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ABSTRACT

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Needs for a Systems Engineering Process based on Human Factors for e-Health Systems Implementation

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Abstract —**e-Health application is a highly complex socio-technical system that depends on human interaction in all steps of the implementation from conception to disposal. Considering a system engineering process based on human factors in e-Health systems implementation is taking into account the nature of the project and the different scenarios where it is applied. This paper proposes the study of systems engineering process applied on e-Health implementation searching for the integration model between technical and human factors (HF) aspects.**

Keywords — **e-Health, e-Infrastructure, Health, Systems engineering.**

I. INTRODUCTION

The integration between healthcare system and electronic infrastructure[1] (e-Health) represents one of the most relevant cases for applying the power of cyberinfrastructures. e-Health systems allow an increase in the number of services that can be provided to the local population, especially in remote regions and communities distant from health services.

e-Health systems are an especial sort of complex engineering systems, namely socio-technical as well as e-Infrastructure systems [1]. In view of this, social and technical aspects are two important key factors to consider in building applications based on electronic infrastructures, since organizations are information processors, people, routines, forms, and classification systems which are as integral information handling as computers, Ethernet cables, and Web protocols [2].

In addition, the socio-technical systems approach views the organization as a work system with two interrelated subsystems, the technical system and the social system. The technical system is concerned with the process tasks, and technology needed to transform inputs such as materials into outputs such as products.

The social system is concerned with the relationships among people and the attributes of these people such as attitudes, skills, and values. The outputs of a work system are the results of the interaction between these two systems [3].

[1] Electronic Infrastructure is also known as cyberinfrastructure and e-Infrastructure, and both terms will be used in this paper [1][4].

Consequently, in developing e-Infrastructures such as e-Health systems engineering (SE) solutions need to take into consideration not only hard systems methodologies, which include technical systems, but also soft systems methodologies which involve social systems [5].

Understanding the relationship between socio and technical aspects in e-Health systems implementation is the focus of this current research and a system engineering process based on human factors supporting engineers and stakeholders in implementing e-Health projects is the main hypothesis considered.

Thus, the proposal is the study of systems engineering process applied in e-Health implementation search for a integration process between technical and human factors aspects. Section 2 presents the main aspects between systems engineering and human factors; Section 3 provides information about e-Health systems; Section 4 emphasizes some important Systems Engineering process characteristics based on human factors for e-Health systems implementation.

II. SYSTEM ENGINEERING AND HUMAN FACTORS

In general, Systems engineering is applied to understand and to solve complex problems, and requires extensive communication and interaction among various engineering disciplines [6].

Hitchins [7] states that System engineering includes people and technology in the whole system and its subsystems emphasizing the inclusion of humans as systems and subsystems, as systems users, as systems operators as a factor that characterizes systems engineering; nevertheless, it excludes the humans from the system, or considers the human aspects as an adjunct to the system.

Including humans in the system is not design human being but identifying functions that the system may have to perform and elaborate functions into human-related activities [7].

Considering the Systems Engineering processes, Martin [8] suggests managing a complex project the integrated product development team approach. Design, production, deployment, logistics, field support and Engineering

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actively participate as members of multidisciplinary teams in the execution of the SE process throughout the product development life cycle.

This 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 mentioned, human factors pertaining to each team also influence every phase of the project life cycle. Thus, the implementation of effective and usable systems requires Human Factors input throughout the entire life cycle from conception, through detailed analyses, design and development to operation and discard.

Figure 1 shows some human factors which can influence a system life cycle. It considers human factors coming from both individuals and organizations as a socio-technical system.

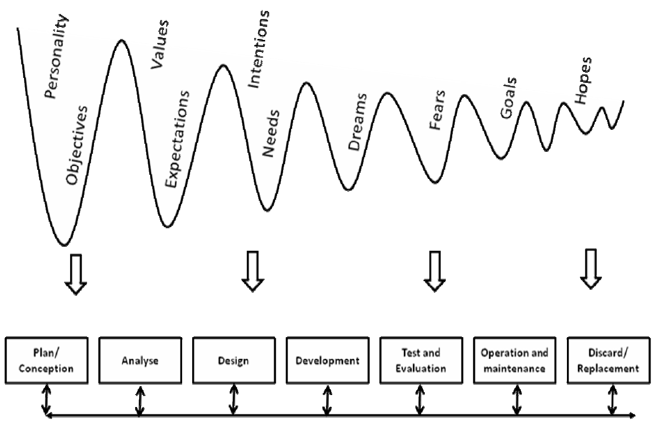

Figure 1: Human Factors influence on System Life Cycle

Taking human factors into account as part of the process engineering requires designing equipment, operations, procedures and work environments in such way that they are compatible with the capabilities, limitations and needs of the human beings [9].

In e-Infrastructure systems, it is exponentially difficult to integrate HF once each system view accommodates human multi-system requirements such as large organization structures, component-equipment-system compatibility and communication, among others.

Although e-Health projects justify observing human factors related in each specific stage of system process and a detailed planning based on human factors requirements other aspects to making an argument for human factors integration in system development are important as highlighted by Bruseberg [10]:

1. To identify influence area for human factors activities (e.g. safety risks, development costs, sub-standard performance inefficient use of resources, legal and insurance costs);
2. To demonstrate how human factors integration adds value – i.e. suggests human factors integration activities (with associated costs) and shows how they can affect overall costs, through savings.

These two steps are important in e-Health implementation once high costs are associated with project budget and because it is an application which involves the human being not only in project stages but also as the end and main goals of the system.

Therefore, defining each step of an e-Health project is important to configure a system life cycle. Besides, to make the integration between systems engineering process and human factors in e-Health systems requires investigating how the system life cycle interacts with human factors. These are the main points here.

III. e-HEALTH SYSTEMS

For a brief introduction about electronic infrastructure, Ottens [1] affirms that e-Infrastructure is an example 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 inherent to the project.

In the health field, the e-Infrastructure resources are used to assist and enhance 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) [11].

In remote regions and communities distant from health services, the resources available with e-Health allow an increase in the number of services provided to the population; 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

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characteristics. Moreover, the government has to identify the populations that 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 aforementioned, other important issues need to be considered such as service boundaries, human activities 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 [11].

In a work named "eHealth benchmarking framework" Meyer [12] suggests important dimensions and categories for e-Health context in the European Community such as actor, activities and application. Likewise, these dimensions and categories can indicate relevant characteristics for the systems engineering process based on human factors for e-Health implementation proposed here.

The tables as follows present some characteristics of e-Health projects concerning its implementation.

TABLE I
APPLICATIONS IN E-HEALTH SYSTEMS [12]

ICT[2] infrastructure (hardware)	Includes computers, servers, local networking infrastructure, internet connection, broadband connection, IT security systems etc.
Hospital information system / clinical information system (HIS /CIS)	All kinds of information management systems used in hospitals. Can cover both administrative and medical purposes, including systems for accounting, duty roster, patient data storage, lab information systems, radiology information systems, pharmacy systems etc.
Electronic health records (EHR) / Electronic medical record (EMR)	All kinds of systems used to store (administrative and/or medical) patient data. May be part of an HIS/CIS, may include lab information systems, radiology information systems, pharmacy systems etc.
Computerized provider/physician/presc riber order entry (CPOE) system	All kinds of systems used to electronically transfer instructions for the treatment of patients between health professionals. May be part of an HIS/CIS.
Emergency medical services (EMS) IT, IT in Intensive Care Units (eICU)	All kinds of systems used in emergency and intensive care. Does not include medical technology.
Public health applications	All kinds of systems used by public health organisations. May include systems for event reporting, alert systems, public health preparedness tools, crisis management tools (detecting / managing emerging epidemic or crisis), etc.
Personal ICT tools	All kinds of systems used by individual citizens/patients. May include biomedical sensors, telemonitoring devices, personal tools for diagnostics and treatment etc.

[2] Information Communication Technology

TABLE II
ACTIVITIES IN E-HEALTH SYSTEMS [12]

Activity	**Remarks**
Administration	All kinds of administrative work including accounting, data storage, making appointments.
e-Health / IT[3] investment	Includes actual investments (e.g. for IT equipment), but also plans for future investment.
e-Health/IT skills	Includes both the (self-) assessment of personal and staff skills, and skills acquisition (participation in training courses, etc.)
Health information provision	General provision of health-related information (e.g. via an internet portal). Does not include consultation.
ICT availability	E.g. availability of computers, internet (broadband) access, website practice, etc. Does not include ICT use.
IT related process	Processes related to the use of ICT, but not of medical nature (e.g. security measures, quality management etc.)
Patient data exchange (generic)	All patient data exchange not directly related to any other activity
Patient data storage (generic)	All patient data storage not directly related to any other Activity
Professional medical education and training	Participation in training courses through IT resources.
Telemedicine / Telemonitoring	All kinds of remote, ICT-based diagnosis / treatment

TABLE III
HUMAN DIMENSION IN E-HEALTH SYSTEMS [12]

Actor	**Remarks**
Citizen	Citizens in general, patients
Health professional	General Practitioners, Specialists, Therapists, Nurses, practice staff
Hospital	All kinds of hospitals; community centres; primary, secondary and tertiary care.
Informal carer	Citizens caring (voluntary) for family members, friends, etc.

Besides, other requirements such as culture, education level, socio-economic status, language, and geographical localization can influence e-Health systems implementation.

IV. Needs for a Systems Engineering Process Based on Human Factors in e-Health Systems Implementation

e-Health system is a highly complex socio-technical system that depends on human interaction in all steps of the implementation, from conception to development, operation and disposal. e-Health is a singular case of cyberinfrastructure application and involves particularities inherent to it.

According to NSF [13] - figure 2 - the cyberinfrastructure vision involves virtual organizations for distributed communities, high performance computing, visualization and interaction among data.

[3] Information Technology

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Figure 2: NSF vision for cyberinfrastructure [13]

Likewise, figure 2 shows the interaction among several subjects and environment levels. For instance, visualization and interaction data are applied in local, regional and global domains allowing communities geographically distributed to access the same content.

Moreover, stages in building e-Infrastructure are associated to the system process such as [13]:

- Design of technology-based services – initial stage in infrastructure formation in system-building;
- Observing variations on the original design – resulting from technology transfer across domains and locations;
- Process of consolidation characterized by gateways that allow dissimilar systems to be linked into networks;

These stages quite well show the complexity associated with implementing e-Infrastructures which demand for a specific implementation process.

Cyberinfrastructure seeks to enable a decentralized research environment that [10]:

1) Permits distributed collaboration;
2) Provides incentives for participation at all levels; and
3) Encourages the advancement of cross-boundary and interdisciplinary.

Edwards [2] comments that, since all three of these goals are simultaneously social and organizational in nature and central to the technical base, designing effective navigation strategies will depend on strategic collaborations between social, domain, and information scientists.

Thus, consider a system engineering process based on human factors in e-Health implementation is taking into consideration the nature of the project and the different scenarios applied to it.

V. Conclusion

Human Factors influence the system life cycle, and understanding the relationship between socio and technical aspects in e-Health systems provides comprehension better how integrating human factor in e-Health system life cycle.

At this moment, the research is being applied to the study of e-Health systems characteristics allowing analyse them by correlating standards process in systems engineering. That step can provide a system engineering process to e-Health systems. Next step in this research considering applying the e-Health system engineering process proposed in the context of e-Health systems in the Amazonas State - Brazil.

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