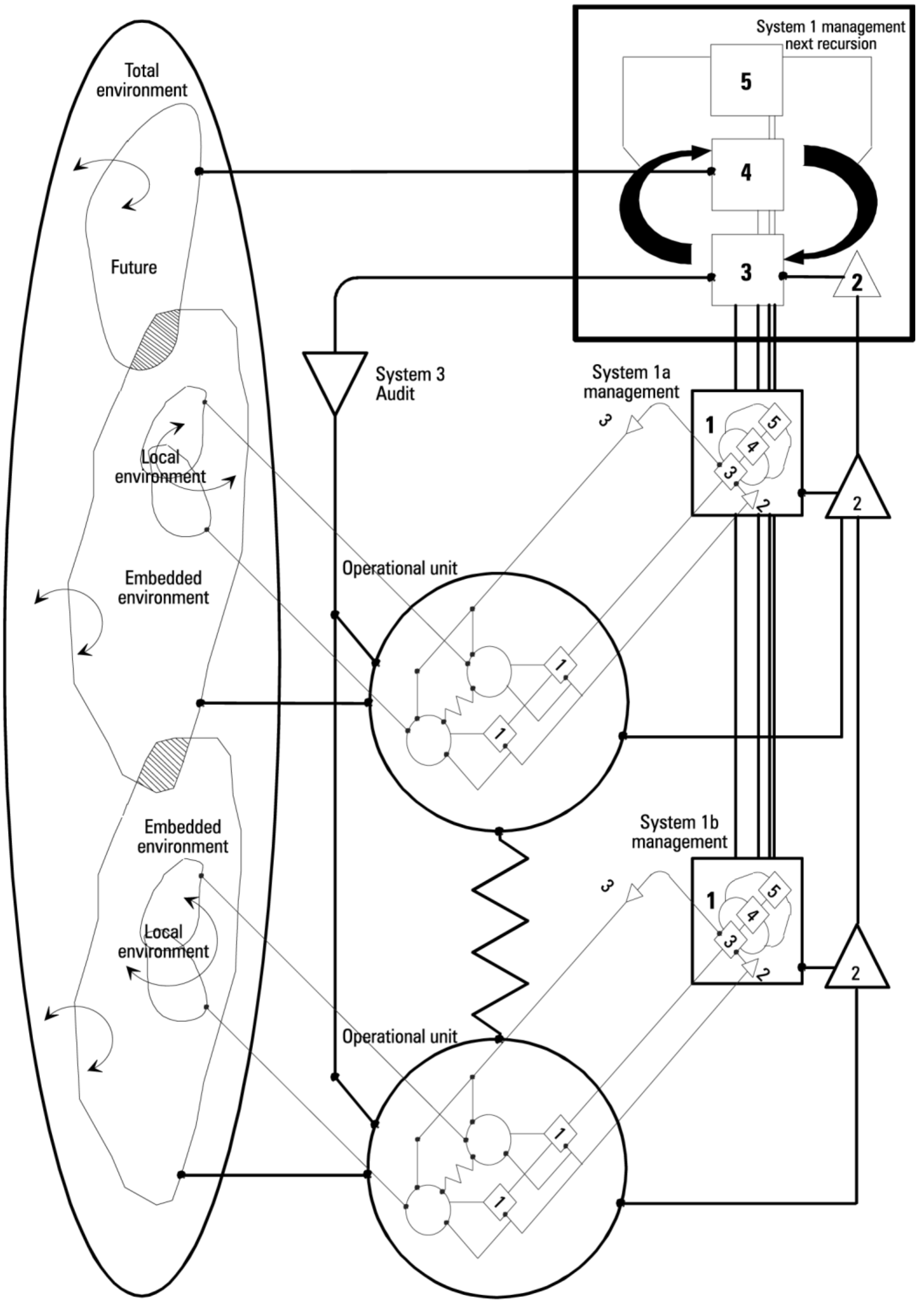

Figure 16 – Viable Information Architecture detailed. (Adapted from: https://blog.appreciatingsystems.com/2011/10/a-layman-explanation-of-viable-system-model-vsm-systemsthinking-stwg/)

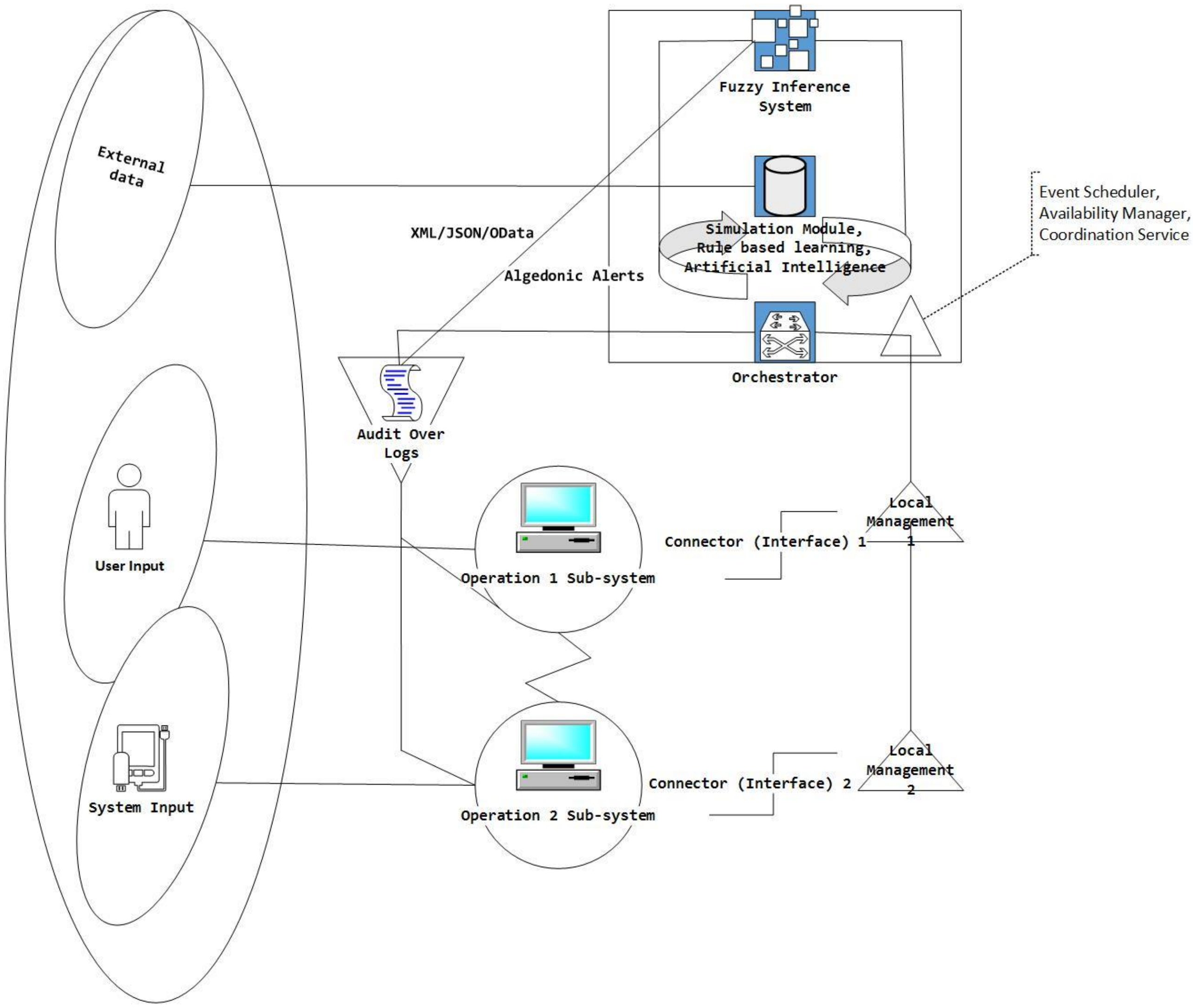

Figure 17 – Viable Information System Architecture

Proposed model

Information systems provide companies with internal and external benefits. Internally, they help to streamline, focus and coordinate the activities of employees and different organizational departments. In turn, companies benefit from having a more efficient workforce, which allow them to focus more time and effort on external affairs such as marketing, sales and establishing a market presence. Everything described above are important pieces and as such they should be measured and managed properly. Here we can argue that not only measuring the internal system capacity is important, but also the performance regarding to the specific environment where the system is integrated, based on the specific work the system is intended to do.

Here we may refer to the book “Brain of the firm” where Beer defines a triple vector to asses’ activities in a system 1.

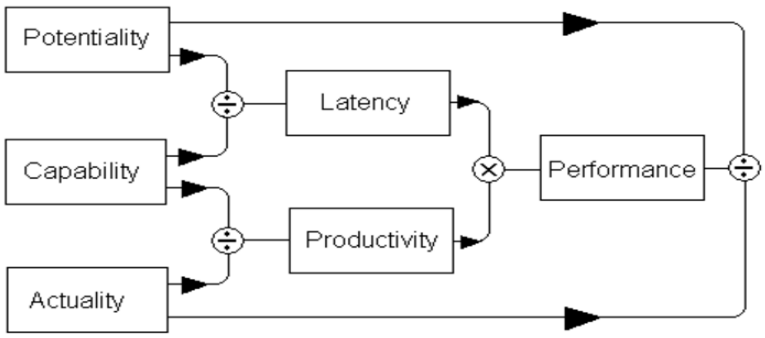

Figure 18 – Triple Vector. (Adapted from: (Beer, Brain of the firm: The managerial cybernetics of organization, 1972))

The components of a vector are:

- Actuality, described as “What we are managing to do now, under existing resources”;
- Capability, described as “What could be done (still right now), with existing resources, under existing constrains, if we really worked at it”;
- Potentiality, described as “what we ought to be doing by developing our resources and removing constraints”;
- Productivity is being defined as the ratio of actuality and capability;
- Latency is defined as the ration of capability and potentiality;
- Performance being defined as the ratio of actuality and potentiality or as a product of latency and productivity.

This piece here is very important and should be implemented within the internal logic of performance measurement of systems of type 1. Since the potentiality of the Information Systems is theoretically are only limited by the physical hardware, the approach for performance management should be taken in order to evaluate this.

Let’s look at the example to better understand what are the measurement of performance should look like. Suppose we have an event processing system which is programmed to process 100 events at time. So, each time it’s going to pick 100 next events from the environment. Let’s suppose that we implemented some rules so the system actually only brings 70 events at each time. 70 would be the Actuality of the system. Then if we remove the rules/constraints the system will start to process the 100 events at a time, and this will be the Capability of our system. The Potentiality of our system then would be the increment of maximum allowed events, which is restricted only by the capacity of the physical hardware. Let’s suppose that maximum hardware capacity is 150 events at each time. That would result in the following calculations:

Productivity: 70/100 = 0.7

Latency: 100/150 = 0.6(6)

Performance: 0.6(6) * 0.7 = 0.46(6)

Then, after performing such calculations the system should automatically analyses weather such productivity is good or not. And with help of intelligence functionality amend the existing rules through the domain of maximum allowed events.

Continuing the example. If For some reason happens that the environment doesn't have enough events to process, let's suppose we only receiving 20 at each time. Then the calculations will be like the following:

Actuality: 20;

Capability: 20;

Potentiality: 150;

Productivity: 20/20 = 1

Latency: 20/150 = 0.13(3)

Performance: 0.13(3) * 1 = 0.13(3)

In this situation, even the productivity is 100%, the actual performance is very low, and so the system should decrease the processing power since that resources are not needed.

On the other hand, if happens that the system hardware is damaged for some reason and the maximum number of events that system can physically process at each time is 60, then we will run into the following problem:

Actuality: 70;

Capability: 60;

Potentiality: 60;

Productivity: 70/60 = 1.16(6)

Latency: 60/60 = 1

Performance: 1.16(6) * 1 = 1.16(6)

Which means that the system is operating over its capacity and the maximum number of allowed events must be decreased dynamically to the levels needed to maintain the system in homeostasis.

4.3. VALIDATION

The validation of the model proposed here was done through several publications of this work in conferences and scientific journals. One of the publications won the prize, what also recognizes the scientific validation of the model.

In the future, as we plan to build a prototype of such system, software artifact will be build based on the model proposed here, what will be another new validation.

So far as this is theoretical model the validation was done mainly by several publications and acceptance by industry experts.

5. CONCLUSION

5.1. MAIN CONTRIBUTION

The main contribution of present work is the investigation that gives guidelines on what information system should look like to be viable. Also, this work gives a possibility to have an information system which is resilient to the changes in the environment.

We have concluded that such system can take advantage of all the benefits provided by the Viable System Model. Given that some may use this work to support their decisions about information systems.

5.2. LIMITATIONS TO THE CURRENT WORK

One of the difficulties that were faced during the development of the current work is that no known existence of the well-defined taxonomy that represent all elements of the information system. So, in that sense, the work was limited to the current knowledge of the author about the information systems artifacts and also to the knowledge gained during the literature review.

Other limitation, is that we are not able at the moment to test the architecture, proposed here, in the real-world organization, and see all outcomes that might come out in the real world. But, we already have seen the real-life scenarios of VSM implementation (in the field of management) and the outcome of that work (Espejo, 2003). But at the same time, there are no known cases of VSM implementations into the information systems.

5.3. FUTURE WORK

The suggestion for the future work would be to study better the influence of the human factor on the implementation (and post implementation) of the Viable Information System. So, the idea would be to implement this architecture in the organization following all the rules described here, and then try to measure the impact that the human factor has on that system, and, otherwise what is the impact of the system on humans (employees) that interacts with a system.

Another suggestion would be to elaborate the guideline or framework which will allow implementing the truly viable information systems in the organizations. This framework should include more deep study and step by step guide to allow transform information system into viable information system at any stage.

BIBLIOGRAPHY

Ackoff, R. L. (1971). Towards a System of Systems Concepts. *Management Science*.

Al-Mamary, Y. H., Shamsuddin, A., & Aziati, N. (2014). The Role of Different Types of Information Systems In Business Organizations. *International Journal of Research*.

Ashby, W. R. (1991). *Requisite Variety and Its Implications for the Control of Complex Systems in Facets of systems science.* Springer US.

Beer, S. (1972). *Brain of the firm: The managerial cybernetics of organization.* London: Allen Lane the Penguin Press.

Beer, S. (1979). *The heart of enterprise.* John Wiley & Sons.

Bertalanffy, L. v., & Rapoport, A. (1957). General Systems. *The Sosciety for General Systems Research*.

Brandon Jr, D. (2002). Crud matrices for detailed object oriented design. *Journal of Computing Sciences in Colleges*, 306-322.

Buttler, R. (2006). *What is Formal Methods?* Retrieved from NASA: http://shemesh.larc.nasa.gov/fm/fm-what.html

Carvalho, J. A. (1998). Using the Viable System Model to Describe the role of Computer-Based Systems in Organizations. *World Multiconference on Systems, Cybernetics and Informatics.* Orlando.

Charles Herring, S. K. (2001). The Viable System Architecture. *Proceedings of the 34th Hawaii International Conference on System Sciences - 2001.* Brisbane: The University of Queensland.

Checkland, P. &. (1997). *Information, systems and information systems: making sense of the field.*

Delone, W. H., & McLean, E. R. (2003). Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems*.

Erl., T. (2005). *Service-Oriented Architecture: Concepts, Technology & Design.* Prentice Hall.

Espejo, R. (2003). *The Viable System Model - a briefing about organisational structure.* SYNCHO Limited.

Henver, A. R., March, S. T., & Park, J. (2004). Design Science in Information Systems Research. *MIS Quarterly*.

Hilder, T. (1995). *The Viable System Model.* Cavendish Software Ltd.

Inmon, W. H. (1997). *Data Stores, Data Warehousing and the Zachman Framework: Managing Enterprise Knowledge.* New York: McGraw-Hill, Inc.

Iwasa, M., Nemoto, H., Kondoh, H., & Ise, H. (1995). *Patent No. US5887154 A.*

Jackson, M. (1991). *Creative Problem Solving: Total Systems Intervention.* Boston: Springer.

Jackson, M. C. (2003). *Creative holism for managers.*

Jang, J.-S. R. (1993). ANFIS: Adaptive-Network-Based Fuzzy Inference System. *IEEE Transactions on Systems, Man, and Cybernetics*.

John Leslie King, E. L. (1978). Cost-Benefit Analysis in Information Systems Development and Operation. *ACM*.

Kawalek, P., & Wastell, D. (1999). A Case Study Evaluation of the Use of the Viable System Model in Information Systems Development. *Journal of Database Management*, 25-26.

Kogetsidis, H. (2011). Systems approaches for organisational analysis", International Journal of Organizational Analysis. *International Journal of Organizational Analysis*, 276-287.

Lyytinen, K. (1987). Different perspectives on information systems: problems and solutions. *ACM Computing Surveys (CSUR)*, 5-46.

Manson, N. (2006). Is operations research really research? *The Operations Research Society of South Africa*, 169-171.

Melville, N. P. (2010). Information systems innovation for environmental sustainability. *MIS Quarterly*, 1-21.

Montangero, C. (1996). Software Process Technology. *5th European Workshop, EWSPT '96* (pp. 260-262). Nancy: Springer Science & Business Media.

Peffers, K. T. (2007). A design science research methodology for information systems research. *Journal of management information systems*, 45-77.

Schramm, D. A. (1985). *Patent No. US4670848 A.*

Šesták, J. M. (2009). Contribution by Lazare and Sadi Carnot to the caloric theory of heat and its inspirative role in thermodynamics. *Journal of Thermal Analysis and Calorimetry*, 97(2), 679.

Sridhar Nerur, R. M. (2005). Challenges of Migrating to Agile Methodologies. *ACM*.

Zeglat, D., AlRawabdeh, W., AlMadi, F., & Shrafat, F. (2012). Performance Measurements Systems: Stages of Development Leading to Success. *INTERDISCIPLINARY JOURNAL OF CONTEMPORARY RESEARCH IN BUSINESS*.

Not cited bibliography

Buckl, S., Matthes, F., & Schweda, C. M. (2009). A viable system perspective on enterprise architecture management. In *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics* (pp. 1483–1488). http://doi.org/10.1109/ICSMC.2009.5346262

DeLone, W. H., & Mclean, E. R. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems / Spring*, *19*(4), 9–30. http://doi.org/10.1073/pnas.0914199107

Garrity, E. J. (2001). Synthesizing User Centered and Designer Centered IS Development Approaches Using General Systems Theory. *Information Systems Frontiers*, *3*(1), 107–121. http://doi.org/10.1023/A:1011457822609

Goodhue, D. L., Chen, D. Q., Claude, M., Davis, A., & Cochran, J. D. (2009). Addressing business agility challenges with enterprise systems. *MIS Quarterly Executive*, *8*(2), 73–87. Retrieved from http://www.linkedin.com/groups/Hey-Mainframers-Whats-best-way-2196066.S.205686527

Harindranath, G., Wojtkowski, G. W., Zupancic, J., & Wrycza, S. (2001). *New Perspectives on Information Systems Development: theory, methods, and practice*.

Reddy, S. K. (1990). The Viable System Model: Interpretations and Applications of Stafford Beer's VSM. *Journal of the Operational Research Society*, *41*(9), 893–894. http://doi.org/10.1057/jors.1990.138

Silver, M. S., Markus, M. L., & Beath, C. M. (1995). The Information Technology Interaction Model: A Foundation for the MBA Core Course. *MISQ*, *19*(3), 361. http://doi.org/10.2307/249600