Toward IoT system project: BRICS Mosaic model and system engineering management

Marcel J. Simonette, Rodrigo F. Maia, José R. A. Amazonas, and Edison Spina

***Abstract*—**One of the targets of Internet of Things (IoT) systems is to provide access to any service, to any user, anytime, anywhere, regardless the access network technology or the type of user device. The development of these systems demand the evaluation of several dimensions that are present in an IoT solution, including the integrated management of the engineering effort throughout system life cycle. As our knowledge about IoT systems grows and evolves, so has our understanding about the need of a management process to conduct the system life cycle. The diversity of dimensions present in IoT systems demands a systemic management process to promote the system vision as a whole. This work presents the BRICS Mosaic Model and the Feasibility Barriers Factors to evaluate IoT solutions. It is a model that quantifies, through the developers' experience and analysis of application scenarios, a numerical relationship that allows identifying barriers to IoT solution development. This model is integrated with systems engineering management concepts, both to reduce a failure point, the managerial error, and to framework and guidance all engineering activities within the IoT system life cycle, from lust-to-dust.

***Keywords*—**Internet of things, systems management, systems modeling, socio, socio-technical systems.

I. Introduction

INTERNET of Things (IoT) is a concept that has several components, such as technology, human factors, business process, and engineering standards [1],[2],[3], and [4]. Model-based systems engineering build models to understand all engineering activities that are present in system life cycle; models allows systems engineers understand problems, develop candidate solutions, and validate their decisions [5]. IoT systems models demand a socio-technical approach because, besides technical and business components, IoT models must consider the environment, regulation rules and humans affect by the IoT solution [4], [6].

System models allow the identification of risks and obstacles to a solution implementation. They represent both the desire outcome of the system engineering design process and what the system will look like [7]. Furthermore, if the system to be developed will offer services for the stakeholders, system model must also allow the identification of the barriers to the offer and use of these services.

The successful implementation of systems engineering processes requires not only engineers' technical skills but managerial traits as well. The combination of technical skills and management principles allow systems engineers address both the technical and managerial issues that are present in systems life cycle [8], [9], and [10].

This paper illustrates how the BRICS Mosaic Model and its Feasibility Barriers Factors can be used to identify the barriers to system implementation and operation. It is an approach to model systems with a holistic approach and to identify the managerial traits necessary to steer the system life cycle from lust-to-dust. Section II is about the inherent complexity of IoT systems; section III presents an answer to deal with IoT complexity: the BRICS Mosaic model and the Feasibility Barriers Factors; section IV presents an application of the model; section V has the conclusion, some considerations about the model, and it is followed by the references.

II. IoT Complexity

Traditionally, engineering makes use of Cartesian approaches to model systems and to search solutions to problems. However, IoT solutions should be modeled by methods that allow engineering to go beyond the technological determinism; Cartesian models present limitations when used to model system of systems such as IoT solutions, that usually have components of different technologies, which are managed and controlled in an independent way. Also, IoT solutions have several layers in which there are interactions, not only technical, among components, but also interactions with people; without these interactions, the system could not execute the tasks that are expected by the stakeholders [4], [6], [11], [12], [13], and [15].

IoT complexity goes beyond the inherent complexity that exists in system components relationships, which are relations with little changes over time and which can be understood and foreseen. IoT solutions have dynamic relations among system

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components, and these dynamic relations characterize the IoT complexity as epistemic, as there are relations among components that are unknown by engineering; relations that engineers discover only when the system as a whole is working [13]. Human presence in IoT solutions, immersed in the ubiquitous environment created by the technology that enables IoT, is one of the reasons for unexpected relations to emerge in IoT systems.

Complex systems life cycle demands not only project management but a systems engineering management as well. Systems engineering managers rely on a combination of technical skills and management principles throughout system life cycle to address both technical and managerial issues. The theory about how the development process of complex systems are managed is limited, also the theory about the management of complex system life cycle. The challenge to address the technical and managerial dimensions of complex systems has become even more important as these kinds of systems are increasingly present in our society. Although there are basic management principles that are present in every engineering project, complex systems push the boundaries of systems engineering and management, the intrinsic innovation that exist in this kind of systems requires new kind of adaptation to risks, resources, and procedures during system life cycle. This adaptation is necessary to prevent accidents or system failures that may occur not only due to engineering issues, but also as a result of the management style used in these systems life cycle [8], [9], [14]. [16], and [17].

III. The BRICS Mosaic Model and Systems Engineer Management

To model an IoT system, it is necessary to develop a context-aware socio-technical model, which allows the representation of the knowledge diversity present in system context and stakeholders objectives [18], [19], [20], and [21].

Based both on concept plans of Next Generation Networks (NGN) [22], and on the results and experience of two projects of 7th Framework Programme for Research and Technological Development (FP7): CSA for Global RFID-related Activities and Standardisation (CASAGRAS2) [23], and Internet of Things Architecture (IoT-A) [24], the BRICS Mosaic Model represents the engineering and non-engineering aspects required for IoT systems. The Model provides a context for a representative concept that organizes the characteristics of the IoT universe into planes of a cylindrical mosaic, which are represented in Fig. 1. Each plane of the cylindrical model of the Mosaic allows the identification of a research area for IoT. That is the reason why the model is named as BRICS, an acronym to: Building blocks of Research for the Internet-Connected objectS.

IoT systems project success depends on proper management style. In other words, IoT projects may fail because systems engineer management may assume that these projects are "just another project". IoT systems complexity demands a systems engineering management framework that help systems engineers managers to identify the appropriate management style for each of the areas represented in the planes of the BRICS Mosaic [16], [25].

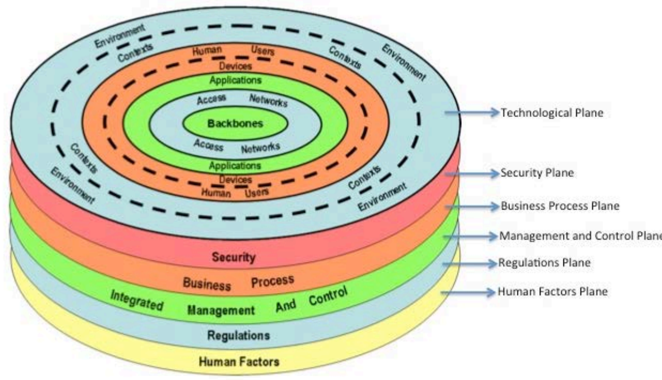


Fig. 1 BRICS Mosaic Model

A. *Mosaic Planes*

BRICS Mosaic planes represent solution views, and are considered “planes of functionality” (Fig. 1). The first plane represents the Technological view, and the other planes represent: Security, Business Process, Integrated Management and Control, Regulations, Human Factors, and Environment Sustainability.

Each plane has the same set of dimensions that drive, influence and affect the development of IoT services provided by IoT systems (Fig. 2). No single plane, and no single dimension of this plane, can yield a satisfactory model for an IoT system.

The BRICS Mosaic Model allows the identification of IoT system views about the main characteristics that drive, influence and impact IoT solutions. If any other view is identified in an IoT solution, it may be another plane in Mosaic.

B. *Feasibility Barrier Factors*

BRICS Mosaic Model represents the Feasibility Factors of each plane of functionality as the area between two concentric circles in this plane; each Feasibility Factor is a barrier, a restriction to be overcome. Also, each of these areas represents a different medium in which information is carried over. The concentric circles represent the fact that data can transit from any point to any other point.

All the planes of the cylindrical model have the same set of concentric areas. The first plane, Technological plane, is used to exemplify the areas model, and it is represented in Fig. 2. The outermost area is the physical environment itself; this area has a self-separation defined by a dotted circumference, which represent the fact that the Environment can have Contexts, or places. The same structure is used in the following area, which represents Human Users; in this area, the dotted circumference is used to represent the separation between humans and their computation devices (mobile or not). Other Feasibility Barrier Factors are Application, Access Networks, and Backbones.

The application area represents the applications that are executed in users devices; Access Networks are both wired and wireless networks, that use others networks to reach the internet Backbones, which are data routes among computer networks and internet routers.

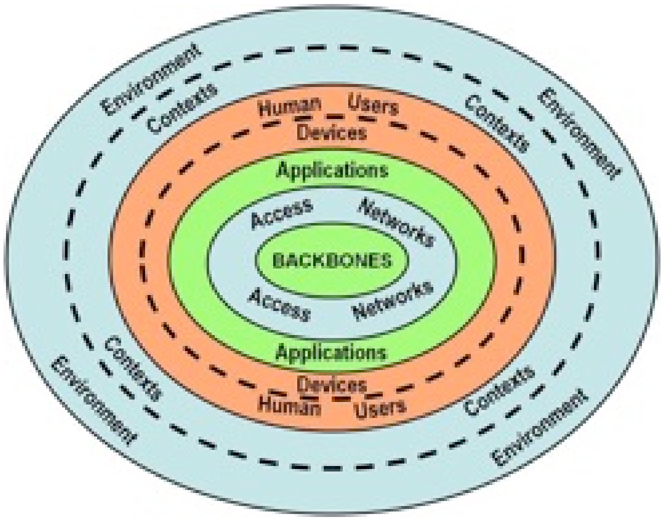


Fig. 2 Feasibility Barrier Factors

Although the walk though the Technological plane arrived to its center, it does not mean the end of an IoT solution. Usually, IoT solutions have services that are executed in service providers servers, and, to reach these servers, data must return through the Access Networks, Applications and service providers computers. And, in several cases, the data is processed by a service provider server and returns through to the user or environment. The typical path is the transversal path, as the represented in Fig. 3.

A typical scenario of a Mosaic plane has 11 components (Fig. 3). It is important to realize that some of these components may represent technological alternatives, while others may be technological requirements. For example, for component 5 in Fig. 3, technology such as WiMax, 3G, and LTE may be considered a solution to deploy the service or it may say that the service requires the possibility to be accessed by these two technologies.

The path represented by the black line in Fig. 3 depicts the kinds of technologies, applications, users, etc., that need to be involved to build the service. Also, these Feasibility Barrier Factors is present in the other planes: Security, Business Processes, Integrated Management and Control, Regulations, Human Factors, and Environment Sustainability.

C. *Systems Engineering Management Framework*

There are several texts and guidelines that present management frameworks for engineering projects. A sub-set of these publications is about the complexity that is intrinsic to systems engineering projects and reason that no single management style can fit all projects [26], [27].

Different project domains demand different management strategies. For instance, management strategies for building a sport car or a music player can be effective and efficient; however, both strategies are different [16]. Pat-Cornell [28] argues that to often the failures in engineering systems occurs due to organizational errors, which demands a link between project domain and management style.

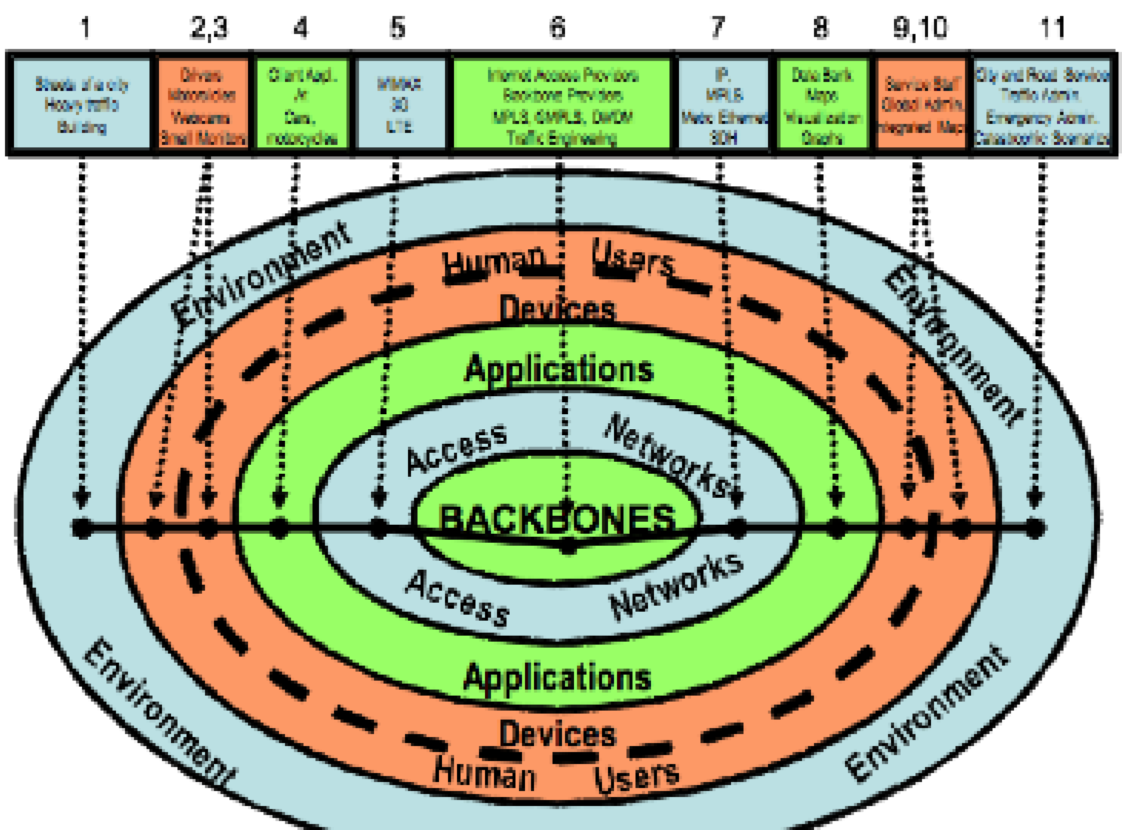


Fig. 3 The transversal path present in Technology plane of BRICS Mosaic applied to Assisted Living IoT service system

Shenhar and Dvir [25] proposed a project typology based in contingency theory for managing different types of projects. Saucer [16] argues that this project typology is the base for a framework that helps systems engineers to plan and execute the phases of a project with a correlation to a management style that includes systems engineering principles for a systems engineering management framework. This framework classifies a project in four dimensions: Novelty, Complexity, Technology, and Pace, it is called NCTP framework, which is used to evaluate the environment and the task to identify the right management style.

The four dimensions of the NCTP framework, and its sub factors, are [16], [25]:

1) **Novelty**: How new is the system (product and/or service) to the market: (i) *Derivative*: Extensions and improvements of existing systems; (ii) *Platform*: New generation in existing systems families; (iii) *Breakthrough*: Introduce a new concept, or a new idea, or a new use.
2) **Complexity:** How complex is the system: (i) *Assembly:* a collection of components in one unit, performing a single function; (ii) *System:* a complex collection of interactive elements and subsystems, jointly dedicated to a wide range of functions to meet a specific operational need; (iii) *Array:* Large systems, widely dispersed collections of systems (system of systems) that function together to achieve a common purpose.
3) **Technology:** Extent of new technology used on the system: (i) *Low-tech:* Rely on existing and well-established technologies; (ii) *Medium-tech*: Use mainly existing or base technology, yet corporate some new technology or new feature that do not exist in previous systems; (iii) *High-tech*: Represent situations in which most of the technologies employed are new, nevertheless, they exist when the system life cycle start; (iv) *Super-high-tech:* Based on new technologies that do not exist at system life cycle initiation. While the system mission is clear, the solution is not.
4) **Pace**: System project urgency and available time frame: (i) *Regular*: Efforts where time is not critical to immediate organizational success; (ii) *Fast-competitive:* Conceived to address market opportunities, create a strategic positioning, or form new business lines. Although missing the deadline may not be fatal, it could hurt profits and competitive positioning; (iii) *Time-critical:* System development completion is time critical with a window of opportunity; (iv) *Critical-Blitz:* Urgent systems developments to solve crisis or emergencies.

This framework allows the classification of a system project that defines characteristics that make the project endeavor unique in how it is managed. Fig. 4 shows the four dimensions on a graph, and the lines connecting the NCTP classification form a diamond that gives a qualitative representation of the level of risk associated with system life cycle.

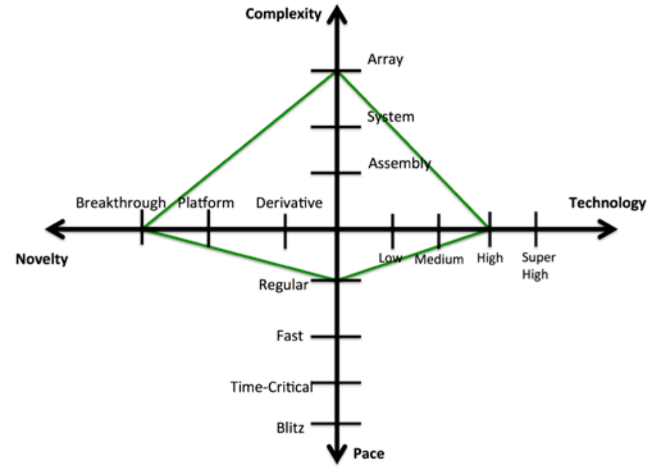


Fig. 4 NCTP framework graph example. The diamond in the graph gives a qualitative representation of the level of risk associated with system life cycle

IV. An Example of use of BRICS Mosaic Model

The objective of this example is to show how BRICS Mosaic Model and NCTP framework for systems engineering management can help engineers both to identify the difficult in deploying an IoT service, and to identify actions to be undertaken to enable the IoT system deployment and maintenance. The example is a case study of an Assisted Living IoT service to elderly people that live alone and need medical assistance.

The authors choose to use a case study methodology because this approach allows the characterization of real-life events, such as requirements constraints, and organizational and managerial processes. Furthermore, this approach allows the development of holistic view about the problem to be treat [29], [30], and [31].

According to BRICS Mosaic Model, the Assisted Living IoT service can be organized into planes: **Technological**, **Security**, **Business Processes**, **Integrated Management and Control**, **Regulations**, and **Human Factors** (Fig. 1). Each of these planes has the same Feasibility Barrier Factors - that are analyzed according to the diversity of events of the services. This is a qualitative analysis of the events, which gives values to the importance of the Factor to the service execution. The possible values to a Feasibility Barrier Factor (FBF) are: Very low (VL); Low (L); Moderate (M); High (H) and Very High (VH).

In the following items the line that represents a diameter in Fig. 3 will be walked, from one side to the other side of the cylindrical model, from FBF number one to FBF number eleven.

A. FBF 1: Environment – Contexts:

The environment for Assisted Living IoT service is a residential dwelling, an apartment or a house, with external yards/gardens or not. After identifying the Environment / Contexts, the next step is to analyze it in all the model planes.

Technological Plane: The environment has to be constantly monitored to check if the behavior of the user deviates from a normal pattern. Any deviation from what is considered normal has to be recorded, analyzed and a proper sequence of events has to be initiated. From the technological point of view, the scenario does not impose major barriers. The infrastructure is easily built and surveillance equipment is available in the marketplace**. FBF evaluation: VL**.

Security Plane: The surveillance equipment has to be protected against any intrusion. Any record of user's behavior data should not be stored longer than a specified amount of time defined by medical experts. Such data will be used only for diagnosis purposes by the medical team. All data must be encrypted and protected by passwords. Security demands by this scenario imply that the system solution must have a security certification; this may take a longer time to achieve. **FBF evaluation: H**.

Business Process Plane: The cost of the system implementation is of paramount importance. The service must be available for low-income people that have poor financial resources to pay for it. This means that public health institutions have to make an investment to provide the system. It is necessary to consider the difficulty in dealing with public health institutions, and to ensure that decision criteria looking for lowest prices solutions are not used, as equipment may not meet technical specifications. **FBF evaluation: VH**.

Integrated Management and Control Plane: There is not any management platform available for a service as Assisted Living IoT service. There is a considerable technical development to be made. **FBF evaluation: VH**.

Regulations Plane: The data that will be collected and manipulated by the system is private. Although privacy is not a consensus, there are serious debates about such topics, and usually there is a good interaction between the legal and the technical communities. **FBF evaluation: M**.

Human Factors Plane: It is a very important dimension of an IoT service. On the one hand, the service is meant for elderly people that may be quite resistant to adopt a technology. On the other hand, a mistake at the specification level may jeopardize thousands of lives. **FBF evaluation: VH**.

B. FBF 2 and 3: Human Users – Devices

There are two groups of users: elderly people that live alone, and the people that help them. The people in the first group need to be identified and automatically recognized by the system. In case of an event that is interpreted as threatening their lives, they should be able to trigger a sequence of events, such as calling an ambulance. The triggering action may be a simple phone call using either a fixed or mobile device. However, it is most likely that the person is in a situation that he/she cannot either reach or talk into the phone. In this case, it is necessary for the system to recognize the risky situation and to trigger the sequence of events. The second group of users is the people that need to trigger the sequence of events to help the people in the first group; usually they are relatives, neighbors, or caretakers.

As far as devices are concerned, automatic identification and data capture (AIDC) devices, along with presence and movement sensors, are necessary.

Technological Plane: Users have to be identified correctly and automatically. Also, his/her presence has to be detected as movement, as well. From the technological point of view, this scenario does not impose major barriers. The AIDC and surveillance devices may be found in the marketplace. However, an integrated solution has to be developed. **FBF evaluation: L**.

Security Plane: The users' personal data must be protected against any intrusion. All data must be encrypted and protected by passwords. Not all personal data should be displayed to anyone that takes part in the service. It is necessary to make a selection according to the role of the person in the service. For example, any medical record should be shown to a physician but not to the ambulance driver in the case of a user rescue. A certification process is necessary, and this requirement may demand longer then desired to be achieved. **FBF evaluation: H**.

Business Process Plane: The cost of the system implementation is of paramount importance. The service must be available to low-income people. Public health institutions must finance the devices to the user. Theses institutions have to make an investment to provide the system. It is necessary to consider the difficulty in dealing with public health institutions, and to ensure that decision criteria looking for lowest prices solutions are not used, as equipment may not meet technical specifications. **FBF evaluation: VH**.

Integrated Management and Control Plane: There is not any management platform available to a service such as Assisted Living IoT service. There is a considerable technical development to be conducted. It is necessary to develop interfaces to communicate with heterogeneous devices by means of a common platform. **FBF evaluation: VH**.

Regulations Plane: The data that will be collected and manipulated by the system concerns people's lives. Although there are serious debates about data privacy, it is necessary to consider that the availability of electronic record of medical data may speed-up the care to the patient. This is particularly important to the elderly, as they may have difficulties in explaining their health status. **FBF evaluation: VH**.

Human Factors Plane: It is a very important dimension of an IoT service. On the one hand, the service is meant for elderly people that may be quite resistant to adopt a technology. On the other hand, a mistake at the specification level may jeopardize thousands of lives. In addition, the easiness to use is a priority. It is not reasonable to imagine that elderly people will learn how to deal with the devices. The solution has to be completely automatic or based on devices with usability that are developed specifically to the elderly. **FBF evaluation: VH**.

C. FBF 4 and 8: Applications

The Application Feasibility Barrier has two components: Client Applications and Sever Applications. It is better understood by an example, such as when it has been detected that a patient needs help. In this case, the system has to call an ambulance and send the identification and localization of the patient (Client Applications). The closest ambulance should be sent, and receive the health data about the patient (Server Applications, and Client Applications). When the paramedic staff arrives and starts the emergency procedures, the staff may decide to consult a physician and to transmit the vital signals to him. If the decision for a removal is taken, an adequate hospital has to be selected. Adequate means: the closest one with the right equipment available. The best route to arrive at the hospital must be chosen, the hospital staff must be warned in advance about the procedure to be undertaken upon arrival and all paperwork sorted out in time.

Technological Plane: It may be considered a challenge. This is because IoT applications depend on different systems that must be available and integrated. For example, it is necessary to identify the availability of equipment in public hospitals. **FBF evaluation: VH**.

Security Plane: Vital signals and the information that someone is being removed from home due to health conditions represent very sensitive data. Despite having a reliable encryption technology, security violations of data administered by public authorities is a concern. A certification process is necessary, and this requirement may demand longer then desired. **FBF evaluation: H**.

Business Process Plane: The cost of the system implementation is of paramount importance. And it is necessary to identify the private and the public institutions that provide health services. Hospitals and Clinics must be identified and their services categorized. In summary, there is a very complex interrelationship among heath institutions that has to be modeled and a procedure has to be implemented. **FBF evaluation: VH**.

Integrated Management and Control Plane: There is not any management platform available for a service such as Assisted Living IoT service. There is a considerable technical development to be conducted. It is necessary to develop interfaces between different databases by means of a common platform. **FBF evaluation: VH**.

Regulations Plane: The data that will be collected and manipulated by the system concerns people’s lives. Although there are serious debates about data privacy, it necessary to consider that the availability of electronic record of medical data may speed-up the care to the patient. This is particularly important to the elderly, as they may have difficulties in explaining their health status. **FBF evaluation: VH**.

Human Factors Plane: It is a very important dimension of an IoT service. It is mandatory that the system be understood as providing service to people that are not able to provide information. It has to be fully automatized and to be a freeway to health care. **FBF evaluation: VH**.

D. FBF 5: Access Networks (Mobile)

Mobile access networks will be used either by the patient to contact the central service of the Assisted Living IoT system and by the paramedics to transmit voice instructions and vital signals to a hospital or to a physician.

Technological Plane: The FBF evaluation is based on the mobile phone network accessibility. Mobile networks are not a technological challenge. However, there are bandwidth limitations to be taken into account. **FBF evaluation: L**.

Security Plane: Security issues are an important point to be taken into account. However, it does not represent a more difficult challenge than that already faced by other applications that demand security in mobile networks. **FBF evaluation: L**.

Business Process Plane: The cost of the system implementation is highly important, and mobile communication is expensive. An appropriate business model has to be developed for the service to become economically feasible. **FBF evaluation: VH**.

Integrated Management and Control Plane: When there is a single mobile operator, the use of different technologies is not a barrier; appropriate management and control tools are available with the operator help. However, in cases in which different mobile operators have to be used, then a technological barrier has to be overcome. **FBF evaluation: M**.

Regulations Plane: Normative procedures have been implemented, but there is work to be done in order to classify the Assisted Living IoT service so as to reduce the taxes that may be charged. **FBF evaluation: M**.

Human Factors Plane: The mobile access network has to be transparent to the system end-user, and the health system staffs have to be adequately trained. It does not represent any challenge. **FBF evaluation: L.**

E. FBF 6: Backbones

The networks backbones will be used both by the patient to contact the central service of the Assisted Living IoT system and by the paramedics to transmit voice instructions and vital signals to a hospital or physician. It has to ensure Quality of Service.

Technological Plane: The FBF evaluation should consider geographical variables related to the availability of wide bandwidth backbones. An average situation may be considered to an initial evaluation, but to propose a real development, this backbones bandwidth has to be assessed. In order to ensure Quality of Service, the employment of virtualization is important. This technology needs to be understood and adequately developed. **FBF evaluation: H**.

Security Plane: Security issues are an important point to be taken into account. However, it does not represent a more difficult challenge than that already faced by other applications that demand security in backbones. Adequate solutions are in place and may be used by Assisted Living IoT system. **FBF evaluation: L**.

Business Process Plane: The cost of the system implementation is of paramount importance, and mobile communication is expensive. An appropriate business model has to be developed so that the service becomes economically feasible. **FBF evaluation: VH**.

Integrated Management and Control Plane: When there is a single mobile operator, the use of different technologies is not a barrier; appropriate management and control tools are available with the operator help. However, in cases in which different mobile operators have to be used, then a technological barrier has to be overcome. **FBF evaluation: M**.

Regulations Plane: Normative procedures are in place, but there is work to be done in order to classify the Assisted Living IoT service so as to reduce the taxes that may be charged. **FBF evaluation: M**.

Human Factors Plane: The backbones networks have to be transparent to all users. It does not represent any challenge. **FBF evaluation: L**.

F. FBF 7: Access Networks (Fixed)

The fixed access network will be used both by the patient to contact central service of the Assisted Living IoT system and by the application servers to transmit information.

Technological Plane: The fixed access networks, with its voice grade low data rate, may be considered an alternative for patients to access the Assisted Living IoT service. The fixed access network is much more important for application servers communication. In this case, high data rate and Quality of Service are very important. The technology is readily available in major hubs; however, it has to be improved in many cities to provide the adequate bandwidth. **FBF evaluation: H**.

Security Plane: Security issues are an important point to be taken into account. However, it does not represent a more difficult challenge than that already faced by other applications that demand security in fixed networks. Adequate solutions are in place and may be used by Assisted Living IoT system. **FBF evaluation: L**.

Business Process Plane: The cost of the system implementation is of paramount importance. An appropriate business model has to be developed so that the service becomes economically feasible. **FBF evaluation: VH**.

Integrated Management and Control Plane: When there is a single operator, the use of different technologies is not a barrier; appropriate management and control tools are available with the operator help. However, in cases in which different operators have to be used, then a technological barrier has to be overcome. **FBF evaluation: M**.

Regulations Plane: Normative procedures are in place, but there is a work to be done in order to classify the Assisted Living IoT service so as to reduce the taxes that may be charged. **FBF evaluation: M**.

Human Factors Plane: The interfaces of the fixed access networks devices are very old and quite well known by the end users. Its use does not represent any challenge. **FBF evaluation: L**.

G. FBF 9 and 10: Human Users – Devices

In this case, the human users are paramedics, Assisted Living IoT service administrators, and hospital and ambulance staffs. Devices are represented by handheld terminals, high definition displays, and multi-technology communication devices.

Technological Plane: From the technological point of view, the scenario does not impose major barriers. The required equipment can be acquired in the market. **FBF evaluation: L**.

Security Plane: The users' personal data must be protected against any intrusion. All data must be encrypted and protected by passwords. Not all personal data should be displayed to anyone that takes part in the service. It is necessary to make a selection according to the role of the person in the service. For example, any medical record should be shown to a physician but not to the ambulance driver in the case of a user rescue. A certification process is necessary, and this requirement may demand longer then desired. **FBF evaluation: H**.

Business Process Plane: The cost of the system implementation is of paramount importance. The server side of the system has a set of equipment that is less sensitive to cost than the set of equipment used by the patients. **FBF evaluation: H**.

Integrated Management and Control Plane: There is not any management platform available for a service as Assisted Living IoT. There is a considerable technical development to be made. It is necessary to integrate heterogeneous devices by means of a common platform. **FBF evaluation: VH**.

Regulations Plane: The data that will be collected and manipulated by the system is about people's lives. Although there are serious debates about data privacy, it necessary to consider that the availability of electronic record of medical data may speed-up the care of the patient. In particular, for elderly people this of paramount importance as they may have difficulties in explaining their health status. It is also important to discuss taxes both at service level and equipment import taxes. The increase in cost may prevent the deployment of the service. **FBF evaluation: VH**.

Human Factors Plane: It is a very important dimension of an IoT service. It is necessary to provide high quality information so that the decision making process is accelerated. **FBF evaluation: VH**.

H. FBF 11: Environment – Contexts

Assisted Living IoT service is a complex system and it needs to interact with other systems to be effective. Information from public hospitals and health care systems must be integrated. All the description has been based on the need of individual patients. However, a catastrophic situation should be considered, too. In this case, integration with the police and firearm forces is necessary.

Technological Plane: The communication among different systems administered by different agencies is a great challenge. A step-by-step development methodology should be employed using a platform that allows such modular approach to the development of system interfaces. **FBF evaluation: VH**.

Security Plane: The transmission of information among different administrations is a serious challenge. At this level, besides the protection of personal data, it is necessary to guarantee that the system will be robust against a denial of service attack, for example. A certification process is necessary, and this requirement may take longer than desired to be achieved. **FBF evaluation: H**.

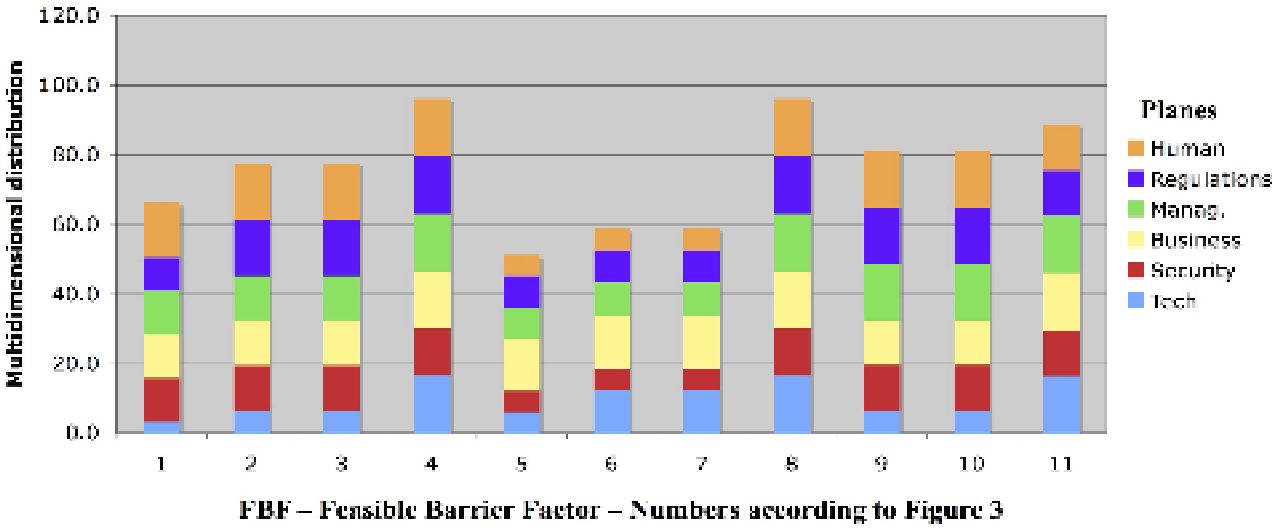


Fig. 5 Multidimensional distribution of the FBF values in Mosaic Planes

Business Process Plane: The cost of the system implementation is of paramount importance. Expenses and revenues from different stakeholders have to be taken into account. It is a difficult equation to be managed to guarantee an appropriate return on investment of a public service. **FBF evaluation: VH**.

Integrated Management and Control Plane: There is not any management platform available for a service as Assisted Living IoT. There is a considerable technical development to be made**. FBF evaluation: VH**.

Regulations Plane: The data that will be collected and manipulated by the system is about people's lives. Data privacy is not a consensus. However, there are serious debates about this topic, and usually there is a good interaction between legal and technical communities, when different entities are involved with privacy issues, the relationship between these entities turns much more complex. **FBF evaluation: H**.

Human Factors Plane: It is a very important dimension. In this case, it is a huge challenge to manage the point of view of the different people. It is necessary to develop a common view and understanding, so that a truly collaborative environment is created. **FBF evaluation: H**.

I. System FBF Evaluation

The same FBF set is presented in all Mosaic planes, and the first approach to understand these feasibility factors is to do a qualitative FBF evaluation. Afterwards, to consider and to compare all FBF in the system, it is used a simple translation table (Table I) to transform the qualitative information in numerical values. It is worth noting that the values in Table I have been chosen just to produce an example, and to show the importance of considering all the FBF simultaneously.

According to Table I, if an FBF has been evaluated as VH in all six planes, then the total evaluation is equal to 6 and this corresponds to a 100% barrier. If a FBF has been evaluated as VL in all six dimensions, then the total evaluation is equal to 1.2 and this has been arbitrarily set to a 10% barrier. Intermediate cases are evaluated by linear interpolation.

Table I: FBF translation from qualitative values to numerical values

FBF evaluation	FBF numerical value
VL	0.2
L	0.4
M	0.6
H	0.8
VH	1.0

Fig. 5 represents the presence of each FBF in each Mosaic Plane. This information is important because it shows the distribution of each FBF for each Mosaic Plane. This vision of the FBF allows the systems engineers to realize that although the system technological aspects are important, they are not the most critical ones. It is remarkable in figure that **Business Process**, **Regulations** and **Human Factors** are points of attention in the system development, as all FBFs have a remarkable presence in these Mosaic Planes. If these planes do not receive the necessary attention, the technological development will be a waste of time and resources, as the system will not meet its objectives.

J. Systems Engineering Management

The BRICS Mosaic Model and the FBFs of the Assisted Living IoT service to elderly people indicate three planes to which special attention is demanded: **Business Process**, **Regulations** and **Human Factors**. These different project domains demand different management strategies.

According to authors experience in systems engineering project and IoT systems, the Assisted Living IoT service as a whole has both technical and management challenges. The Novelty, Complexity, Technology, and Pace of this system as a whole - the NCTP framework - is represented Figure 4. The straight line that form a diagram in Figure 4 gives a qualitative representation of the level of risk associated with the IoT service development and maintenance. However, the FBFs and BRICS Mosaic Model indicate that **Business Process**, **Regulations** and **Human Factors** are points of attention in the system development. The NCTP framework may help systems engineers to identify if this IoT planes differ in its level of risk of the IoT systems as a whole.

The **Business Process** plane has Feasibility Factors such as the difficulty in dealing with public health institutions, the decision criteria looking for lowest prices solutions must not used, and the complex interrelationship among heath institutions. Also, the cost of the system implementation is highly important, and mobile communication is expensive. The values of NCTP dimensions to this plane are: Novelty = *platform*, Complexity = *system*, Technology = *Medium-tech*, and Pace = *Regular*. Fig. 6 represent the NCTP framework in which the solid line represents the initial authors approach to the IoT service development and maintenance, and the dashed line represents the approach specific to the **Business Process** plane. There is not a linear relationship between the areas of the two diamonds formed by the initial approach and the one specific to the **Business Process** plane, the visual difference represents a qualitative difference in the degree of risk and helps systems engineers to choose a managing approach specific to this plane characteristics.

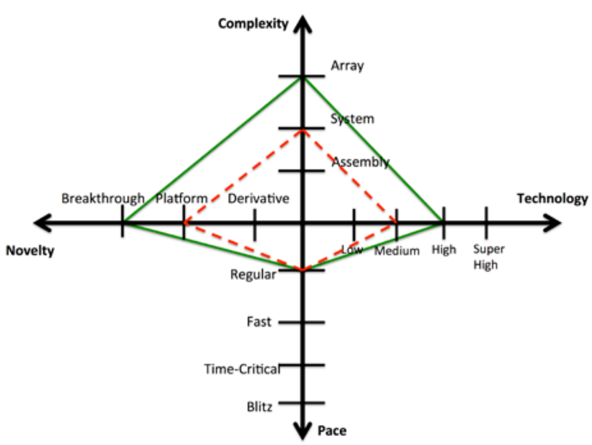


Fig. 6 NCTP framework for Business Process plane of the Assisted Living IoT service

The NCTP framework development for **Regulations** and **Human Factors** planes is similar to the **Business Process** plane; they are represented at Fig. 7 and Fig. 8 respectively.

V. Conclusion

The BRICS Mosaic Model aims to emphasize that other dimensions rather than the technological ones need to be considered in an IoT system, and that the interplay among these dimensions has to be understood to produce realistic models.

The FBF concept and the BRICS Mosaic Planes help to produce a global view of an IoT system. They capture system requirements and allow the development of a strategy to achieve results. This system model can be used to mobilize stakeholders that have the appropriate expertise and tools to deal with the identified barriers.

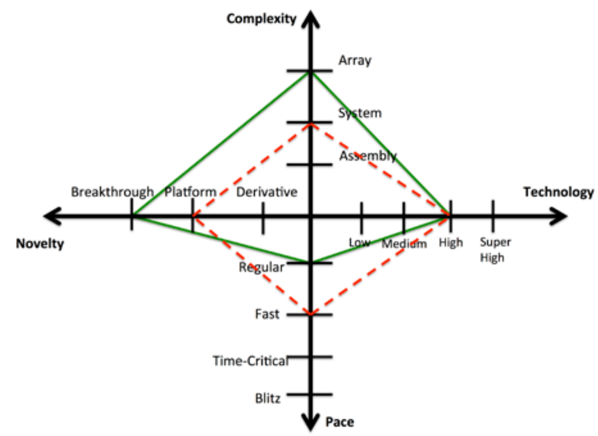
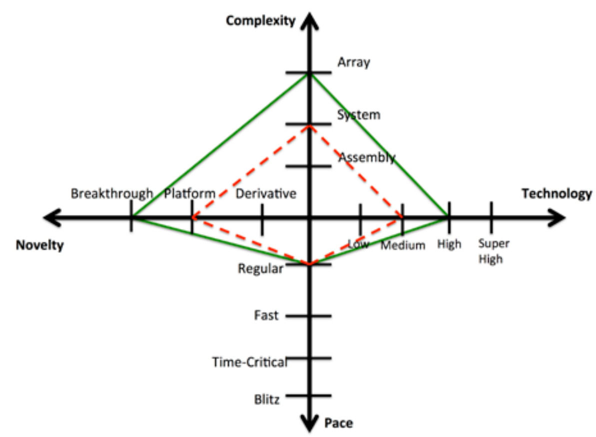


Fig. 7 NCTP framework for Regulations plane of the Assisted Living



IoT service

Fig. 8 NCTP framework for Human Factors plane of the Assisted Living IoT service. It has the same NCTP dimensions as the Business Process.

The combination of FBFs and NCTP framework for systems engineering management allows systems engineers to choose the right management skills for each IoT plane that drive, influence and impact IoT solutions. The identification of the NCTP dimensions and the appropriate management skills has significant impact on a system success, as a strategy to reduce a system failure point, the managerial error.

The example developed herein is quite simple. It is an ad-hoc assessment of a service. However, it is good enough to demonstrate the need to consider the multidimensional nature of IoT systems. Further development of this concept may pave the way for specifying a tool for system development that will take into account all the IoT planes and will enable to explore different implementation alternatives of services.

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