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E-HEALTH IN AMAZONAS STATE AND THE NEED FOR A SYSTEMS ENGINEERING MODEL BASED ON HUMAN FACTORS

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Abstract

The application of systems engineering processes in any project involving electronic infrastructures can provide valuable support through which the systems engineers and stakeholders may view systems as a socio-technical approach. This paper is organized to show the e-Infrastructure concepts associated to the Health System in the context of the Amazonas State and the main aspects related to the Amazonas human factors, important components in scope of the Healthcare System.

Keywords:

Health, e-Health, Systems Engineering, Amazonas State, e-Infrastructure.

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Introduction

Electronic Infrastructure Resources – also known as e-Infrastructure or cyberinfrastructure – enable innovations in many areas such as Health, Education and Science. Electronic Infrastructure provides support for research, observation, and simulation; especially in fields such as healthcare.

Currently one of the most important e-Infrastructure applications is e-Health. The e-Health system is used to assist and enhance the prevention, diagnosis, treatment and monitoring of a patient's health as well as to facilitate the overall healthcare system management. The term e-Health is relatively recent and refers to healthcare services based on Information and Communication Technologies (ICTs).

e-Health is especially practical in remote areas where patients have to travel long distances to meet health professionals. In the Amazonas State – the largest state of Brazil in surface area – about 4 million people live within considerable distances, making their access to basic services such as health and education difficult. One of the Amazonas State action points is to promote researches which look at new ways to decrease the impacts caused by long distances between local populations and basic services.

However, projects involving technologies and people are complex; studies investigating the interaction between the components are required. Furthermore, important emergent properties in the system still need to be known and analysed. Systems Engineering provides reliable processes to projects that involve complex components, e.g. people, technologies and ecosystems.

Therefore, studies involving subjects such as the Amazonas State ecosystems, electronic infrastructure and healthcare services require a direction which congregates all these elements and that can be provided by Systems Engineering.

The need of a Systems Engineering model, based on human factors, which applies to the Healthcare system and electronic infrastructure in the Amazonas State ecosystem is presented and supported.

Section 2 of this paper presents important concepts concerning electronic infrastructure; Section 3 shows the Amazonas State Scenario and draws the reader's attention to the importance of the human factors in the Amazonas State – Brazil; Section 4 provides information on the connection between Systems Engineering and e-Infrastructure; the last section emphasizes the need of a Systems Engineering model based on human factors for e-Health initiatives in the Amazonas State

2 Electronic Infrastructure

According to the National Science Foundation, cyberinfrastructure integrates hardware for computing, data and networks; digitally enabled sensors, observatories and experimental facilities; and an interoperable suite of software and middleware services and tools. Investments in training interdisciplinary teams and cyberinfrastructure professionals with expertise in algorithm development, system operations, and applications development, are also essential in order to exploit the full power of cyberinfrastructures and to create, disseminate, and preserve scientific data, information, and knowledge (EDWARDS, 2007: 5).

Following the e-Infrastructure Unit, electronic research infrastructures are collections of ICT-based resources and services used by the worldwide research and education community to conduct collaborative projects, generate, exchange, and preserve knowledge. The resources consist of telecommunication links, computers, storage systems, instruments and related computer technology and are 'distributed' in the sense that the components belong to a number of different research organisations and businesses operating in a variety of locations (EGEE-II, 2007: 6).

Both term and concept – cyberinfrastructure and e-Infrastructure as respectively used by American and European teams – are similar in idea and notion, and are complementary. In the context of this paper, the term "e-Infrastructure" will be used to represent the concept of electronic infrastructure.

Due to increasingly effective data organization, access and usage, e-Infrastructures enable the emergence of new scientific opportunities. Together with the growing availability and capability of tools to mine, analyze and visualize data, the emerging data from e-Infrastructure is revealing new knowledge and fundamental insights.

e-Infrastructures involve social and technical aspects which are two important key factors to be considered in building electronic infrastructures, since organizations are information processor; people, routines, forms, and classification systems are as integral information handling as are computers, Ethernet cables, and Web protocols. The boundary between technological and organizational means of information processing is mobile. It can be shifted in either direction, and technological mechanisms can only substitute for human and organizational ones when the latter are prepared to support the substitution. (EDWARDS, 2007: 3).

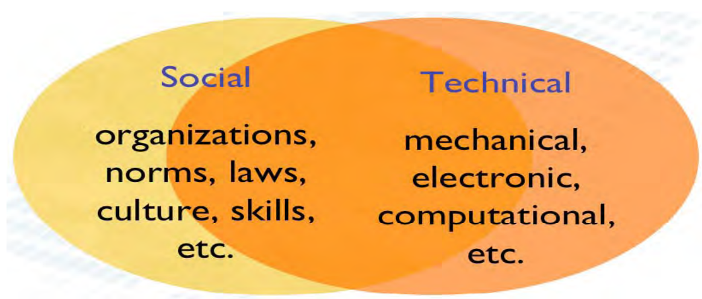

Figure 1: Boundaries between social and technical action can often be shifted in either direction (EDWARDS, 2007: 4)

It is important to take into account that e-Infrastructures are composed of interoperating systems, each of which had a builder. But complex structures have different types of builders and are not always the result of intentional planning.

Thus e-Infrastructure is the set of organizational practices, technical infrastructures and social norms that collectively provide direction and guidelines enabling the operation of scientific work at a distance. In this context, important components cannot be ignored and need to take into consideration as Systems Engineering; e-Infrastructure, and the ecosystem.

Systems Engineering methods provide support to the full development of e-Health, since it can not only provide sustainable but different solutions to several kinds of problems. The e-Infrastructure supply the technical mechanisms and the framework needed, bringing a solution to the problems identified. Finally, all of the processes have to take into consideration the ecosystem in its globality.

Those important elements are presented in the next sections within the context of Healthcare services and look at a specific Systems Engineering model which could be suitable for The Amazonas State scenario.

2.1 e-Infrastructure and Health Systems

Generally, the health systems e-Infrastructures are developed to solve problems pertaining to their own scope. These technologies are important components of the health system services; they permit the prevention, diagnosis and treatment of diseases as well as alleviate disabilities and functional deficiencies in patients.

In general, the e-Infrastructure used in the Health systems context is known as e-Health, and may be used to describe the delivery of healthcare and the exchange of information across distances using ICTs. Synonymous with e-Health, other terms such as telemedicine, mobile health, and health care information systems are often used interchangeably.

The possibilities for using information and communication technologies to improve healthcare delivery are increasingly being acknowledged. There is also evidence of governmental interest with regards to the benefits that these technologies might bring to healthcare at national and sub-national levels.

Access to safe and effective health technologies, including primary healthcare, relies on selection and management policies that are based on scientific studies and best practice in various organizations around the globe.

In a remote region and communities distant from health services, the e-Health resources allow an increase in the number of services that can be provided to the local populations; thus, the patient no longer needs to travel long distances to see a specialist.

However, it is mandatory for each community to define its requirements before implementing this technology and practices, since the local population has its own needs and characteristics. Moreover, the government has to identify the populations who have difficult access to medical assistance.

In this context, the requirements emanate from the community to which the system is proposed while the government indicates the appropriate services configuration needed to deliver healthcare to patients. Notwithstanding the above, other important issues need to be considered such as the service boundaries, human process, and local as well as political issues. Subsequently, all configurations need to be analyzed so as to ensure that they make sense and can be delivered by the project.

Considering e-Infrastructure in The Amazonas State scenario, the solution should comprise not only the technology or organizational process involved, but also the people within this community as the human factors present in this ecosystem can make or not the implementation possible.

Thus, knowledge of the scenario is essential to the success of the e-Health project there. The next section presents this scenario and shows the relevant aspects of the Healthcare in that region of Brazil.

3. The Amazonas State Scenario

Brazil is a country of continental dimensions, and is the fifth largest country in geographical area, occupying nearly half of South America and the fifth most populous country in the world. It is characterized by contrasting social and socio-economic factors, different structures, and degrees of professional qualification. These factors, added to the important geographical distances, create a wide array in the quality of the health services which are provided in the various regions of the country.

Besides optimizing Healthcare, e-Health is of strategic importance at a national level, as it allows quick access to medical resources by streamlining and facilitating Healthcare services.

In the case of the Amazonas State, the sectors of Science and Technology are the two fastest growing areas. The Federal, the Amazonas State and the municipal governments are all investing in these sectors.

Before presenting the actual situation of the Amazonas State healthcare services, it is important to know some relevant information about this state.

The Amazonas is the largest state of Brazil, with a current area of 1,558,987 square kilometres. Much of it is occupied by flora reserve and water. Access to the region is mainly by boat or air. The climate is equatorial, with an average yearly day temperature above 26.7º Celsius. The relative humidity is around 80% and the state has only two seasons: rainy in the winter and dry or less rainy in the summer.(ESTADO DO AMAZONAS, 2009)

In the Amazonas State, the rivers are the roads and vast distances are measured in hours or days of boat travel. Sixty-two municipalities make up this state and the main city is Manaus.

In the last population census (IBGE, 2008), the Amazonas State had around 3,341,096 inhabitants, most of which live in Manaus (approximately 1.7 billion people).

However, the population access to the basic services such as Education and Health is made difficult by the state large surface area. The government has invested in basic services but some problems are still persistent in the cities.

The Government of the Amazonas State faces challenges maintaining public policies in this region due to the distances between local populations as a large number of inhabitants live far from the most developed cities and public services offered – specially the "ribeirinhos" (local population living on the banks of the rivers).

Many of the Government state-wide initiatives have been successful; it is the case of Distance Education, which has reached most municipalities in the state using Information Communication Technologies and electronic infrastructure as its base. Nowadays, the results obtained by these projects are presented and used as an example for other regions.

Thus the use of technology and electronic infrastructures to solve problems involving long distances are an alternative to be considered also when enhancing Healthcare public services in this region.

3.1 The Amazonas Human Factors

Studies involving Human Factors consider all aspects of the way humans relate to the world around them. Their aim to improve operational performance and safety while measuring the project life cycle costs and improving the experience of the end user.

The projects need to include and observe the human factors in all of the project steps. Furthermore, a model of the system functionality is required and needs to be developed for the whole life cycle. The model has to be an accurate description of how the human and technological components interact in order to achieve the overall system functions. This model can be used as a basis for analysis when identifying potential improvements.

Another observation is that the inclusion of human factors activities to the system development life cycle can result in both short-term and long-term benefits. Human factors work can result in development cost reduction by identifying and solving design problems prior to coding and integration testing. (OHNEMUS, 1996)

The people (e.g. the stakeholders, partners, developers, users, etc.) involved in e-Infrastructure projects perform quite diverse functions and this diversity makes them particularly useful components in systems but it introduces many opportunities for failure. One must accept is that it is almost impossible to get the human factors aspects of a system correct in the first attempt; Also, the nature of the systems is that these continually evolve and a static solution is unlikely to result in a system achieving its full potential. It is important, therefore, that the incorporation of human factors is considered as part of the systems evolution over its full life cycle. This is why the cultural aspects are so important. (BRAZIER, 1999:2)

In the same way, projects involving the Amazonas State need to observe the regional history and culture as well as the geographical distribution.

The Amazonas State population has its own historical, cultural, economic and educational criteria which need to be included in e-Health projects consideration; with this in mind, one of the proposals of this research is to develop a Human Factors Taxonomy for the Amazonas State to be used as a base for a Systems Engineering model.

4. Systems Engineering and Human Factors

Systems Engineering – SE – is used to understand and solve complex problems, and requires extensive communication and interaction between and among the various engineering disciplines.

The SE processes suggest that, to manage a complex project, an integrated product development team approach is required. Design, production, deployment, logistics, field support and Engineering actively participate as members of multidisciplinary teams in the execution of the SE process throughout the product development life cycle. (MARTIN, 1997:5)

Systems Engineering Process involves:

1. SE management team,
2. Requirements and architecture team,
3. Development team – software, electrical, mechanical, materials, etc.,
4. Systems integration and verification team.

Throughout the Systems Engineering Process, human factors pertaining to each team also influence every phase of the project life cycle.

The implementation of effective and usable systems requires Human Factors input throughout the life cycle from conception, through detailed analyzes, design and development for operation and discard. Figure 2 shows the some human factors which influence a system life cycle. It considers human factors coming from both individuals and organizations as a socio-technical system.

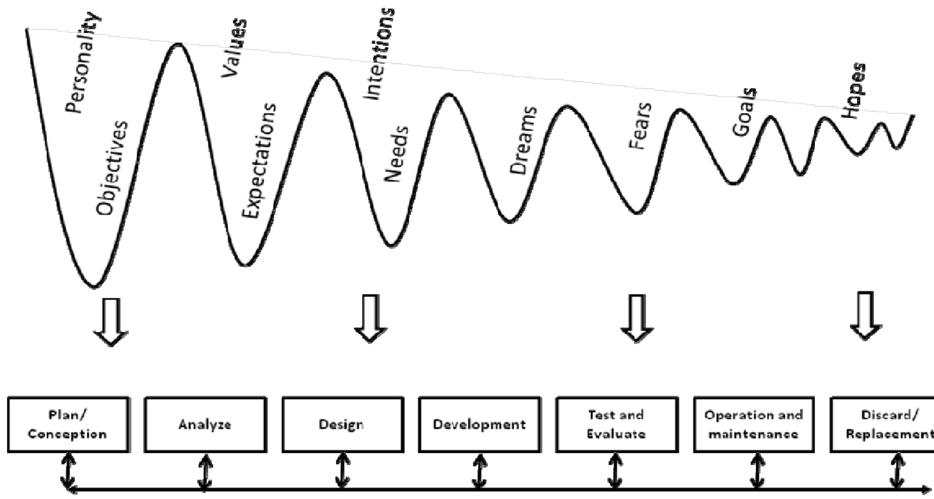

Figure 2: Human Factors influence on System Life Cycle

Complex man-made systems require a holistic, systemic understanding of both the technical problem and the contextual framework present in order to attain satisfactory solutions. Systems engineers must be ensured to have access to solutions based upon formal principles, methodologies, and supporting techniques or methods.

Moreover, e-Infrastructures involve socio-technical systems due to the fact that their functions are developed and used by human beings. The socio-technical systems should include institutional actions and policies which are relevant to the systems and should consider the interactions between technical (i.e. machines and processes) and social systems (i.e. humans).

Speaking of e-Infrastructure as a machine to be built or a technical system to be designed tends to downplay the importance of social, institutional, organizational, legal, cultural, and other non-technical problems developers always face.

Axelrod and Cohen's idea of harnessing complexity cautions against seeking tight control over technologically-enabled organizational structures; even if it were a good idea, it simply would not work. (AXELROD, 2001)

By extension, the organizational aspects of science and the role of the social sciences in e-Infrastructure should be integrated into the work of design. e-Infrastructures are fixed in modular increments, not all at once or globally. Because e-Infrastructures are big, layered, and complex, and because it means different things locally, it is never changed from above. Changes take time and negotiation, and adjustments with other aspects of the systems are involved.

Since e-Infrastructures are incremental and modular, they are always constructed in many places (local), combined and recombined (modular), and they take on new meaning in both different times and spaces (contextual). Better, then, to deploy a vocabulary of "growing," "fostering," or "encouraging" in the evolutionary sense when analyzing e-Infrastructure. (EDWARDS, 2007: 7) e-Infrastructures are examples of complex engineering systems which are in many ways different from other engineering systems, such as satellites or computer processor chips, e-Infrastructures should therefore comprise more than just a technological frameset, they should also comprehend the social factors that are inherent to the project.

Studies involving the Amazonas State Ecosystem need to draw attention to the social components, i.e. the local community and the government. These elements are part of the human factors and will help ensuring the success of the e-Health project.

Embedding the human factors in the Systems Engineering model process throughout the implementation of an e-Health system in the Amazonas State will highlight the importance of the scenario.

5. Systems engineering model for the Amazonas e-Health scenario

Public health infrastructures are highly complex socio-technical systems that depend on human interaction in all steps of the project from conception, development, operation and disposal. Failures and confused specifications often indicate inappropriate direction; this also applies to the e-Health project since its goals are to deliver health services to the population or, more specifically, to the Amazonas State population, in this case.

Moreover, socio-technical systems engineering is an approach to complex systems development where a socio-technical approach pervades the entire systems engineering life-cycle. (LSCITS, 2008)

Nowadays engineers, designers and managers investigate the use context and users' needs while being alert to and actively exploring ambiguities found in specific cultures. Part of the paradigm shift in practice includes engineers acting as moral agents balancing technical and social factors.

Considering the Amazonas State e-Health as a socio-technical system, some steps are required so as to provide an important base such as the mapping of Amazonas human factors by their classification.

Thus, to know, analyse and create a Human Factors Taxonomy associated with the Amazonas as an essential stage in this approach, as commented in section 3.

It is proposed that, as part of this research, the interaction between Human Factors taxonomy and Systems Engineering will enable the implementation of the model required to support the e-Health projects in the Amazonas State Scenario, as presented in figure 3.

At this stage of research, a generic system engineering life-cycle is being considered; however, in-depth studies about potential standards from System Engineering, such as EIA 632 and ISO 15288 are required. They can also provide a framework for the implementation of the developed taxonomy.

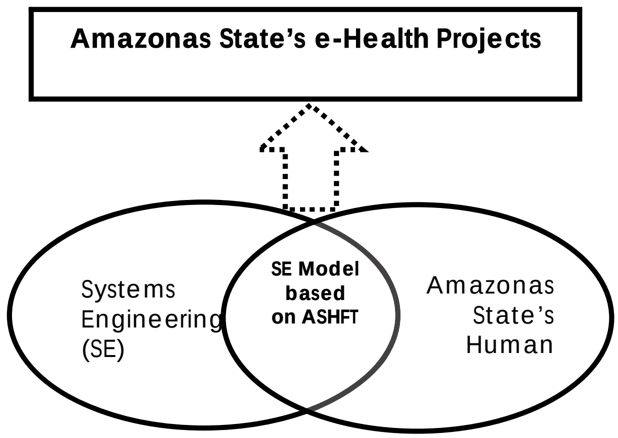

Figure 3: Structure proposed to Systems Engineering Model based on Human Factors in the Amazonas State Scenario Research

As a methodology, this approach follows the guidelines provided by Derek K. Hitchins (HITCHINS, 1992: 272) relating to a new Engineering Systems which takes into consideration ethical and social issues.

Step 1 - Establish the objectives and requirements of the system of interest (SOI);

Step 2 - Identify (sibling) systems and their interactions to be perturbed by the SOI;

Step 3 - Conceive complementary systems as new/modified siblings to neutralize unwanted perturbations;

Step 4 - Design the SOI as an open system to complement sibling systems in contributing to containing system(s) objectives;

Step 5 - Partition the SOI, promoting internal connected variety, avoiding dominance;

Step 6 - Enhance the SOI cohesive, diminish dispersive;

Step 7 - Interconnect that variety to promote sibling stability, mutual self-reward;

These steps are generic stages to support this research organization, indicating possible ways to follow in its development.

Conclusions

Electronic infrastructures are applied in several projects in the world. They provide support by ICT in research and projects. In the Amazonas State context, e-

Infrastructure applications can improve the Healthcare system.

The implementation of an e-Health system involving the Amazonas scenario and e-Infrastructure requires an approach which takes into consideration socio-technical aspects.

The Human Factors influence the system life cycle by important interrelations; therefore, the Systems Engineering model involved needs to observe and consider these relations since these can modify the system requirements, as well as guide system management.

A proposal to develop a model to support e-Health initiatives in Amazonas State scenario is presented. This model is based on Socio-technical Systems Engineering Approach and Amazonas Human Factors Taxonomy.

References

AXELROD, R. M. D. COHEN (2001). Harnessing Complexity: Organizational Implications of a Scientific Frontier. New York, NY, Basic Books.

BRAZIER, Andrew (1999). Human Factors in Systems Engineering. IEE Colloquium Success ful Introduction of Systems Engineering into an Organization.

CHECKLAND, Peter. (1999) Systems, Thinking, Systems Practice. John Wiley & Sons, Ltd. (UK).

EDWARDS, Paul N., et all. (2007). Understanding Infrastructure: dynamics, tensions and design. On http://deepblue.lib.umich.edu/about/index.html.

EGEE-II et all. (2007). A guide to European flagship e-Infrastructure projects. On http://www.beliefproject.org/docs/European%20e-Infrastructure%20guide.pdf/view.

ESTADO DO AMAZONAS. História do Estado do Amazonas. Available on: www.amazonas.am.gov.br

HITCHINS, Derek K. (1992). Putting Systems to Work. John Wiley & Sons, ISBN-13: 978-0471934267. 342 pages. Chichester.

IBGE. Instituto Brasileiro de Geografia e Estatística (2009). Estimativas populacionais dos municípios em 2009. Disponível em www.ibge.gov.br

LSCITS Briefing Note StA/1/2008 - Socio-technical systems engineering. On www.lscits.org/pubs/LSCITS_BN_STA0801.pdf

MARTIN, J N. (1997) Systems Engineering Guidebook. A Process for Developing Systems and Products. CRC Press. ISBN: 0-8493-7837-0. Florida. USA.

MATHEU, Marlene M. Whitten, Pamela. Allen, Ace (2001). E-health, tele-Health, and telemedicine: A guide to start-up and success;. John Wiley & Sons, Ltd. ISBN

0-7879-4420-3. http://www.asianhhm.com/information_technology/e-health.htm

NORRI, Anthony Charles (2002). Essentials of telemedicine and telecare. England: John Wiley & Sons, Ltd. Baffins Lane, Chichester. West Sussex PO 19 1UD. ISBN 0-471-53151-0 (pbk)

OHNEMUS, K.R. CSC, Cincinnati, OH (1996); Incorporating Human Factors in the System Development Life Cycle: Marketing and Management Approaches. Professional Communication Conference, 1996. IPCC '96 Proceedings. 'Communication on the Fast Track'., International. Pags. 46-53. ISBN: 0-7803-3689-5. Saratoga Springs, NY, USA

WOOTTON, Richard. CRAIG, John. PATTERSON, Victor (2006). Introduction to telemedicine. Second edition. London: The Royal Society of Medicine Press Ltd. 206p. ISBN: 1 85315 677 9.