BRICS Mosaic Model for IoT Feasibility Barriers

MARCEL JACQUES SIMONETTE[1]
RODRIGO FILEV[2]
DENIS GABOS[1]
JOSÉ ROBERTO AMAZONAS[1]
EDISON SPINA[1]
[1]Engineering School
Universidade de São Paulo, São Paulo, Brazil
[2]Computer Science
University Center of FEI, São Bernardo do Campo, São Paulo, Brazil
marceljs@usp.br, rfilev@fei.edu.br, dgabos@larc.usp.br, jra@lcs.poli.usp.br, spina@usp.br

Abstract: The evaluation of the several factors involved in an Internet of Things design is a complexity activity. Although there are some systems models to evaluate Internet of Things design alternatives, few models identify and emphasize - at the same time - the importance of the interrelationship among the various technical components and among non-technical dimensions of these components. A design evaluation system model allows quantification of the technical and non-technical components that are the most difficult to be implemented, and that demands greater attention. This work defines the BRICS MOSAIC Model and the Feasibility Barriers Factors to evaluate Internet of Things system solutions. It is a model that quantify, through the developers experience and analysis of application scenarios, a numerical relationship that allows the identification of barriers to Internet of Things solution development. The Feasibility Barriers Factors allow the identification of each component, or dimension, that will affect the system development process.

Key-Words: systems modelling, internet of things, socio-technical systems, system of systems

1. Introduction

Internet of Things (IoT) is a concept that has several components, such as technology, humans relation, business process, and engineering standards [1], [2], [3], [4]. Usually, engineering has disciplines that allow the development of models, both to propose new solutions and to develop understanding about the impact of the solution in society. IoT 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], [5].

Systems models should allow the identification of risks and obstacles to solution implementation. Furthermore, when the solution has services that will be available for solution users, these models should also identify the barriers to the offer and use of services by their users. Our work propose the BRICS Mosaic Model and its Feasibility Barriers Factors to map the complexity of IoT systems; an approach to develop IoT systems models with a holistic approach, considering people, technology, and the relationship between them. In section II it is presented the problem: IoT systems complexity; section III presents our solution proposal to the problem: the BRICS Mosaic model and the Feasibility Barriers Factors; also, section III presents an application of the model; section IV has the conclusion, some considerations about the model, and it is followed by the references.

2. Problem Formulation – IoT Complexity

Traditionally, engineering makes use of Cartesian approaches to model systems and to search solutions for problems. However, IoT solutions should be modelled 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 independent way. Also, IoT solutions have several layers in which there are interactions, not only technical, among components, but also interactions with people; interactions that must be present to systems commit the tasks that are expect by the stakeholders [4], [5], [6], [7], [8].

IoT complexity goes beyond the inherent complexity that exists in system components relationships, which are relations with little changes over time and can be understood and foreseen. IoT solutions have dynamic relations among system components, and these dynamic relations characterized 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 [8]. Human presence in IoT solutions, immersed in the ubiquitous environment created by the technology that enables IoT, is one of the reasons to unexpected relations emerge in IoT systems.

3. Problem Solution – The BRICS Mosaic Model

To model IoT systems we developed a context-aware socio-technical model, which allow the model to represent interpretations of the knowledge that are present in system context. This model can represent the several components of a IoT solution, taking in account the specific knowledge background and objectives of the IoT system stakeholder [9], [10], [11].

Based on concept plans of Next Generation Networks (NGN) [12], and on the results and experience of two projects of the 7th Framework Programme for Research and Technological Development (FP7): CSA for Global RFID-related Activities and Standardisation (CASAGRAS2) [13], and Internet of Things Architecture (IoT-A) [14], we developed hypotheses regarding engineering and non-engineering aspects required for IoT systems. These hypotheses provided a context for a representative concept that organizes the characteristics of IoT universe into planes of a cylindrical mosaic, which are represented in Figure 1. Each plane has the same set of dimensions that drive, influence and affect the development of IoT services that are provided by IoT systems. No single plane, and no single dimension of this plane, can yield a satisfactory model an IoT system.

3.1. Mosaic Planes

Each plane of the cylindrical model of the Mosaic allows the identification of a research area for IoT. That is the reason because we also named it as BRICS, an acronym to: Building blocks of Research for the Internet-Connected objectS. These planes represent solutions views, and are considered as "planes of functionality". In our model, the first plane represents the Technological view, and the other planes represent: Security, Business Process, Integrated Management and Control, Regulations, and Human Factors.

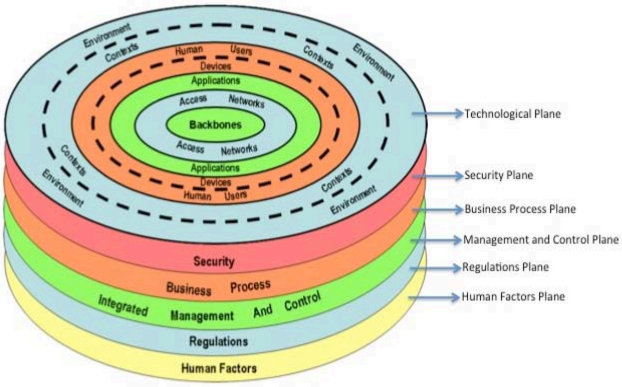

Figure 1 – BRICS Mosaic Model

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.

3.2. Feasibility Barriers Factors

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

All the planes of our 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 Figure 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 to 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 Barriers Factors are Application, Access Networks, and Backbones. 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.

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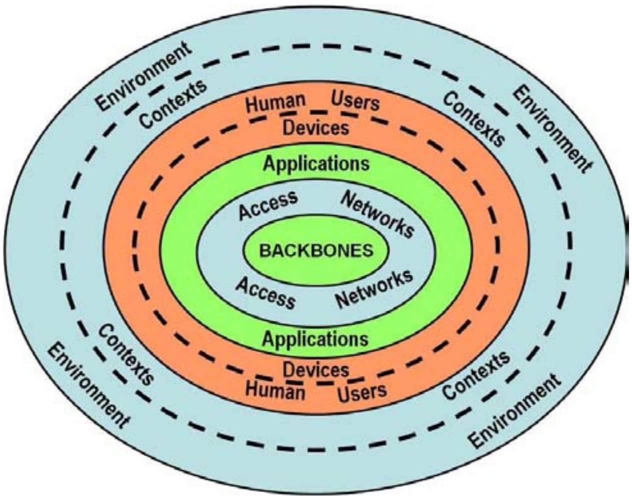

Figure 2 - Feasibility Barrier Factors

Although our walk though the Technological plane arrived to its centre, it does not mean the end of an IoT solution. Usually, IoT solutions has 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 service provider server and returns through to the user or environment. A typical path is a transversal path, as the represented in Figure 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 Figure 3, technology such as WiMax, 3G, and LTE may be considered as a solution to deploy the service or it may say that the service requires the possibility to be accessed by this two technologies.

The path represented by the black line in Figure 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, and Human Factors

3.3. An Example of use of BRICS Mosaic Model

The objective of this example it to show how the BRICS Mosaic Model can help engineers to identify the difficulties to deploy an IoT service, and also to identify the actions to be undertaken to enable the system deployment.

The case study in the example is an Assisted Living IoT service to elderly people that lives alone, and needs medical assistance. According to our system model, the IoT service is organizer into planes: **Technological**, **Security**, **Business Processes**, **Integrated Management and Control**, **Regulations**, and **Human Factors** (Fig. 1)**.** Each of these planes has the same set of components – Feasibility Barrier Factors - that we analyse according to the several events of the service. This is a qualitative analyse of the event, that 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 we walk the line represented in Figure 3, from one side to the other of the cylindrical model, from FBF number one to FBF number 11.

3.3.1. FBF 1: Environment - Contexts

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

Technological Plane: The environment has to be constantly monitored to check if the behaviour of the user deviates from a normal pattern. Any deviation from what is considered normal has to be recorded, analysed 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's are available in marketplace. **FBF evaluation: VL**.

Security Plane: The surveillance equipment has to be protected against any intrusion. Any record of user's behaviour data should not be stored longer than a specified amount of time defined by medical experts. Such data will be used only for diagnostics purpose by the medical team. All data must be encrypted and protected by passwords. Security demands by this scenario implies that the system solution must have a security certification, this may take a longer time to achieved. **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 the public health institutions have to make an investment to provide the system. It is necessary to consider the difficulty to deal public health institutions, and to work to not use decision

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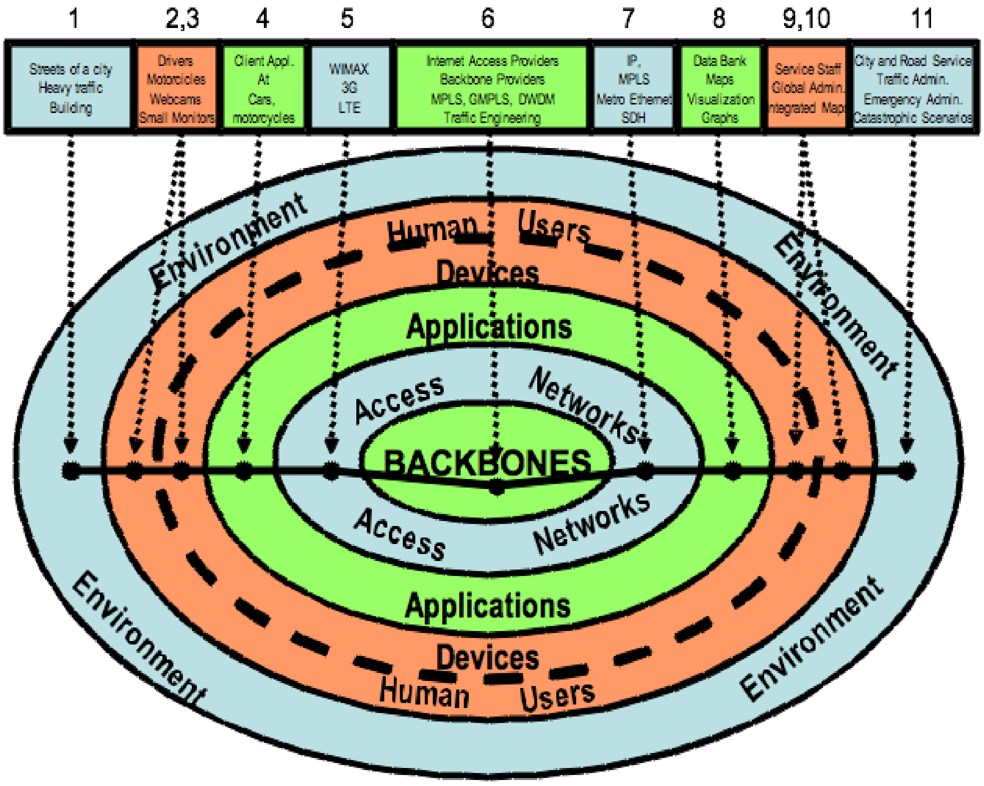

Figure 3 - The transversal path present in Technology plane of BRICS Mosaic applied to Assisted Living IoT service system.

criteria looking for lowest prices solutions that may not fulfil 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 huge technical development to be put in place. . **FBF evaluation: VH.**

Regulations Plane: The data that will be collected and manipulated by the system is about the life a people. Data privacy is not a consensus. However, there are serious debates about such topic and usually there is a good interaction between juridical and 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 target to elderly people that may be quite resistant to technology adoption. On the other hand, a mistake at the specification level may put in danger thousands of lives. **FBF evaluation: VH.**

3.3.2. FBF 2 and 3: Human Users - Devices

There are two groups of users: the elderly people that live alone, and the people that help them. The people in first group need to be identified and automatically recognized by the system. In case of an event that is interpreted as putting into risk their lives they may be able to trigger a sequence of events as, for example, 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 that the system recognizes the risky situation and triggers the sequence of events. The second group of users is the people that need to trigger the sequence of events to help the people of the first group; usually they are the relatives, neighbours, or caregiver.

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

Technological Plane: Users have to be identified in a correctly and automatically way. Also, his/her presence has to be detected as the 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 personal data of the users 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

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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. It is necessary a certification process, and this requirement may demand longer time 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 for low-income people that have poor financial resources to pay for it. The 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 to deal public health institutions, and to work to not use decision criteria looking for lowest prices solutions that may not fulfil 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 huge technical development to be put in place. 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 is about the life a people. 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 for 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 target to elderly people that may be quite resistant to technology adoption. On the other hand, a mistake at the specification level may put in danger 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 elderly. **FBF evaluation: VH.**

3.3.3. FBF 4 and 8: Applications

Applications Feasibility Barrier has two components: Client Applications and Sever Applications. It is better understood by an example, such as the case in which 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 the 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. It is necessary a certification process, and this requirement may demand longer time then desired to be achieved. **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 modelled and a procedure has to be put in place. **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 huge technical development to be put in place. 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 is about the life a people. 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 for 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 is not in condition to provide information. It has to be fully automatized and to be a freeway to the health care. **FBF evaluation: VH.**

3.3.4. FBF 5: Access Networks (Mobile)

Mobile access networks will be used either by the patient to contact 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 challenge more difficult than what is already faced by other applications that demand security in mobile networks. **FBF evaluation: L**

Business Process Plane: The cost of the system implementation is of paramount importance, and mobile communications is expensive. An appropriate business model has to be developed so 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 that 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 a work to be done in order to classify the Assisted Living IoT service in a way 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.**

3.3.5. 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. Such 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 challenge more difficult than what is 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 communications is expensive. An appropriate business model has to be developed so 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 that 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 a work to be done in order to classify the Assisted Living IoT service in a way 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.**

3.3.6. FBF 7: Access Networks (Fixed)

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 as an alternative to patient 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, but it has to be improved in many cities to provide the adequate bandwidth. **FBF evaluation: H.**

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Security Plane: Security issues are an important point to be taken into account. However, it does not represent a challenge more difficult than what is 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 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 that 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 in a way 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.**

3.3.7. 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. Examples of devices are 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 market. **FBF evaluation: L**

Security Plane The personal data of the users 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. It is necessary a certification process, and this requirement may demand longer time then desired to be achieved. **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's that is less sensitive to cost than the set of equipment's used by the patients. **FBF evaluation: H.**

Integrated Management and Control Plane: There isn't any management platform available for a service as Assisted Living IoT. There is a huge technical development to be put in place. 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 the life a people. 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 for 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 the decision making process is accelerated. **FBF evaluation: VH.**

3.3.8. FBF 11: Environment - Contexts

Assisted Living IoT service is a complex system and it needs to dialogue with other systems to be effective. Information from public hospitals and health care systems must be integrated. All description has been based on the need of individual patients. However, 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 big challenge. A step-by-step development methodology should be employed using a platform that allows such modular approach to the development of systems interfaces. **FBF evaluation: VH**.

Security Plane: The transmission of information among different administrations is a big 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. It is necessary a certification process, and this requirement may demand longer time then desired to be achieved. **FBF evaluation: H.**

Business Process Plane The cost of the system implementation is of paramount importance. Expenses and revenues from different stakeholders

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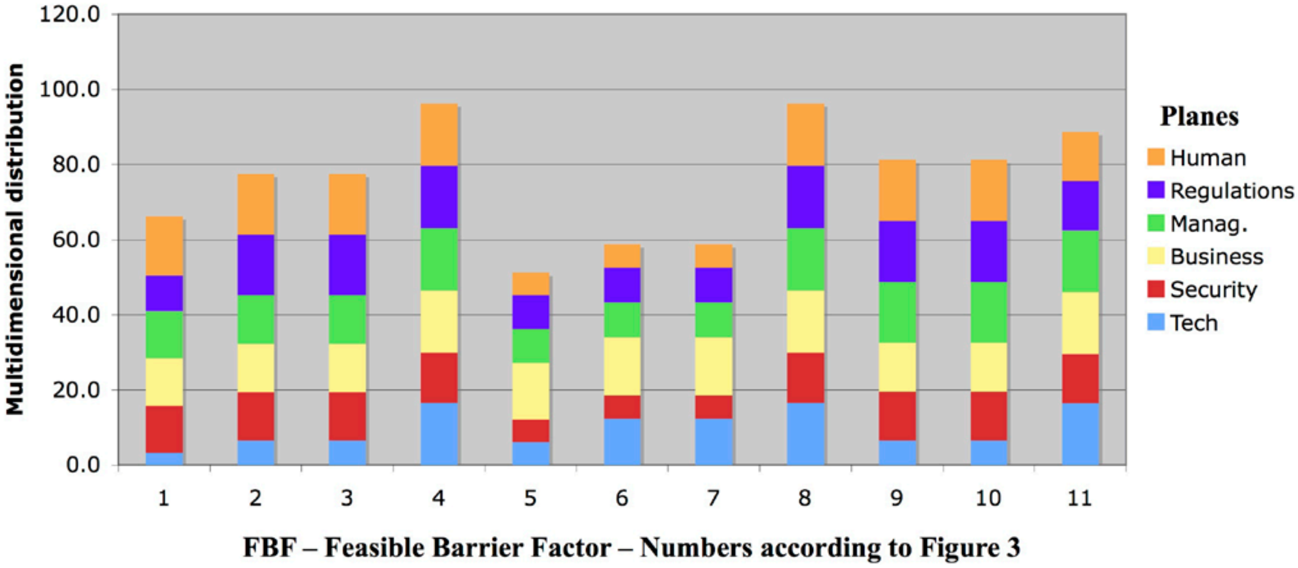

Figure 4 – Multidimensional distribution of the FBF values in Mosaic Planes.

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 isn't any management platform available for a service as Assisted Living IoT. There is a huge technical development to be put in place. **FBF evaluation: VH.**

Regulations Plane: The data that will be collected and manipulated by the system is about the people life. Data privacy is not a consensus. Although there are serious debates about such topic and usually there is a good interaction between juridical and technical communities, when different entities are involved with privacy issues, the relationship between these entities gets much more complicated. **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**.

3.3.9. System FBF Evaluation

The same FBF is presented in all Mosaic planes, and our first approach to understand these feasibility factors is to do qualitative FBF evaluation. Afterwards, to consider and compare all FBF in the system, we use a simple translate table (Table 1) to transform the qualitative information in numerical values. It is important to realize that the values in Table 1 have been chosen just to produce an example, and to show the importance to consider all FBF simultaneously.

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

TABLE 1 - FBF translation from qualitative values to numerical values

According to Table 1, 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 10% barrier. Intermediate cases are evaluated by linear interpolation.

Figure 4 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 is important because it allow us 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 FBF have a remarkable presence in these Mosaic Planes. If these planes do not receive the necessary attention, the technological development will be waste of time and resources, as the system will not fulfil its objectives.

4. Conclusion

The BRICS Mosaic Model has the objective of emphasize that other dimensions rather than the technological need to be considered, and that the interplay among them has to be understood to produce realistic models.

The FBF concepts, and the 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.

The example developed in this paper is quite simple or simplistic. 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 systems development that will take into account all the IoT planes and will enable to explore different implementation alternatives of services.

The interplay between all FBF and Mosaic Planes, and the appropriate way to assign numerical values to FBF is under research by our group at the Society and Technology Study Center (or, CEST – Centro de Estudos Sociedade e Tecnologia, in Portuguese) at Universidade de São Paulo.

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