FOCUSED -LIQUID ENTERPRISE SYSTEM ARCHITECTURE TO SUPPORT E-HEALTH APPLICATIONS

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The industrial trend is to adopt and adjust the general framework of enterprise architecture for the specificity of each sector[1]. Thus, for the health sector, we propose an enterprise architecture that will optimize and transform fragmented processes, information, eHealth applications and technologies into an efficient, integrated and supportive environment for the accomplishment of the health system related strategy and objectives.

Keywords: Information System, Enterprise Architecture, e-Health Framework

1. Introduction

As the society evolves, it faces more and more important challenges in the health sector. As shown by statistic studies, the health system must treat more and more individuals for lower and lower costs. This fact is due to the modifications occurred in population aging at a national and European level, in the increase of life expectancy, the increase in the number of chronically sick patients as well as the screening for new and rare diseases for which no proper treatments have been found yet.

In a global context, the international concerns are: population mobility due to the liberalization of labour market; patients' expectations for a high quality level of the services provided; unbalanced repartition of doctors and medical staff within various geographical areas; increase of medical care related costs, etc.

Another challenge relates to the adoption of new concepts as the society evolves and the degree of civilization increases. Thus, we witness a transition from health systems based on the volumes of medical services provided towards

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systems centred on the patient's needs, for prevention, treatment and monitoring issues, and on the citizen, for public health issues.

The dynamics and exceptional development in the field of technics and technology during the past decades lead to the conclusion that international platforms, catalysing actors and information, have the capacity and potential to indicate, based on the data, the issues encountered by an entire society, and to specify the needs and requirements for their fulfilment. The primary data which was carefully gathered and analysed as well as the desire and strength to follow the assumed strategy can generate new progress in the health sector.

We are currently witnessing the transition to the paradigm from the "old economy" to the "new economy" [2]. Specialists consider that old economy is based on the logics of processing industry management which focuses on a high degree of product standardisation and process automation in order to reduce costs. To obtain higher profits, the organizations are trying to extend to external markets and to increase their capacities, by applying the principle of efficiency. On the other hand, the new or digital economy is based on the conquests of digital revolution and on the management of information industry [3].

Based on the patient's individual requirements, the task of the health system is to create services and related products, context related experiences in line with the patient's needs. In order to analyse, create and provide value to each patient, all interested parties must be informed and work together: authorities, beneficiaries, doctors, hospitals, laboratories, pharmaceutical companies, clinics, etc. Everyone's participation is required in order to contribute to the accomplishment of a value creating system for each actor involved in the process.

The reason of the research regarding the health IT system was the analysis of the health sector in order to come up with a realistic and holistic approach in view of the paradigm change in the health sector. The transition from the volumes and amounts of provided services, the number of visited patients, to the paradigm of having the patient placed in the centre of medical care services and the system analysis in view of the results of the final beneficiary, i.e. the patient. How can we reach an added value system in the health sector; what is the politically supported value creating chain, the strategy, objectives, business flows, activities and capacities of each actor; what are the computer-based applications and IT systems which coordinate data, information and knowledge in an harmonious manner so that they provide an actual support in the decisional clinical process of medical professionals, on the one hand, and the support to manage their own information concerning the health condition from the patient's perspective, on the other hand. What are the needs of technological infrastructure to support the health system's objectives in line with the processes, the capacities and the health IT system. A holistic approach is required with regard to the individual health condition, to the factors influencing our health, ecosystem, health system and the health IT system.

The interdependency of sectors such as sociology, politics, economy, research, IT and communication technology, agriculture, environment, etc. – all these have a direct or indirect impact upon the health system and definitely contribute to the development of a sustainable system for citizens. When we receive accurate and reliable information, any circumstances may be changed, providing them with a new direction.

E-Health plays an essential part and is a fundamental component which enables the improvement of access to health services as well as the high, operative and efficient quality in the medical sector, when implemented in the health system. The study performed by Silber Denise [4] presents concrete applicability examples for the e-health solutions, which prove the positive results for patients as well as the streamline, the decrease of error rates, the information sharing, the remote monitoring, the immediate intervention, etc. in the medical care process.

E-Health instruments concern: the patient's electronic file, telemedicine services, electronic prescriptions, information networks, personal portable communication systems, health portals, preventive medical care technologies, diagnosis, treatment, interventions, life style monitoring and management.

Consequently, this study intends to use a multidisciplinary approach in order to develop an enterprise architecture that would: (1) uphold the decisional support which the legal authorities in the health sector can use in a practical and efficient manner; (2) create new capacities and facilities in the Romanian e-Health field; (3) point out the essential components and elements for the development of an enterprise architecture in the e-Health field; (4) provide a management and architectural methodology for clinical processes; (5) align and bring closer the understanding and knowledge with regard to the records and clinical processes between all the interested parties of the health system and collaborative network: patient, medical professionals, IT specialists, legal authorities, etc.; (4) create activity flows for the clinical record of a patient diagnosed with a rare disease which requires cross-border treatment or medical care services; (5) provide IT support for the further research of e-Health improvement methods in the field of rare diseases.

The general purpose of the article is the elaboration and proposal of a conceptual shaping framework of enterprise architecture for the holistic health IT system. The purpose of this framework is to be applied both at the general level of the health system as well as in the development and implementation of subsystems within the specific scope of a certain area in the health sector. The architecture of clinical processes and their integration into a common flow of activities between the participants to the clinical record of patients with rare diseases is the priority of this work.

The reason for selecting a specific medical field is based on the specific characteristics of rare diseases, a limited number of patients, the insufficient field

specific knowledge and expertise, the individualization as a special field with a high added value at the European level. The challenges in the field of rare diseases occur from the fact that patients are rare, as well as experts and professional expertise. As they are numerous and complex, it is difficult for the medical staff and health system officials to recognise them. They concern all medical specialties and always require interdisciplinary coordinated approaches and their degree of severity is extremely variable, depending on the disease and patient [5].

The development of an IT system that will support the gathering of digital data with regard to the record of the patient with rare diseases, the configuration of the collaborative network for the automation of the flow of approvals required for the record in view of a treatment abroad would lead to the fluidization and decrease of blockage and pre delays of the health system, which are often fatal for the patients diagnosed with rare diseases.

2. Enterprise Architecture based e-Health Framework

The health system in an adaptive complex open system, influenced by a large number of determining factors from various sectors of the society, by the environment and the challenges encountered by this system, can only be settled in an interdisciplinary manner.

As the health system includes many actors with various individual interests, objectives and tasks, all leading to a common purpose – medical insurance and care, the elaboration of a common shaping framework is required, where all the participants would contribute to the achievement of an integrated system, for the common benefit of the citizen, on the one hand, and for the remaining actors involved, on the other hand.

Enterprise Architecture - EA identifies the business processes performed in line with the vision and the mission of the organization and defines the way in which ICT allows for the development of these processes. The purpose of EA is to optimise and transform the fragmented processes, information, applications and technologies of the system into an efficient, integrated environment that would support the accomplishment of the organisation's strategy. EA has the role of collaboration between the business planning aspects, such as governing objectives, visions, strategies and principles; aspects of business operations, such as business terms, organisational structures, tasks, activities and information; automation aspects, such as information systems and databases which would enable the use of the business technological infrastructure, such as computers, operating systems and networks. Within a large modern organisation or institution, a rigorously defines EA framework must be able to capture a vision of the "entire enterprise" in its entire size and complexity.

In the context of creating the Enterprise Architecture in accordance with Péter Bernus, three up to four types of architectures are established, each of them corresponding to its special architectural field (Fig. 1).

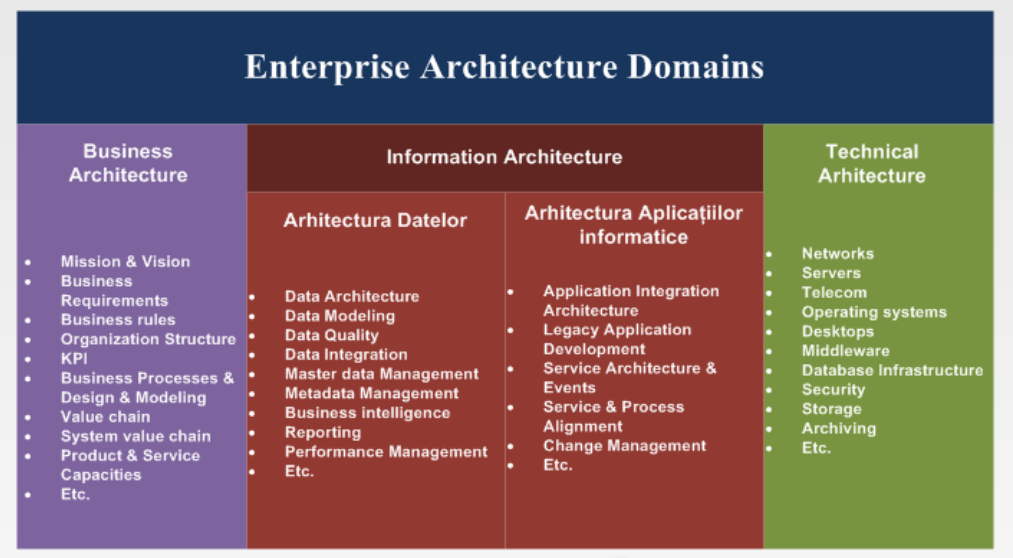

Fig. 1. Components of Enterprise Architecture, adapted after Péter Bernus (2005)

The e-Health Enterprise Architecture (EAeH) provides the organisation with a logical framework for business processes and IT infrastructure. This offers a long-term vision of clinical processes, of systems and technologies so that individual projects can build new capacities. EAeH integrates the standardisation of clinical and business processes.

From a historical point of view, an important part of the data has been recorded in unstructured formats (text, voice/dictation, image, etc.), but the industry is heading towards structured data with standardised codification and terminology. EAeH can ensure that the data structures and taxonomies adopted within the organisation are internally in line with and externally compatible with business partners, legislators and tax payers.

The provision of medical services is an extremely complex system which requires precise synchronisation, accurate information, excellent communication as well as safe protection of private life. The same as a hospital would not be built without detailed architectural plans; it is imprudent to build a complex information exchange system without equally detailed plans. Some of the benefits of an EAeH are: the improvement of efficiency, productivity and safety for medical specialists, their patients and all interested parties of the health system.

Thus, EAeH provides a coherent conceptual framework for e-health solutions, which, if holistically approached, will form a unitary and integrated whole with the final purpose of gathering and sharing data, information, knowledge and know-how for all the interested parties of the health care process.

The enterprise architecture framework proposed for the e-health system in order to guide the development and progress of the national health information system is represented in Fig. 2. The description of EAeH entities is also discussed in [6].

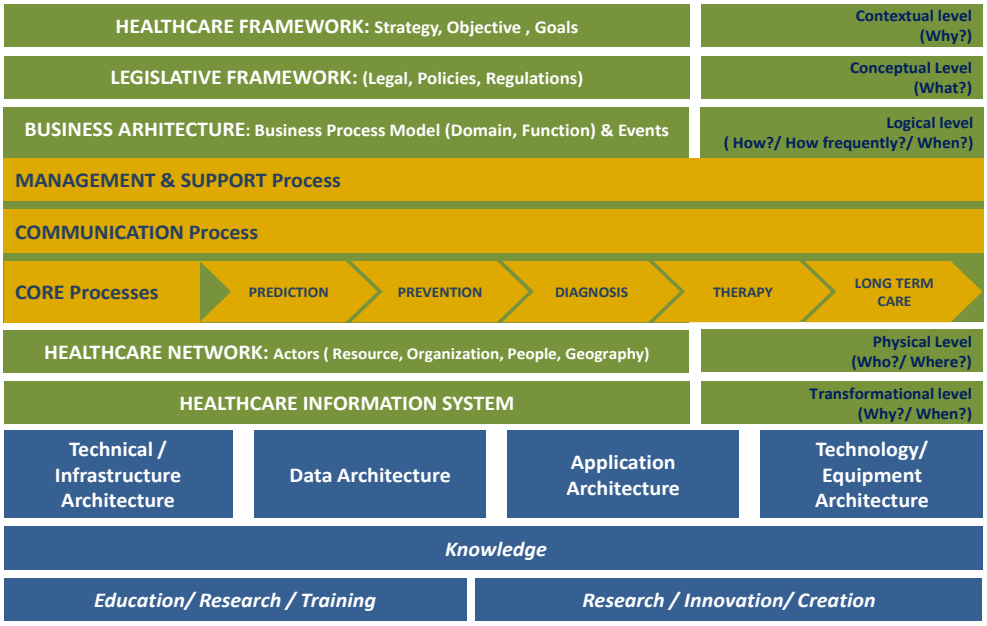

Fig. 2. Enterprise Architecture for e-Health system

The Technical Architecture is a very important part of the Enterprise Architecture, together with the Business Architecture and Information Architecture, as it is the base of the Enterprise Architecture, involving the use of Wireless Sensor Networks, hardware and software systems (servers, communication systems, database infrastructures, security, storage), as well as middleware solutions in order to assure the interoperability of the systems involved with the help of web services [14].

In order to achieve a comprehensive e-Health Framework several dimensions are addressed:

1. Enterprise Architecture implementations must focus on identifying: Strategy, Objective, Goals of an organization. This allows a careful consideration

and definition of what is appropriate and marks the highest priority for e-Health area.

2. The scope and strategy are completed by a legislative framework that allows for an appropriate behaviour for implementing and acting according to defined strategy. In order to integrate the Enterprise Architecture with the health care services, political and policy background is necessary.

3. Business architecture defines the following aspects: business domains, business services, Business networks, Business Process and Model (domains, functions). The Core processes (prediction, prevention, diagnosis, therapy and long term care) are different functions within the healthcare framework, executed automatically, based on the acquired data, integrating the different sets of rules at the communication level (taking into consideration protocols, standards, routing, network security, systems' interoperability, energy/efficiency).

4. Health systems are networks of actors: define resources, organizations, people, geography, actors, parties and roles

5. Healthcare Information System includes: Information management Principles Information Management Policies and Rules

6. Technical / Infrastructure Architecture includes: Hardware platforms, Data centers, Local and wide area network, Operating system interoperability (semantic and syntactic), Security Infrastructure, Client technology platforms, Protocols and technology choices

7. Data Architecture includes: Data model, Meta data dictionary, Classification. From the technical perspective, the data acquisition (as part of the data architecture) is made using several sets of sensors, grouped in different Wireless Sensor Networks. The communication is done by assuring the right level of interoperability between the central nodes placed according to the chosen topology. Thus, based on the chosen Business Architecture (taking into consideration the Policies and Regulations), the Enterprise Architecture framework is built based on the acquired data from sensors and involved actors.

8. Application Architecture includes: Software applications, Interfaces, User. The application architecture is based on the usage of web services [15], in order to assure the right workflow at the Business Level, as well as to take the right decision in the process of prediction / prevention / diagnosis and therapy.

9. Technology / Equipment Architecture. The technical layer is the bottom layer, integrating all the architectures involved in the Enterprise Architecture, including the technical architecture, the data architecture, the application architecture and the equipment architecture. With the development of the Cyber Physical Systems concept and implicitly, the Cyber Intelligent Enterprises there are a series of enablers that must be considered:

- Wireless Sensor Networks / MANET with low-power microprocessors / microcontrollers + improved battery technology,

efficient communication and routing protocols designed for low-powered devices and ad-hoc networks that will allow for self-organization / network flexibility, algorithms for the dissemination of collected data in the network / publish-subscribe

- Internet of Things as a reference architectures for integrating physical devices in existing IT systems.
- Semantic Web including ontologies, semantic annotation standards for data and business objects – services –semantic query languages
- Interoperability at data and information level.

10. As knowledge "is a fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information the architect must take into consideration the management aspect. In organizations, it becomes embedded. In this context, knowledge is supporting layer for e-Health framework in order to enhance the value of the personal capital solely by deployment of systems, processes and technologies.

11. Educational/Research/Training and Research / Innovation/ Creation are important steps to support and continue the improvement and changes of e-Health system.

As an integrant part of a proposed framework, it must also join its development and implementation methodology. In addition to methodology, it is important that enterprise architecture holds the set of methods, instruments and specifications of the target field which will be submitted in a storage field at each development and elaboration phase and will be further used and reused for future developments and implementations. The development of any enterprise architecture framework aims three main phases: the definition of the current situation, the definition of the target situation and the transformation phase, the transition from the current situation to the target one.

The methodology that we will focus on is the following (Fig. 3):

1. Analysis of the Health System's Objectives at the contextual level, focusing on the field of Rare Diseases [7];

2. Legislative Framework of the Health System for the conceptual level, focusing on the field of Rare Diseases;

3. Business related architecture for the development of clinical processes in specialized units, focusing on paediatric hospitals and patients diagnosed with rare diseases;

4. Actors and the collaborative network in the context of the eHealth system;

5. Information System for the Field of Rare Diseases, i.e. representation of the activity flow for the elaboration of the "Digital Record for Patients with Rare Diseases";

7. Specific requirements for the development of the information system used for tracking the record of Patients with Rare Diseases and the Digital Record of Patients with Rare Diseases.

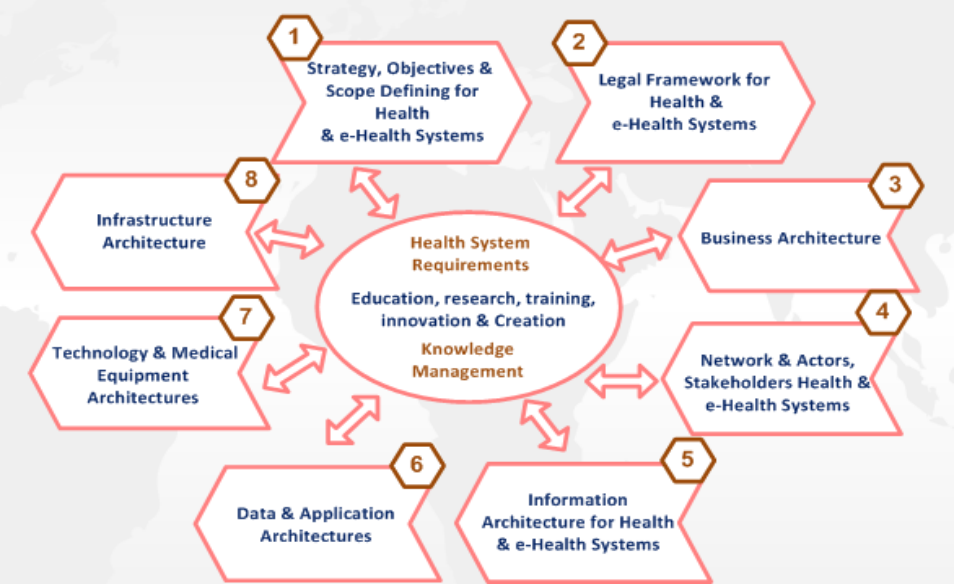

Fig. 3. Development methodology for the eHealth system

3. Business related architecture for the Health and eHealth System

According to the TOGAF definition [8],[10], "the business architecture is the systemic description of the interaction between the business strategy, organisations, functional organisation, business processes and information needs". This phase will cover: the performance motivations and metrics [12]; the strategies of medical care services; the organisational and functional structure; the description of clinical processes; the information needs for participants. Another aspect is the integration of interests for each group of actors and the way they will relate to the developed system.

The process based approach provides the possibility to organise and manage activities so that the organisation creates value for the final beneficiary and other interested parties. Companies are usually structured into a hierarchy of functional units.

A business process is a succession of activities unfolded in a constant manner, organised, managed and performed according to a logical flow that will achieve an organisation specific objective.

Four key components have been identified in the conceptual paradigm of the health system [9]:

1. Basic processes of the health care system: value creating chain related health services;
2. Support processes: purchases, financial accounting, managerial accounting, human resources, research, professional development, training and ICT;
3. Management processes: report, organisation, analysis of performance indicators, decision making;

The aforementioned components are integrated within the context of the regional and national health system; of the infrastructure (institutions, public health care, e-health infrastructure, etc.) and of the health legal framework: laws, norms, regulation, etc.

Fig. 4 shows the aggregate BPM under the form of a continuous cycle for the phases described. It contributes to the understanding of the role of technology in BPM.

We integrate the fragmented processes, we create the collaborative network where participants are coordinated and each actor has the holistic vision of the clinical process. A proper instrument for the achievement of this objective is represented by the Workflow Management Systems [11],[13]. According to the definition of the Workflow Management Coalition (WfMC), a workflow is the complete or partial automation of a business process where documents, information and tasks go through a predefined path from one participant to another for the completion of certain actions, in accordance with a set of procedural rules and with the patient's condition and with well-defined roles for those who intervene in the clinical process.

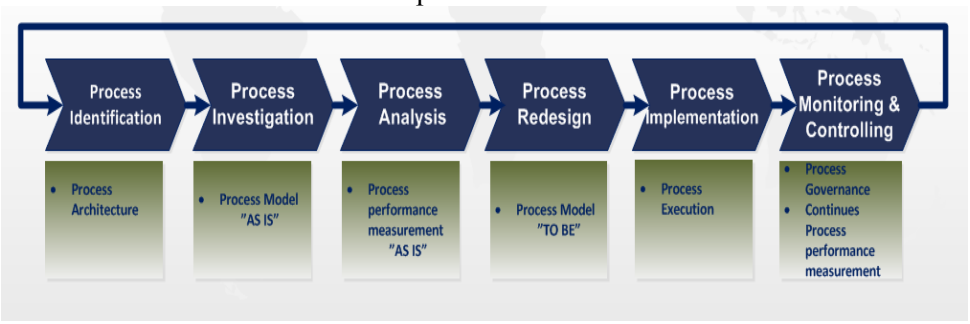

Fig. 4. BPM life cycle

Thus, Fig. 5 shows the actual representation of a workflow, performed in the ADONIS system and represented in Fig. 6.

A general process for the Digital Record of Patients with Rare Diseases (DDPBP) is represented in Fig. 6 where actors, documents, processes and information are integrated and arranged in an automated workflow, oriented towards the patient centred health services.

Due to the complex and dynamic number of clinical and business processes within the health system, there is an acute need for the elaboration of an optimal framework of transparency, coordination, collaboration and integration in view of the optimal, effective, fair and efficient management of the clinical trajectory.

Certain clinical processes are large consumers in terms of time and resources. Moreover, agility is required for the modifications occurred with regard to the requirements for diagnosis and treatment. For a group of patients affected by the same illness, a series of medical investigations and exams from various specialists may be required, but their order may differ from one patient to another. The objective is to ensure the coordination of medical care services in due and satisfactory time for the patient.

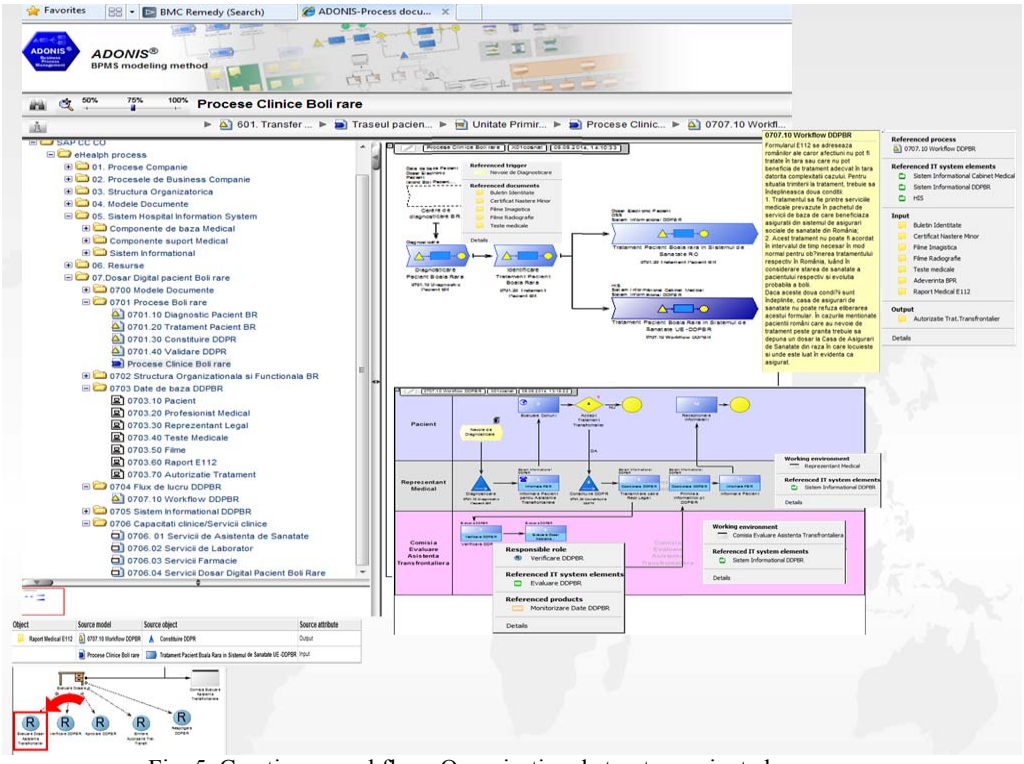

Fig. 5. Creating a workflow: Organisational structure oriented process

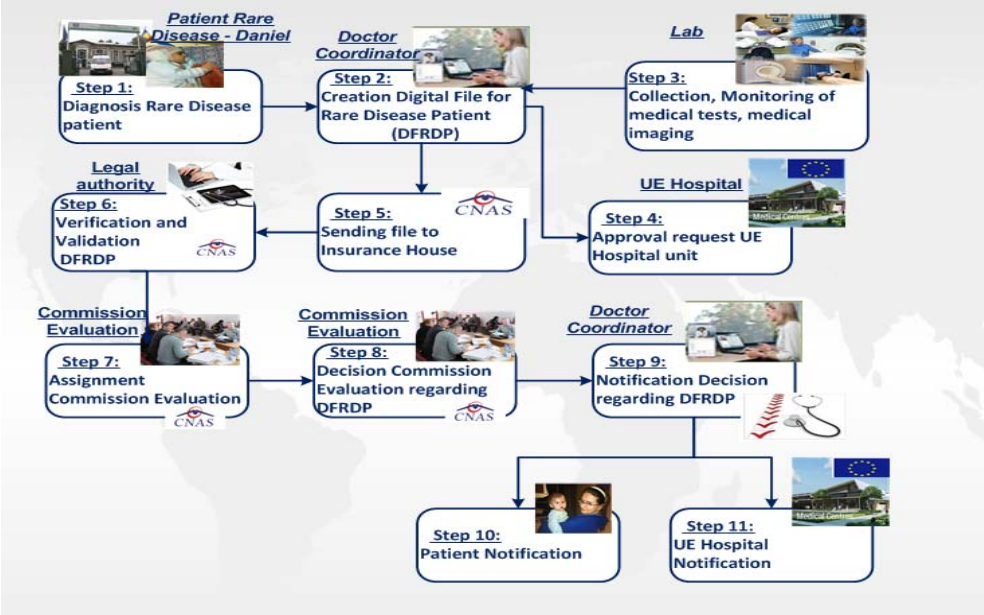

Fig. 6. DDPBR General Workflow

Currently, it is necessary that hospitals and legal authorities operate as components of an integrated health care system. The patients, the information flow, the innovating technologies, the information and communication systems, the medical care service providers, congruently coordinated, offer numerous opportunities for patients, larger traceability, flexibility and choice, as well as the increase of access to available services.

4. Conclusions

The research performed during the PhD study convinced us that a successful health system does not reside solely in the availability of medical service providers, but also in the level of penetration of the information and communication technologies used in the daily practice by all the participants to this important process. The adoption of ICT in the medical field is not completed through the purchase of new technology, but through the radical change of processes in this field.

The data exchange in the health information system provides the opportunity to gather, distribute and share patient related information in due time and encourages a more efficient use of resources.

EAeH provides the health system with a framework where the provision of medical services, the sharing of health related information, the mapping of data

and of clinical and business processes, the definition of the "veridical source" of standardised data represent an efficient basis for the measurement of the objectives established as compared to the results recorded by the health system or a specific selected field.

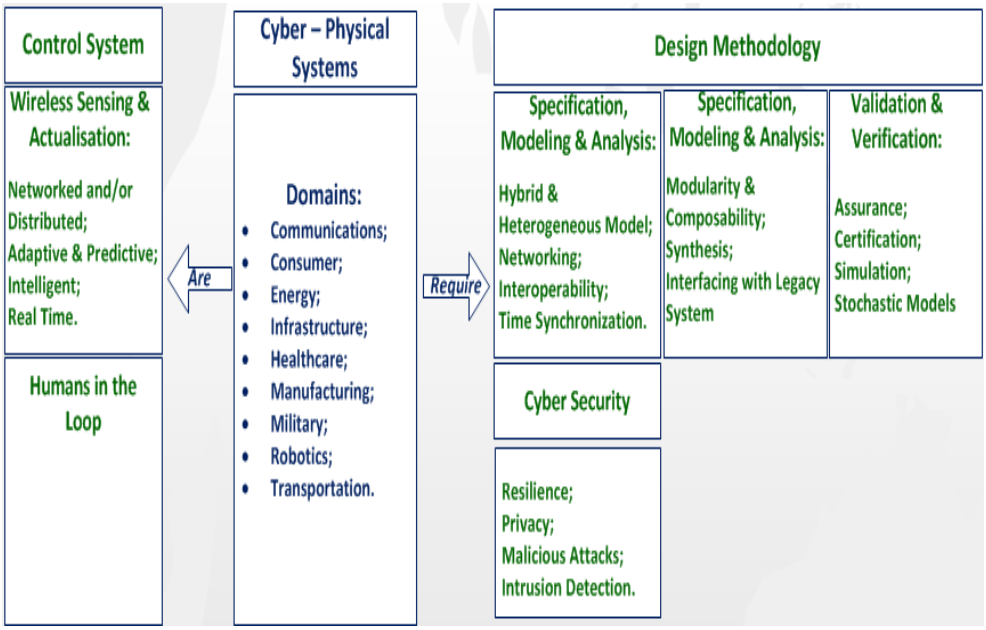

Fig. 7. Cyber Physical System conceptual pattern

The final benefit obtained from the implementation of an EAeH is the registration of all participants into an interconnected complex digital health system and the integration of the clinical workflow in a transparent, coherent, standardised manner that will decrease patients' pure delays and long waiting in order to benefit from cross-border treatment according to the legislation in force.

The perspective for the development of the research topic is possible within the integration of applications while preserving the interoperability features in the design methodology of the Cyber Physical Systems class, the conceptual pattern shown in Fig. 7.

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R E F E R E N C E S

[1] *Ludvig von Bertallanfy,* An outline of general system theory, Vols. 1, nr.2, British Journal
Philosophy of Sience, 1950.

[2] *W. Brian Arthur*, «The second economy,» 2011 McKinsey & Company.

[3] *Philip Kotler, Dipak jain, Suivit Maesincee*, Marketing Moves: A New Approach to Profi
Growth, and Renewal, M. Press, Éd., Bucure□ti, 2009.

[4] *D. Silber*, «The case for ehealth,» Presented at the European Commission's first high- le
conference on eHealth, May 22/23 2003.

[5] *Commission of the Europen Communities*, «Communication from the Commission to
European Parliament, the Council, the European Economic and Social Committee of the regi
on Rare Diseases: Europe's challenges,» Bruxelles, 11.11.2008.

[6] *Natalia Costetchi, Cristian Danila, Aurelian Mihai Stanescu*, «Enterprise System Architecture
sustain cross-domain eHealthcare Applications,» 2014.

[7] *The Council of the European Union* , «Council recommendation on an action in the field of r
diseases,» chez *Official Journal of the European Union*, Brussel, 2009.

[8] *TOGAF, «*The Open Group Architecture Framework,». Availab
http://pubs.opengroup.org/architecture/togaf811-doc/arch/toc.html.

[9] *Gartner* on behalf of The Ministry of Health and Social Affairs in Sweden, «Study eHealth fo
Healthier Europe! – opportunities for a better use of healthcare resources,» 2009.

[10] *W. Keller*, «EA Frameworks &TOGAF,» Potsdam, 2012.

[11] *Wil M. P. van der Aalst*, «Data Scientist: The Engineer of the Future,» , *Proceedings of the
ESA Conferences 7*, 2014.

[12] *Irene Papanicolas, Peter C. Smith*, «EuroREACH Framework for healthsystem performanc
chez *EuroREACH project*, 2010.

[13] *Wil van der Aalst, Kees van Hee*, «Workflow Management Models, methods and systems», M
Press, Cambridge, MA,, 2002.

[14] *Mihnea Moisescu, Ioan Sacala*, «Towards the Development of Interoperable Sensing Syste
for the Future Enterprise« Journal of Intelligent Manufacturing, March 2014, Print ISSN 09
5515, Online ISSN 1572-8145, DOI 10.1007/s10845-014-0900-0, Springer Eds.

[15] *Georgiana Stegaru, Cristian Danila, Ioan Stefan Sacala, Mihnea Moisescu, Aurelian Mil
Stanescu*, «E-Services Quality assessment framework for collaborative networks«, Enterpr
Information Systems Journal, Taylor & Francis Eds, 2014, pp.1-24, ISSN: 1751-7575 D
10.1080/17517575.2013.879213.