13

A System Engineering Approach to e-Infrastructure

Marcel J. Simonette and Edison Spina
University of São Paulo, Escola Politécnica,
Computer and Digital Systems Department,
Brazil

1. Introduction

Electronic infrastructures (e-Infrastructures) are the basic resources used by Information and Communication Technologies. These resources are heterogeneous networks, which together constitute a large computing and storage power, allowing resources, facilities and services to be provided to the creation of systems in which communication and business operations are almost immediate, with implications in business organization, task management and human relations, forming a kind of patchwork of technologies, people and social institutions.

e-Infrastructure are present in several areas of knowledge, and they are helping the competitiveness of economies and societies. However, in order to continue with this paradigm, e-Infrastructures must be used in a sustainable and continuous way, respecting the humans and the social institutions that ultimately use them, demand their development and fund their paradigm.

This work presents an approach to deal with the interactions between e-Infrastructure technologies, humans and social institutions, ensuring that the emergent properties of this system may be synthesized, engaging the right system parts in the right way to create a unified whole, greater than the sum of its parts. The social components of this system have needs. The answers to these needs must not be associated with the engineering old philosophy of “giving the customers what they want”, as the technology alone does not have a purpose; it is only a technological artifact. Technology has a purpose only when one or more humans use it to perform a task. This human presence in a e-Infrastructure System make it a complex system, because humans are diverse - multi cultural, multi generational multi skilled. This diversity can lead to differences between what is expected (planned) and the actual System behavior, and this variation is called complexity in this study.

Soft System Methods emerged as a way of addressing complex and fuzzy problems, the objectives of which may be uncertain. Soft methods are aimed at systems in which human and social institutions are present, these methods have an underlying concept and theory of systems, with which the Systems Engineering approach can focus on solving the customer’s problem and provides all the customer needs, not only on what has been required (Hitchins, 2007).

e-Infrastructure design should have a holistic approach, seeking steps that ensure functional and failsafe systems, respecting humans and social institutions dimensions. This chapter is about Systems Engineering in the design of e-Infrastructure Systems, using Soft System Methods to develop a Systemic Socio-technical approach, crucial in order to identify the correct quality factors and expectations of the social infrastructure in an e-Infrastructure. The following sections, Dealing with Complexity, and e-Infrastructure as a Socio-technical System, introduce background information related to System Engineering and Socio-technical Systems. Next, the Soft System Method Approach section is about design process of systems in which human and socio institutions are present; in this section, the Consensual Methods are highlighted, and a perspective to a method selection is presented. Next, this chapter presents a Case Study, the design of an e-Infrastructure to be used by ALCUE Units of the Vertebralcue Project, from the ALFA III Program of the European Commission. A Conclusion section is followed by Acknowledgment and References.

2. Dealing with complexity

Problems arise in many ways, several problems are complex, difficult to be understood and analyzed; problems the solution of which is often only a "good enough" response, based on previous experience, common sense, and subjective judgment. Sometimes, the response to this kind of problem is just a change in the problem domain, so that the problem disappears.

Addressing problems is part of human nature. Humans have already faced numerous problems in history, and, especially after the Scientific Revolution, the approach adopted to deal with problems is to divide them into smaller parts, prioritizing and addressing the parts thought to be the most important first. Unfortunately, sometimes this approach fails, especially when it is necessary to deal with multiple aspects of a problem at the same time. When an aspect is prioritized, either it is not possible to have an understanding of emergent properties that may exist, or the problem can change in nature, emerging with another format. Neither scenario allow the identification of the existing complexity in the original problematic situation. Systems Engineers need to deal with complexity, identifying the interrelationships that exist in problematic situations, especially those related with human demands.

3. e-infrastructure as socio-technical system

The operation of e-Infrastructures depends both on the technology involved (developed by several engineering disciplines), and humans and social institutions interfaces (social interfaces), i.e., the operation depends on technological and social infrastructures. People, social institutions and technology result in a Socio-technical System, which has a social infrastructure and a technological infrastructure (Hitchins, 2007; Sommerville, 2007).

Although the Traditional Engineering methods with their reductionist approach, successfully address technological components and Human Factors (Chapanis, 1996; Nemeth, 2004; Sadom, 2004), these methods have difficulties in the treatment of the social infrastructure of e-Infrastructures Systems, both for addressing people and social institutions, which are often seen only as part of a context, without directly belonging to the System, treating human and social dimensions as constants, or some-times, ignores them (Bryl et al. 2009; Fiadeiro, 2008; Hollnagel & Woods, 2005; Nissenbaum, 2001; Ottens et al., 2006).

The social infraestrucure actors of an e-Infrastructure are more than system components, a part of the context, they want to optimize their decisions, considering their own subsystems, proposes and interests (Houwing et al., 2006).

4. Soft system method approach

There are several Systems Engineering approaches to address a solution to a problem. Nevertheless, Hitchins (2007) argues that the approach that makes use of Soft System Methods is the one that investigates the problem to be treated, looking for practical experiences and interactions with the problematic situation, trying to develop an understanding about the nature of problem symptoms and to propose solutions.

The use of Soft System Methods - a Soft Systems Approach - both allows the System Engineer to understand the problem domain, and helps him with the identification of social and human dimensions present in the problem domain. The former is because the activity to understand the problem domain is essentially an activity in which the components are human activities, and the second because there is an intrinsic complexity for accurately identifying human and social dimensions all along the System life.

The approach to go beyond Human Factors, and deal with the humans dimensions, is the use of the Soft System Approach with an evolutionary approach strategy. This approach deals with the interaction between Reality and Thought, and the interaction between Problem and Solution, it is represented at Figure 1 and was proposed by Soares (1986) as a way to understand, design, and implement solutions to a problematic situation.

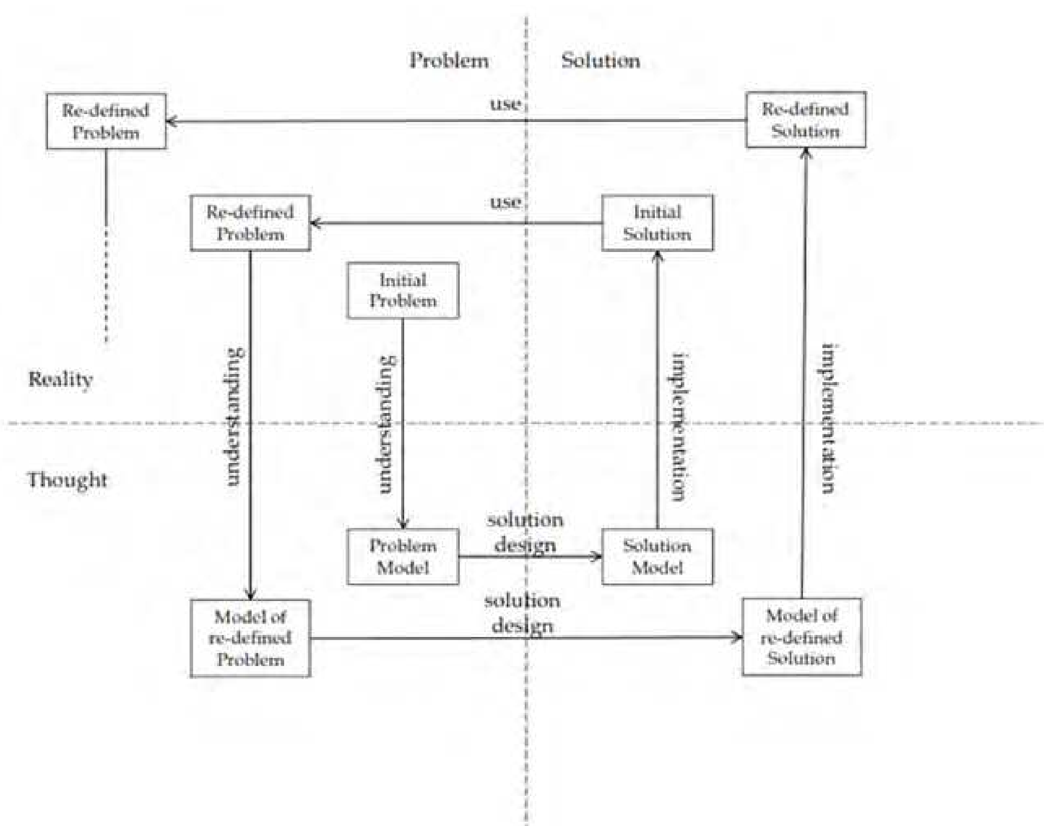


Fig. 1. Representation of the Evolutionary Spiral Approach.

From the two interactions - Reality x Thought and Problem x Solution, there are four actions that generate a cycle to treat a problem. These actions are: (i) *Understanding*: when the System Engineer develops an understanding, an abstract representation of the real problem, (ii) *Design*: when the System Engineer creates a response to the problem that satisfies the Problem in the Thought dimension, (iii) *Implementation*: the construction of the response to the problem in terms of Reality, (iv) *Use:* set up of a response to the Problem, in the environment of the Problem.

The set up of a response to a Problem may cause changes in Reality, emerging scenarios not previously determined, giving rise to new demands and a redefinition of the Problem. The treatment sequence of the problems leads to an Evolutionary Spiral as in Figure 1.

However, different from Soares, the authors of this chapter consider Solution not only as a response to a problem, but also as an overcoming restrictions, improvements in an existing Reality through actions to treat the problematic situation. Solution is an indicative of an improvement, a response that satisfies, but does not always solve, the problem, i.e., a response to the problem that is the best at that moment.

Although the identification of human and social dimension all along the System life is important to System success; the first action of the process - *Understanding* - is crucial.

4.1 Consensual methods

Understanding the Problem in the Reality dimension (Fig. 1) is the first step to determine the System construction possibilities. A proposal to develop this understanding and reduce users' dissatisfaction - respecting the human and social dimensions - is the use of Consensual Methods

Consensual Methods are not only about getting a consensus about a problem to be treated, it is also about getting the Systems Requirements from the people that have interests in the System. The consensual processes deal with the human activities involved in identifying the requirements and the human and social dimensions, reducing the discrepancy between the expected Systems features and the ones that will be perceived by the users.

Next, the Consensual Methods used by the authors in their work are listed. Hitchins (2007) stated that these methods are specifically meant to the front end of the Systems methodology, they are: Brainstorming, Nominal Group Technique, Idea Writing, Warfield's Interpretive Structural Modeling, Checkland's Soft System Methodology, Hitchins' Rigorous Soft Method.

4.1.1 Brainstorming

This method is an approach in which a selected group of people is encouraged by a moderator to come up with ideas in response to a topic or a triggering question.

4.1.2 Nominal Group Technique (NGT)

This method is similar to Brainstorming. A moderator introduces a problematic situation to a group of people and asks participants to write down their ideas about the problem on a sheet of paper. After a suitable time for people to generate their ideas, all participants read their ideas and the moderator, or an assistant, write them in a flip chart. With all the ideas written, the moderator conducts a discussion about these ideas, and then the participants are invited to rank all ideas. An idea-ordered list is generated and this constitutes the ideas that have been produced by the group as whole.

4.1.3 Idea writing

This method takes TGN a little farther. The moderator introduces the theme, and the participants are asked to write their ideas, suggestions, etc., on a piece of paper. After two or three minutes, the moderator asks each participant to pass his sheet on to another person, to pass the sheet to the second person on the left, for example. The one who receives the sheet can see the ideas already written, which may lead him (her) to a new set of ideas. After a short time, the moderator asks for the sheet recirculation, this time, to a different number of people. The process is repeated for about 30 minutes, or until the moderator notes that most people do not have any more ideas. There are two purposes in this strategy: encouraging ideas emergence within the working group and hiding the origin of a particular idea. The lists of ideas are worked later through Brainstorming or TGN to generate an action plan.

4.1.4 Interpretive Structural Modelling (ISM)

This method is similar to a computer-assisted learning process that enables individuals or groups to map complex relationships between many elements, providing a fundamental understanding and the development of action courses to treat a problem. An ISM session starts with a set of elements (entities) to which a relationship must be established. These entities are identified using any other method. The result of ISM is a kind of graph, where the entities are nodes and the relations are edges. The whole process can be time-consuming, especially when there are many divergences among the group members. Therefore, this time is important. It is essential for participants to understand and to recognize the each other' arguments, reaching a consensus.

4.1.5 Checkland's Soft Systems Methodology (SSM)

This method promotes the understanding of a problematic situation through the interaction between the people involved in the problematic situation. It promotes the agreement of the multiple problem views and multiple interests, and may be represented by a seven-stage model. Stages one and two explore the problematic situation (unstructured) and express it in a rich picture. Stage three is the root definition of the relevant systems describing six aspect of the problem, which are called CATWOE, they are: Customers, Actors, Transformation process, World view, Owner and Environment constrains. In stage four, the conceptual models of the relevant systems are developed, and, in stage 5, the conceptual model is compared with the perceptions of the real situation. In stage six, an action plan is developed for the changes, which are feasible and desirable; and in stage seven, the action plan is implemented. As a method developed from the Soft Systems Thinking, SSM does not produce a final answer to the problematic situation, it seeks to understand the problem situation and find the best possible response (Checkland, 2000).

4.1.6 Hitchins' Rigorous Soft Method (RSM)

As SSM, this method is based on the General-Purpose Problem-Solving Paradigm and is context free. The people who are experiencing a problem, and have knowledge about it, provide information about it in meetings with a coordinator. This investigation, which searches for dysfunction sources related to the problem, can create a lot of information and data. Differently from SSM, RSM employs tools and methods for treating, organizing and processing information; the action of "process" implies a gradual reduction of the problematic situation by ordering the data, transforming them into information for the treatment of the problem. RSM has seven steps: (1) *Nominate Issue & Issue domain*, in which the problem issues are indentified and a description of the situation is made; (2) *Identify Issue Symptoms & Factors*, that identifies the symptoms of the problem, and the factors that make them significant to be explored; (3) *Generate implicit systems,* each symptom implies the existence of at least one implicit system in the problem situation; (4) *Group into Containing System:* at this step, the implicit systems are aggregated to form clusters, one cluster for each symptom, named containing system, which can generate a hierarchy of systems, highlighting issues related to the problem; (5) *Understanding Containing Systems, interactions, imbalances*: at this step, the interactions between the containing systems are evaluated; (6) *Propose Containing Systems Imbalance resolution:* this step uses the differences between an ideal world, where the symptoms do not exist, and the real world, to propose Socio-technical solutions to the imbalances identified in the previous step; (7) *Verify proposal against original symptoms*: at this step, the system model are tested to see if they would, if implemented, eliminate the symptoms identified at step two and the imbalance found at step six. This model could also be tested for cultural acceptability by the people that are experiencing the problem (Hitchins, 2007).

4.2 Perspectives of consensual method selection

The diversity of people involved in an e-Infrastructure System development is a reality that Engineering must deal with. Zhang (2007) states that it is impractical to limit the diversity of people involved in a process to get a consensus about a problem to be treated. However, the methods to develop Systems requirements are under the Engineer's control.

Kossiakoff & Sweet (2003) stated that the function of System Engineering is to guide the Engineering of complex Systems, and that System Engineering is an inherent part of Project Management - the part that is concerned with guiding the Engineering effort itself. Kossiakoff and Sweet also propose a System Engineering life cycle model that corresponds to significant transitions in Systems Engineering activities, and it is the model adopted as the life cycle framework to this work. It has three broad stages: (i) *Concept Development Stage*: with the Needs Analysis, Concept Exploration and Concept Definition phases; (ii) *Engineering Development Stage*: with: Advanced Development, Engineering Design and Integration & Evaluation phases; (iii) *Post development* with the Production and Operation & Support phase.

The use of Consensual Methods to get a consensus about the problematic situation is a System requirements elicitation process. Consequently, a Consensual Method is a technique to implement the *Concept Development Stage;* thus, to be adherent to the System life cycle, the Consensual Methods must also provide information to other phases that are dependent on the requirement definition process. The information that is demanded by the following phases, and its purpose, is presented in Table 1.

The authors' experience in dealing with Consensual Methods has allowed the development of a comparison context, which considers if a Method complies with the demands of the Primary Purpose and the Inputs of each phase listed in Table 1.

	Main Activity	Primary Purpose	Inputs
Advanced Development	Risk Abatement	Identification and reduction of development risks.	System functional specification and defined system concept
Engineering Design	Component Engineering	Ensuring that individual components faithfully implement the functional and compatibility requirements.	System design specification and validated development model
Integration & Evaluation	System Integration	Ensures that all interfaces are fit and component interactions are compatible with functional requirements.	Test & Evaluation Plan and Engineered Prototype
Production	Production Process	Diagnosing the source of problems and finding effective solution.	Production specification and production systems
Operation & Support	Logistic Support System	Continuous training programs for operators and maintenance personnel.	Operation & Maintenance documents and installed operational system

Table 1. List of System Engineering life cycle phases after the Concept Development stage.

In Table 2, the adherence of each Consensual Method to System Engineering life cycle model phases is summarized. The first cell of the left column is a label that presents the level of adherence.

+++: Method recognizes the phase issues and provides means to deal with it; **++**: Method supports the phase issues but not as strongly as before; **+**: Method addresses the phase need but weakly or indirectly; **-**: Method does not address the phase issues.	Brainstorming	Nominal Group Technique (NGT)	Idea Writing	Interpretive Structural Modeling (ISM)	Soft Systems Methodology (SSM)	Rigorous Soft Method (RSM)
Advanced Development	+++	+++	+++	+++	+++	+++
Engineering Design	++	++	++	+++	++	+++
Integration & Evaluation	-	-	-	+	++	+++
Production	++	++	++	-	++	+++
Operation & Support	-	-	-	+	+	+++

Table 2. Table of Method Selection.

Table 2 is illustrative, rather than comprehensive. It is based on empirical findings from the authors' experience. It provides a practical starting point for organizing an approach to identify the Consensual Method that complies with the demands of the System life cycle.

5. Case study: e-Infrastructure for an ALCUE unit

From the Perspective of Method Selection, RSM is the Consensual Method that provides more information for the phases of the System life cycle. As a Consensual Method, it promotes the consensus among people about the problem issues, so that people feel welcomed by the process. Of course, as Hitchins (2007) argues, people who feel dissatisfied with this approach are those who have no interest in consensus, who want to impose their worldview.

As a Case Study, the RSM is used to understand the problem of developing an e-Infrastructure to an ALCUE Unit, a kernel concept of Vertebralcue Project from the ALFA III Program of the European Commission. This Case Study also assessed whether the information obtained by RSM may actually contribute to other life system stages, according to the Perspective of Comparison of Consensus Methods.

5.1 The issue and its domain

KNOMA is designing an ALCUE Unit, and desires to develop and maintain an e-Infrastructure to support it.

As usually occurs in Engineering practice, the demand comes to the Engineer with words that are known by the people involved with the problematic situation, which the Engineer is still unaware of.

5.1.1 Issue

The concern about the e-Infrastructure to be developed and maintained is about what needs to be done. However, this depends on the features needed for an ALCUE Unit, which are not clear.

5.1.2 Domain

The Knowledge Engineering Laboratory (KNOMA) is a research laboratory of the Department of Computer Engineering and Digital Systems (PCS) of the School of Engineering (EPUSP) of the University of São Paulo (USP), and acts as a partner in projects sponsored by the European Commission (EC), including Vertebralcue from the ALFAIII Program of the EC.

Each project partner should develop and implement an ALCUE Unit (VERTEBRALCUE, 2011). These Units must operate independently from each other; however, they must be linked as "vertebras" of the framework, strengthening the academic cooperation networks that already exist between the project partners institutions, providing structural support for new partnerships and corporations networks. The Vertebralcue Project board stated that each ALCUE Units operate as an Information Center, broadcasting information about both the intuition and the region it belongs to. Likewise, the Unit must receive information from partner institutions for internal disclosure.

The ALCUE Unit operation deal with information and policy, as an academic collaborative process consists of multiple academic partners working together for information exchange and development of policy cooperation. In this operation process, there are interests of multiple actors: students, professors, researchers, and academic and social institutions. In the scenario of ALCUE Unit as an information center, there may be a distortion of information due to political interests, which can occur with pressures related to the disclosure of information or not. Uncertainty, diversity, quality and quantity of information are factors that can lead to a variation between the expected (planned) for a ALCUE Unit and the actual situation, perceived by the people who interact with the Unit, this variation is called complexity in this study.

5.2 Symptoms and Issue factors

The e-Infrastructure required for an ALCUE Unit depends on the purposes of the people who interact with the Unit. In order to indentify these purposes, meetings have been held with diverse groups of people who had interest in an ALCUE Unit. Furthermore, the Vertebralcue Project documentation and documents about the EPUSP academic cooperation was studied.

5.2.1 A Socio-technical System

e-Infrastructures are Socio-technical Systems. The technology in these Systems does not have a purpose by itself; this technology must meet the purpose of the people and institutions that interact with it. The difficulty in identifying the purpose of an ALCUE Unit can be seen by the description of the domain of the problematic situation.

The existence of a relationship between ALCUE Units and academic cooperation networks is evidence that there are different people's and institutions' interests in the System. This diversity of institutions and people, possibly with different cultures, makes it difficult to identify the specific System goals. Consequently, the identification of e-Infrastructure technological requirement is also made difficult.

5.2.2 Information center

The demand for an ALCUE Unit to be an Information Center is vague. As an Information Center, the Unit must both generate and disclose the information, and receive information and publish it. Nevertheless, before defining how the information will be received or generated, and how access will be provided to this information, it is necessary to identify what information is of interest to the people involved with the ALCUE Unit and what information is of interest to the academic cooperation networks. All this information has been identified by a Brainstorming session with the topic: "What subjects related to academic cooperation would you like to know?"

The Brainstorming session identified the following subjects: (i) Equivalence of titles between higher education institutions; (ii) Graduate and Undergraduate courses offered by institutions, including information about the disciplines and curriculum; (iii) Training programs and continuous education programs offered by institutions; (iv) Distance Learning; (v) Scholarships and funding of studies and research in institutions; (vi) Qualifications of faculty and researchers; and (vii) Mobility and exchange between institutions for faculty, students and researchers.

This list was not definitive; it was a first sample of what a group of people with interest in an ALCUE Unit had thought to be relevant at that stage of the problem treatment. Figure 2 presents the Brainstorming diagram that was created during the session. Diagrams were used in the Brainstorming session to improve communication and association of ideas.

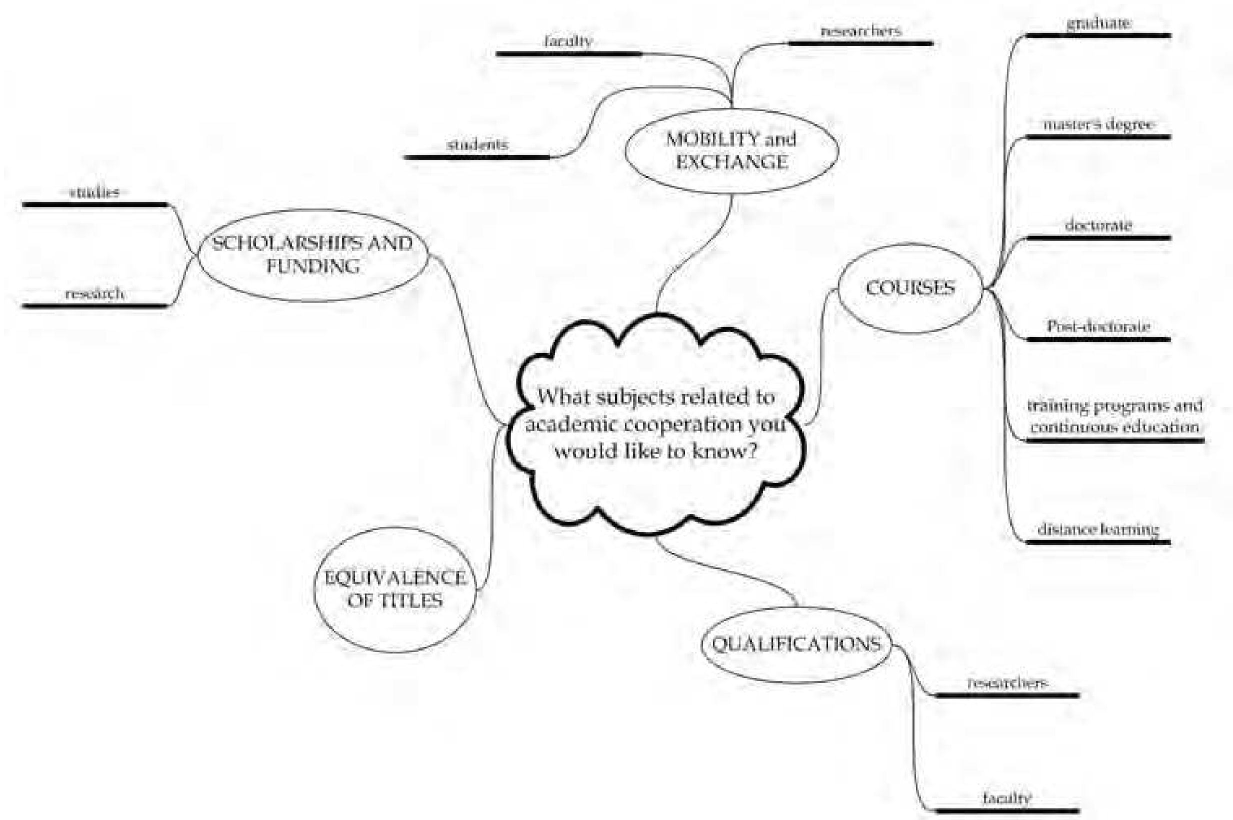


Fig. 2. Brainstorming diagram.

5.2.3 The relationships

The information, generated or received by the ALCUE Unit, occurs within a context with several institutions that have interests in academic cooperation. In order to identify some institutions, the Nominal Group Technique was used with the subjects that were identified in the Brainstorming session as a starting point. The Nominal Group session resulted in Table 2, in which the first column shows the identified institutions; the second column indicates if the institution is a funding institution, a support foundation, an academic institution, or an international cooperation institution. The third column was not identified in that session; it was identified only in the workshop that followed that session, and presents the characteristic of each type of institution.

The list of the institutions indentified in the Nominal Group session was used in a workshop, which aimed to build an institution chart and identify the relationship and information flow between them. In that workshop, the Interpretative Structural Modeling was used, and the work group decided to group institutions according to their characteristics - the results of which are present in the third column in Table 3. Figure 3 presents the institutions relationship and the information flow that was identified in the workshop.

INSTITUTION	TYPE	CHARACTERISTIC
Private Companies	Funding	Provides scholarships and grants, financial or not, for scientific and technological research.
European Commission	Funding	
Fundação de Amparo a Pesquisa do Estado de São Paulo - (FAPESP)	Funding	
Financiadora de Estudos e Projetos (FINEP)	Funding	
Fundação de Apoio à Universidade de São Paulo - (FUSP)	Support Foundation	Provides scholarships that are associated to research projects also provide institutional support to projects.
Fundação para o Desenvolvimento Tecnológico da Engenharia - (FDTE)	Support Foundation	
Universidade de São Paulo - (USP)	Academic	Belonging to the USP structure
Escola Politécnica da Universidade de São Paulo - (EPUSP)	Academic	
Departamento de Engenharia de Computação e Sistemas Digitais da EPUSP - PCS	Academic	
Laboratório de Engenharia do Conhecimento do PCS-EPUSP - (KNOMA)	Academic	
Comissão de Relações Internacionais da EPUSP - CRInt-POLI	International Cooperation	
Comissão de Cooperação Internacional (CCInt)	International Cooperation	
ALCUE Units	Academic Cooperation	Support academic networks at various levels: regional, national and international.

Table 3. Institutions with interests in academic cooperation.

5.2.4 Threats, opportunities, weaknesses and strengths

When the System Engineer deals with a problem such as the design of e-Infrastructure Systems to support the ALCUE Unit, he must not only be concerned about the needs to have the System operating according to the demands at the moment when he understands the problem domain. If the Engineer only considers these needs, the product of the design may be a System in which the changes and the evolutions required to meet new demands will be impossible. Therefore, to identify future scenarios for the ALCUE Unit, a situational analysis tool was used: the TOWS Matrix. This Matrix is a tool that allows the formulation of a strategy for the future by examining the present.

In a single workshop, the ALCUE Unit internal factors - Strengths and Weaknesses - and external factors - Threats and Opportunities - were identified and the relationship between them were established. Table 4 presents the result of this workshop: the TOWS Matrix.

5.3 Implicit systems

The Symptoms and Issue Factors imply the existence of Implicit Systems[1] in problematic situations. At this point in the RSM process, the needs of the ALCUE Unit that indicate the existence of Implicit Systems in the e-Infrastructure System are indentified.

Usually, skilled System Engineering can indentify Implicit Systems by the analysis and synthesis of the content in Figure 3, a rich picture - as in SSM - and the content in Table 4, the TOWS Matrix. The Implicit Systems identified by the authors are:

- System to store information: all the information obtained or generated should be stored for later access;
- System to support static disclosure: a system that allows access to information when people want it;
- System to support dynamic disclosure: a system that sends information to people who are interested in receiving them;
- System to support relationship networks: a system that allows the construction and operation of social and thematic networks;
- System for obtaining[2] information from FUSP: a system that accesses an interface at FUSP to retrieve information;
- System for obtaining information from FAPESP: a system that accesses an interface at FAPESP to retrieve information;
- System for obtaining information from Private Companies: a system that accesses an interface at a Private Company to retrieve information. There may be a different system for each Company that wishes to disclose information;
- System for obtaining information from FDTE: a system that accesses an interface at FDTE to retrieve information;
- System for obtaining and sending information to CRInt-POLI: a system that accesses an interface at CRInt-POLI to send and retrieve information;
- System for obtaining and sending information to CCInt: a system that accesses an interface at CCInt to send and retrieve information;
- System for obtaining and sending information to other ALCUE Units: a system that accesses an interface at another ALCUE Unit to send and retrieve information. There may be a different system for each ALCUE Unit.

[1] The authors consider that Implicit Systems are sub-systems of the e-Infrastructure System, but the term Implicit Systems is used to follow the RSM pattern.

[2] Another possibility would be to have Implicit Systems that receive information from these sources, which was discarded by the authors, because this involves a demand for work in the partner institution.

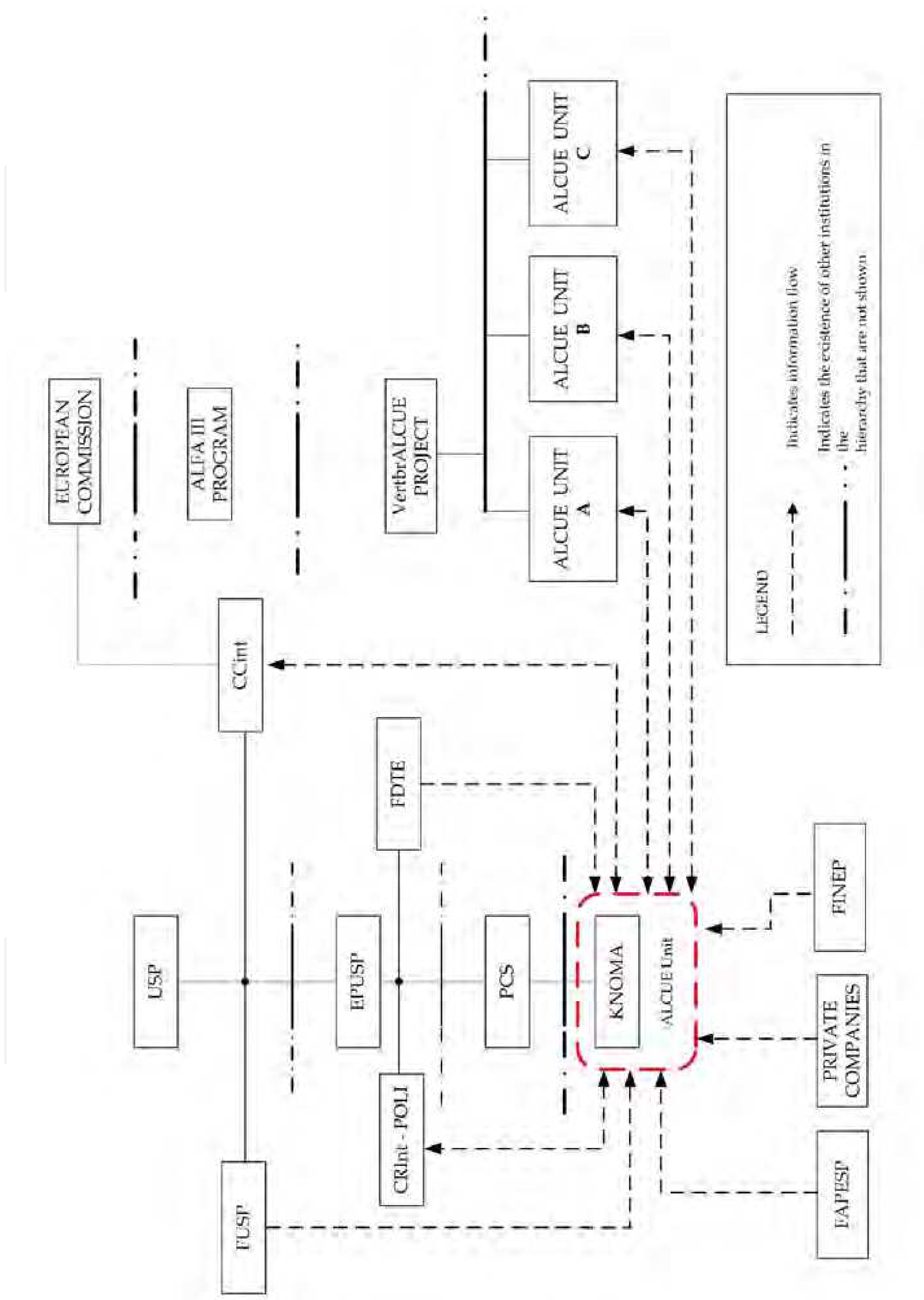


Fig. 3. Relationship between institutions.

		Internal Factors	
TOWS Matrix		**STRENGTHS (S)** **S1**. The Unit is an access point that consolidates information from various institutions on academic networks of cooperation, interchanges, scholarships and research funding. **S2**. The Unit is a place of permanent dissemination of key policies and projects of academic cooperation. **S3**. The Unit can disseminate institutional contacts of several universities, not only of the institutions involved in the Vertebralcue Project.	**WEAKNESSES (W)** **W1**. Inefficient cooperation between institutions that promote academic cooperation. **W2**. The people with interest in academic cooperation do not know the real dimension and importance of the actual cooperation process and agreements. **W3**. There is a delay between the identification of the needs of the academic community and the identification of programs that already exist, or the creation of a new program. No tools are available to accelerate this process.
External Factors	**OPPORTUNITIES (O)** **O1.** Strengthening relationships between universities. **O2.** Strengthening relations between universities and society. **O3**. It is possible to use academic knowledge to develop and to implement an Information Center. **O4**. It is possible to access and to use advanced networking infrastructure, such as RNP (Rede Nacional de Ensino e Pesquisa) in Brazil, CLARA in Latin America, and Géant in Europe.	ALCUE Unit Strengths are based on information. Both for its potential to consolidate information from multiple sources such as the ability to be a permanent location to be used to access this information. It is possible to use the academic knowledge to develop techniques to organize and maintain the information. The social networks can be used for information dissemination, strengthening the relationship between universities and society. The communication structure can use the network infrastructure that interconnects several institutions in different countries for information dissemination. In short: **Strengths** S1 and S2 can be used to make good use of **Opportunities** O2, O3, and O4. **Strenghts** S2 and S3 can be used to make good use of **Opportunities** O1, O3, and O4.	The development of social networks and thematic networks that are specific for representatives of institutions can promote and make the relationship between institutions more efficient. On the other hand, the mere existence of social and thematic networks does not guarantee agility in identifying new needs, or agility in the treatment of these needs. No action has been identified to overcome **Weaknesses** W3, and take advantages of the **Opportunities**. In short: **Weaknesses** W1 and W2 can be overcome by the development of social and thematic networks specific for institutions representatives, to take advantage of **Opportunities** O1, O3, and O4. No actions can be taken to overcome **Weaknesses** W3, and take advantages of the **Opportunities**
	THREATS (T) **T1**. There is a concentration of few countries in academic interchanges. **T2**. There is an overlapping between the activities of the Unit and other institutions, which already have academic Information Systems. **T3**. There are other institutions that only take care of the dissemination of academic scholarships and funding. **T4**. Maintenance costs	All the Strengths can be used for information dissemination, contributing to more institutions and being aware of opportunities to participate in academics networks of cooperation, and scholarships and funding to students, faculty and researchers interchange. The Unit must create and maintain contact with other institutions, providing room for information dissemination. How the Strengths can be used in relation to any of the other Threats has not been identified. Notably, a way to ensure the ALCUE Unit sustainability after the end of the Vertebralcue Project was not identified. In short: **Strengths** S1, S2, and S3 can be used to protect against **Threat** T1. None of the **Strengths** can be used against **Threats** T2, T3, and T4	To overcome the W**eaknesses** that do not help in dealing with threats, the Unit can create a network of contacts for the promotion, development, and operation of cooperation and academic interchanges. This network can promote and coordinate the knowledge exchange about cooperation projects. The improvement of information exchange and dissemination of knowledge can reduce the concentration of interchanges between the same institutions. No action has been identified that could overcome **Weaknesses** W3, and take advantages of the **Opportunities.** In short: **Weaknesses** W1 and W2 can be used to help with dealing with **Threat** T1. No actions can be taken to overcome **Weaknesses** W3, to help in dealing with **Threats.**

Table 4. TOWS Matrix for ALCUE Unit

5.4 Containing systems

The authors have decided not to use any special technique of clustering to group the Implicit Systems in containing sets. Therefore, the Implicit Systems have been grouped together according to partners indentified in their own characteristics, in order to get sets of systems grouped by the symptoms of the ALCUE Unit e-Infrastructure. The resulting Containing Systems are:

- **Storage System:** System that contain as elements the following Implicit System:
  - System to store information.
- **Disclosure Support System:** System that contain as elements the following Implicit System:
  - System to support static disclosure;
  - System to support dynamic disclosure;
  - System to support relationship networks.
- **Information Gathering System:** System that contain as elements the following Implicit System:
  - System for obtaining information from FUSP;
  - System for obtaining information from FAPESP;
  - System for obtaining information from Private Companies;
  - System for obtaining information from FDTE.
- **Information Gathering/Dispatch System:** System that contain as elements the following Implicit System:
  - System for obtaining and sending information to CRInt-POLI;
  - System for obtaining and sending information to CCInt;
  - System for obtaining and sending information to other ALCUE Units.

The systems identified represent a perspective about the problematic situation in an ideal world. This means that they do not necessarily have to be designed and implemented in the real world. Furthermore, it does not mean that they are the only systems in the problematic situation. During the following phases of the System life cycle, new symptoms may appear that were not determined in this phase of the method execution, which can lead to a redefinition of the issue or the emergence of new issues. The sequence of treatments for these symptoms follows the concept of the previously mentioned Evolutionary Spiral.

5.5 Interactions and imbalances of containing systems

The interactions between Containing Systems always occur when there is an information related demand. These interactions are represented in Figure 4, in which the arrow indicates the direction in which information is being sent.

Following the concept of the Evolutionary Spiral (Fig. 1), a new workshop was held with the aim of assessing the interactions identified in reality dimension. At that meeting, it was identified:

- The **Disclosure Support System** contains the Implicit System that supports relationship networks, and this Implicit System also generates information to be stored.

- Two distinct Containing Systems - **Information Gathering System** and **Information Gathering/Dispatch System** - have Implicit Systems with the same characteristic: obtaining information in as institution. This scenario indicates a duplication of systems, even if the institutions are of different types, as identified in Table 2.

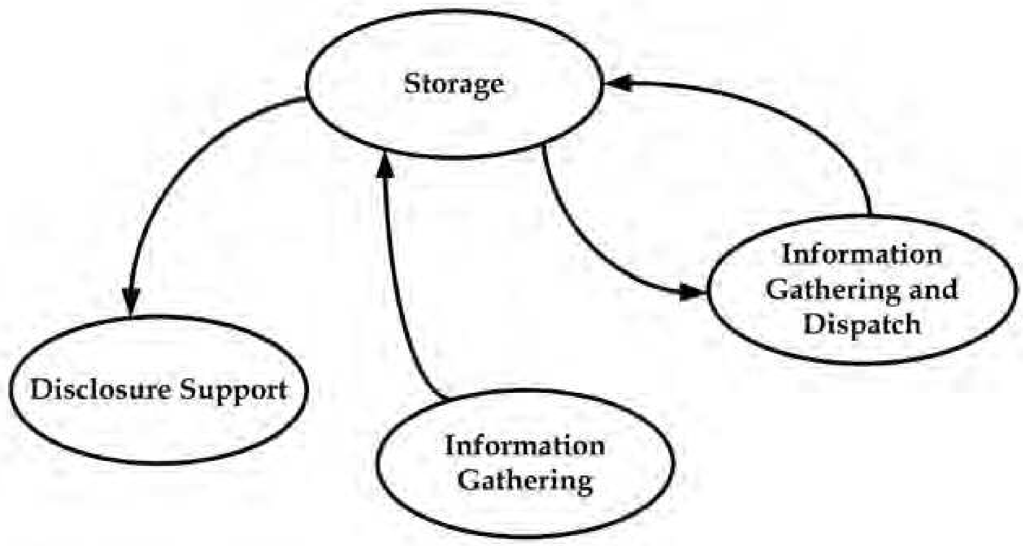


Fig. 4. Containing Systems Interaction.

5.6 Treatment for Imbalance and impact of the proposal

The new symptoms, identified in the workshop commented above, were considered in a new proposal for the Containing Systems, in which the **Information Gathering System** was merged with the **Information Gathering/Dispatch System.** The proposal also considered the symptom that the **Disclosure Support System** demands interactions with the **Storage System,** generating information that should also be accessed later by the system. This new scenario is depicted in Figure 5, where the arrows indicate the direction in which information is being sent.

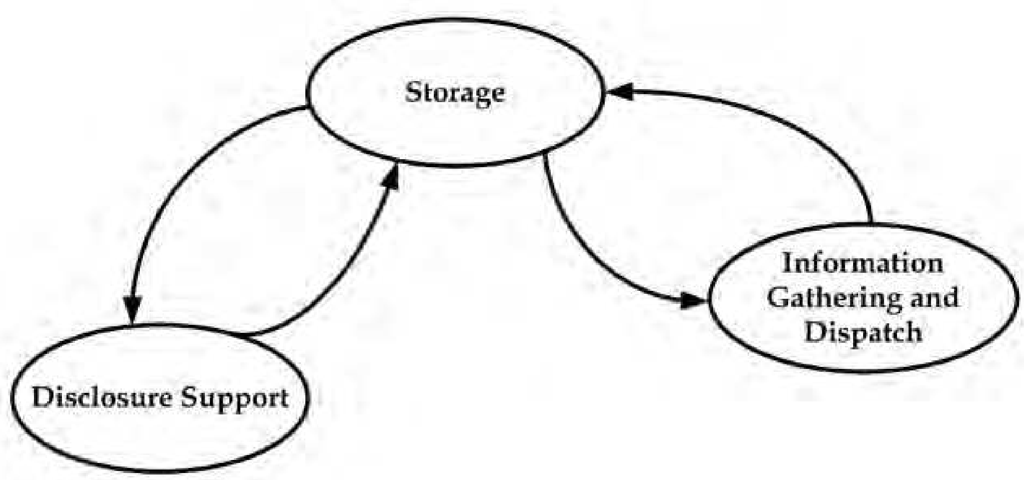


Fig. 5. Containing Systems Interaction, after the treatment of symptoms.

	Main Activity	Primary Purpose	Inputs	
Advanced Development	Risk Abatement	Identification and abatement of development risks.	System functional specification and defined system concept	The rich TOWS (
Engineering Design	Component Engineering	Ensuring that individual's components faithfully implements the functional and compatibility requirements.	System design specification and validated development model	The Imp rich Pi
Integration & Evaluation	System Integration	Ensure that all interfaces are fit and components interactions are compatible with functional requirements.	Test & Evaluation Plan and Engineered Prototype	The ro (Figure 5 Matrix T
Production	Production Process	Diagnose the source of problems and find effective solution.	Production specification and production systems	The ro (Figur identif which c one, o produ ele
Operation & Support	Logistic Support	Continuous training programs for operators and maintenance personnel.	Operation & Maintenance documents and installed operational system	The rich

Table 5. RSM Consensual Method outputs and contribution to System life cycle

5.6.1 Proposal impact

Store and make available information generated by social networks organized by the ALCUE Unit does not affect the **Storage Containing System.** Store information already was its original function.

The merge of the Containing Systems that was implemented may cause internal systems imbalances at the resulting system, because the different institutions with which the Implicit Systems are connected may demand different connection properties. However, in this phase of the System life cycle, it is too early to determine clearly this dependence scenario of connection, and "how" these connections with the different institutions will be held.

The purpose duplication of distinct systems was resolved.

5.7 Potential solution

The e-Infrastructure systems that KNOMA wishes to develop and maintain to support the ALCUE Unit activities is composed of three Containing Systems, which interact between themselves always that information is demanded or disclosed. The interaction between these systems is shown in Figure 5, in which arrows indicate the direction in which information is being sent.

5.8 Contribution to next phases of project life cycle

The process of RSM identified the symptoms and treatments of the issue on to develop and maintain an e-Infrastructure for ALCUE Unit. RSM has been chosen because according to the perspective presented earlier, it is the consensual method that provides more information for the phases that follows the requirement elicitation phase. Table 5 presents the contributions that the application of RSM brings to the phases of System Engineering life cycle model proposed by Kossiakoff and Sweet (2003).

6. Conclusion

This chapter addressed the use of Consensual Methods to assist the authors in the process of understanding a problematic situation: Design an e-Infrastructure to be used by KNOMA ALCUE Unit of VertebrALCUE Project, from ALFA III Program. According to the perspective adopted, the use of RSM provides information to all the phases of Project life cycle and was adopted. The meetings organized by the authors enabled the engagement of people with interest in the ALCUE Unit development, reduce the people dissatisfactions about the requirement elicitation process and respect the human and social dimensions. This scenario allows the development of a e-Infrastructure that minimized the difference between what is expected and what will be verified in reality. The authors decisions about the development of a TOWS Matrix was supported by VertebrALCUE Project board, which after evaluating the results obtained, demanded to all ALCUE Units the development of a TOWS Matrix.

7. Acknowledgments

The research and scholarships are partially funded by the Vertebralcue Project (http://www.vertebralcue.org). An ALFA III Program Project that aims to contribute to the

development process of the regional integration among Latin American Higher Education Systems (HES´s), and the implementing process of the Common Area of Higher Education between Latin America, the Caribbean and the European Union (ALCUE in Spanish), by exploring and strengthening different levels of articulation of Latin America-Latin America and EU-Latin America academic cooperation through the design and implementation of a cooperation infrastructure at institutional, national and regional level.

8. References

Bryl, V.; Giorgini, P. & Mylopoulos, J. (2009). Designing socio-technical systems: from stakeholder goals to social networks. *Requirements Engineering*, Springer London, Vol. 14, n. 1,p. 47-70, Feb. 2009.

Chapanis, A. (1996). Human *Factors in Systems Engineering,* John Wiley & Sons, ISBN: 0471137820, New York.

Checkland, P. (2000). Soft Systems Methodology: A Thirty Year Retrospective. Systems Research and Behavioral Science Syst. Res. 17, S11–S58 , 2000

Fiadeiro, J. L. (2008). On the Challenge of Engineering Socio-Technical Systems. In: Software-Intensive Systems and New Computing Paradigms. ISBN 9783540894360. Heidelberg: Springer Berlin, v. 5380, p. 80-91, 2008.

Hitchins, D. K. (2007). Systems Engineering: A 21st Century Systems Methodology. John Wiley & Sons, ISBN 9780470058565, Chichester.

Hollnagel, E. & Woods, D.D. (2005). Joint Cognitive Systems: Foundations of Cognitive Systems Engineering, CRC Press, ISBN 9780849328213, Boca Raton.

Houwing, M; Heijnen P.W. & Bouwmans, I. (2006). Socio-Technical Complexity in Energy Infrastructures - Conceptual Framework to Study the Impact of Domestic Level Energy Generation, Storage and Exchange. In: Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics. October 8-11, 2006, Taipei, Taiwan.

Kossiakoff A. & Sweet W. N. (2003), Systems Engineering Principles and Practice.: John Wiley & Sons Inc., ISBN 9780471234432. Hoboken

Nemeth, C.P. (2004), Human Factors Methods for Design: Making Systems Human-centered. CRC Press,ISBN: 0415297982. Boca Raton

Nissenbaum, H. (2001). How Computer Systems Embody Values, Computer, vol. 34, no. 3, pp. 120, 118-119, Mar. 2001, doi:10.1109/2.910905.

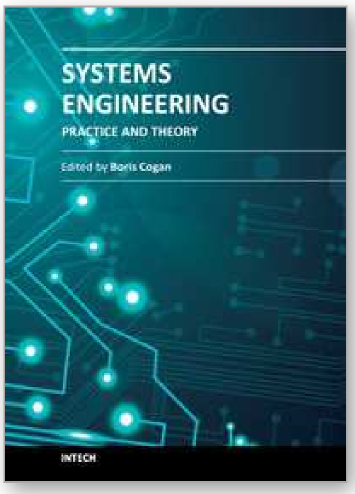
Ottens, M.; Franssen, M.; Kroes, P & Van de Poel, I. (2006). Modelling infrastructures as socio-technical systems. International Journal of Critical Infrastructures, 2006, Volume 2, No. 2/3, pp. 133-145.

Sandom, C. (2004), Human Factors for Engineers. Institution of Electrical Engineers, ISBN: 0863413293. London.

Soares, J. O. P. (1986), Especificação de Métodos de Desenvolvimento de Sistemas - Aplicação a Sistemas de Tempo Real. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo, São Paulo, Brasil.

Sommerville, I. (2007), Software Engineering. Addison-Wiley, ISBN: 9780321313799, Boston.

VERTEBRALCUE (September 2011), Project web site, presents its goals and activities. Available from http://www.vertebralcue.org



Systems Engineering - Practice and Theory
Edited by Prof. Boris Cogan

ISBN 978-953-51-0322-6
Hard cover, 354 pages
Publisher InTech
Published online 16, March, 2012
Published in print edition March, 2012

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821