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▶ **To cite this version:**

Fabrice Forest, Olivier Lavoisy, Valérie Chanal. Integrated Scenario-based Design Methodology for Collaborative Technology Innovation. The Future of Innovation (ISPIM - International Journal of Innovation Management), Jun 2009, Vienne, Austria. pp.99. halshs-00417935

HAL Id: halshs-00417935
https://shs.hal.science/halshs-00417935

Submitted on 18 Sep 2009

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Integrated Scenario-based Design Methodology for Collaborative Technology Innovation

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Abstract: The paper presents a scenario-based methodology developed and tested throughout cooperative research and development projects. It is aimed at supporting information technology innovation with an end-to-end Human and Social Sciences assistance. This methodology provides an integrated approach combining a vision of the potential users, business aspects and technological challenges throughout the design process. An original combination of different methods is proposed and experimented: user-centred design, scenario-based design, user and functional requirements analysis, business value analysis, user acceptance studies, and visualization methods. This methodology has been implemented in three European R&D projects, in the domain of the telecommunications and Internet infrastructure. The key contributions of this approach are that it unifies brings together visions of the users, potential business value and technology challenges thanks to scenario construction.

Keywords: Scenario-based design; user requirements; business economics; functional requirements, visualization.

1 Introduction

Technological innovation often requires large scale collaborative partnership between many heterogeneous and scattered stakeholders, organisations and expertises during the given time period of the design process. This is particularly the case when technological developments are oriented towards the elaboration of a new system or infrastructure rather than towards a specific product or service. There is then a challenge to build the

partners' common vision and to coordinate the stakeholders' roles into a continuous and coherent design flow towards a common objective. The scenario-based design literature proposes many methods to manage the different steps of the technology innovation using different types of scenario-based tools [], Nevertheless, there is no global and integrated method ensuring that the entire design process is continuously driven by a consistent, evolving and operational vision combining the technology challenges, business opportunities and user acceptance. The objective of this paper is to bring such a scenario-based design methodology to the Human and Social Sciences (HSS) research community involved in the design processes of technology innovations. Additionally, this methodology can be appropriated by technology innovation stakeholders to support or their collaborative projects.

The methodological approach presented in this paper has been developed and tested throughout several European research and development projects [] [] [] in the Information and Communication Technologies (ICT) in order to support the system design, taking into account both the end-user practices and potential conditions of acceptance and the business context. The elaboration of a scenario portfolio, of different nature, and at different phases is at the core of this process. We bring together different approaches developed in the design literature, but often presented and implemented separately: user-centric design [], scenario-based design [], user and functional requirements [], business modelling []. The idea is that a global approach is needed because these different methods are often based on similar concepts but do not dialog with each-other. The concept of value proposition for example, largely used in the business model literature in management, has to do with the user requirements or user acceptance, in so far it is necessary to apprehend what the user will finally value in the solution under development. The key contribution of this approach is that it turns Scenario-based Design from a simple engineering tool to an integrated management methodology for collaborative technology innovation.

In section 2, the context of the methodology is introduced along with the constraints in of the R&D projects within it was applied. Section 3 provides an overview of the entire scenario-based process and how it is supposed to interact with technological development. Section 4 describes the scenarios elaboration along with the making of artefacts such as audio visual demonstrators. Section 5 presents the scenario-based analysis of the user and functional requirements that drive the technology developments. Section 6 depicts the user and business acceptance studies which enable to refine the application scenarios and to derive final design recommendations for the technology. The concluding section 7 highlights the methodological findings, contribution and further developments of the presented approach.

2 Context of the research and development projects

The proposed scenario-based innovation method has been developed and implemented in a particular type of research and development projects which it is necessary to define in order to weigh the application fields. However, there are generic factors in these projects that could be common with other projects in different innovation fields, so that it is realistic to consider this methodology as applicable beyond the fields it was tested.

Application fields

There are common characteristics on the contexts where we have developed and tested the methodology. The research domain is the technology innovation in the area of information and communication technologies (ICT), in particular telecoms, Internet and ambient intelligence. Depending on the project, the technology innovation can focus on the software or hardware innovation (or both), system infrastructure or application oriented innovation, short or medium term industrial exploitation.

The project consortiums in which it has been tested are made of multiple partners, from seven to twenty: industrials (large companies and SMEs) and academics (most of them are technology institutes and universities). Their motivations (depending on their markets and industrial businesses), as well as their scientific and technology expertises, are heterogeneous. The partners of the projects are spread in a multiplicity of European countries and they are partially funded by national ministries or the European Commission. The total duration of the projects is from two to three years.

Scenario-based Design

Scenario-based Design is a conventional tool in the research and development area: computing and software engineering have developed it as a method for the technology innovation []. In particular, software engineers have developed the "use case" concept in order to model the human-computer interaction to design usable system and to anticipate the human-machine interfaces (ergonomics) in the design process. This is why the underlying principles of our method have been easily accepted by the project members who were familiar with key concepts such as "scenario", "use case", "scenario" "user requirement" or "functional or application requirement", "acceptability", etc.

However, most of the existing scenario-based methods are engineering tools dedicated to specific phases of the technology design process or to particular technology innovation (e.g. software engineering). It is commonly admitted that scenarios as design methods can be used to:

- "describe problems to be solved;
- catalyze interaction within a design team, thus improving teambuilding;
- facilitate user involvement in the early design;
- support collaborative design where all the participants don't need to know the technology;
- help in transferring and explaining design ideas;" []

Therefore, these methods are for the experts involved in specific tasks of the design process. From a design step to another one, using these methods involves sequentially technology pushed (use cases), user centred (functional analysis) or business oriented expertises (market segmentation, business models, etc.). Even in user centric approaches scenarios are used only to anticipate the user acceptance and usability as stated by Rosson:

> "The basic argument behind scenario-based methods is that descriptions of people using technology are essential in discussing and analyzing how technology is (or could be) used to reshape their activities. A secondary advantage is that scenario descriptions can be created before a system is built and its impacts felt" []

Business modelling methods use scenarios to envision how value can be created and captured from the innovative technology []. Consequently, not all the contributors' expertises are engaged in each design step. The risk is then a breakdown of the common stakeholders' vision and a drift between the initial design goals and the real technology developments. Therefore such a sequential approach requires iterative - costly and time consuming - loops in the design process to implement the findings or assumptions of each domain of expertise (e.g. user centric analysis, business analysis, functional analysis) involved in the understanding of use and market contexts.

This is why we think that an integrated approach would contribute to build a global and common vision throughout a design project. Such an approach would integrate from the beginning of the project a vision of potential applications of the technology for the users and business value creation and sharing.

3 Method engineering

This method cannot be performed by an isolated team providing "on-demand" a scenario expertise to the technology designers. On the contrary, it is key to bring together from the beginning of the project, various expertise, including researchers and engineers of the industrial partners themselves. To this extent, the design of the scenario "task-force" is very much a political decision. Indeed, each industrial member of the consortium will have some stakes to push in the choice of the application domains and the scenario, because it can then guide fundamental technological design choices. Moreover, the scenario team has to combine the technology, industrial and user centric expertises necessary to operate the basic components of the application scenarios: innovative technologies, market opportunities and society expectations. These three types of expertises will be pooled all along the scenario-based design process that combines three high-level phases: scenario elaboration, application requirements and acceptance studies.

Project organisation and structure of the scenario-based work package

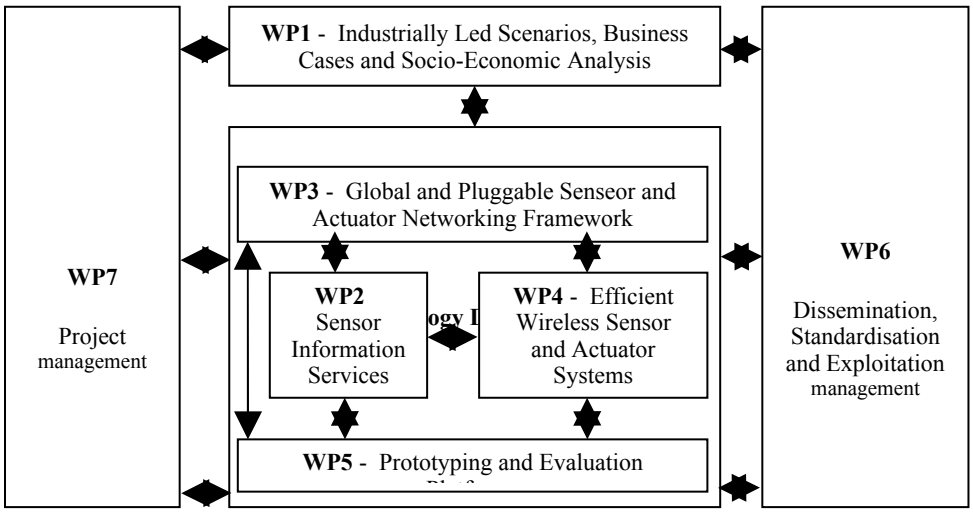
In the three projects in which our team were involved, the socio-economical tasks were grouped into one specific work-package (WP). The subtasks of this WP are typically reflecting the aggregation of different methods of scenario elaboration, user requirements definition, user acceptance, and business modelling:

1. Task 1 – Scenarios Elaboration
2. Task 2 – User and application/functional requirements
3. Task 3 – User and society acceptance
4. Task 4 – Business ecosystem and value network analysis

As stated before, our aim has been to build an overall coherence between these different subtasks in order to provide a global vision of the condition under which the technology can bring value on the market.

Moreover, this WP has to be coordinated with other technical work packages in order to provide guidelines for the R&D process. Figure 1 details the typical project organisation with WP1 scenario-based activities networked with the technology development. In the next section, the role of each subtask is detailed.

Figure 1 Work packages breakdown in SENSEI project [].



Industrial representation in the scenario work package

A key aspect of the project engineering is the composition of the scenario-based task force with a representative team of industrial expertise. The scenario process has to be supported by the industrial members who have to provide their knowledge (both market- and technological knowledge) for the scenario construction. This is a key foundation step which represents the real starting point of the scenario-based research because the pool of industrial partners will decide which application domains will be further investigated, according to their own interests. It does not mean that the technology will be applicable only in these domains but that the technology will be developed first according to the requirements and rationales of these domains.

As we suggested, this phase is quite political and there is a risk that an industrial partner tries to influence the scenario elaboration phase according to its own agenda. It is therefore important that the leadership of this scenario WP be given to a "neutral" team, namely researchers in the HSS field who do not have specific interests in the choice of target applications and who can play a mediation role between multiple interests.

At this stage it is crucial to take into account the overall objective of the R&D project when gathering the required industrial partners. In the ADAMOS project [], where the objective was to focus on adaptive mobile services for end-users, the application domain was represented by a telco operator whereas the technology expertise was mostly

provided by academic laboratories. In the SENSEI project, the objective was more to focus on the development of a new Internet infrastructure that could potentially address a variety of applications. In that case we have been cautious to bring together industrial partners representing a variety of application domains and also having different positions in the value chain, from service providers close to the end-customers to system component suppliers. In the SENSEI scenario work package, ten industrials are pooled to explore the application of the system architecture in a wide range of application domains. Only two were involved in ADAMOS project.

Coordination with technical work packages

It is important that the members of the scenario WP1 represent the variety of knowledge and business interest to build a consensual vision. But it is also important that this vision be disseminated in the other technical WPs so that people in charge of technological R&D can understand it and implement it in their daily work. To a certain extent, we need "boundary spanning" researchers, also involved in other WPs to translate the vision provided by the scenario work. For instance, as task 2 deals with the requirements, there is a key linkage task with the other technical work packages. Thus, in SENSEI project, the task leader of task 2 is an industrial partner also involved in the leadership of work package 3 in order to interface with the system architecture activity (Figure 1).

At last, as all for all development projects, the deliverables of the scenario activities – scenarios, requirements, acceptance evaluations and business analysis – have to be coordinated with the other work packages in order to support the technical developments. From that point of view, a critical issue for our methodology is that application scenarios have to influence the technology design from the very opening of the project. So it is necessary to deliver initial scenarios as early as possible to the other work packages in order to enable them to model the development tasks. We now turn to a detailed description of the different phases of the method.

4 Elaboration of the scenarios

The project starts with the industrially led elaboration of the project architectural vision and key concepts through a portfolio of scenarios. This section scenario depicts the making of the scenarios according to four combined dimensions: a storyline that depicts realistic usage contexts and functions in a narrative way, the user and society expectations, the business rationales and the technology challenges underlying each scenario. This is done jointly by the technology engineers, HSS researchers and industrial experts by using networking web-based collaborative platforms. Then, audiovisual showcases are created based on innovative graphics, animations and interactive techniques that are adapted to the targeted users and business actors.

Application spaces

The first step of the scenario elaboration is to define the application spaces with the partners. When the project objective is to develop end-user applications, then the scenario portfolio can be reduced to the amount of targeted applications. However, when the project objective is to design a system architecture for the infrastructure layer (e.g.

SENSEI real world internet framework), it is necessary to envision an extensive range of applications in order to cover the variety of requirements that could arise in diverse application spaces. For instance in SENSEI project, eighteen scenarios have been created within eight application spaces covering the variety of business domains of the industrial partners (Table 1).

Table 1 Application spaces and related scenarios in SENSEI project

APPLICATION SPACES	SCENARIOS		
Transport	Robot taxis	Multimodal traveller	Sustainable transport
Smart city	City information model	Smart places	Networked inhabitants
Building and Home	Intelligent & energy efficient home	Facility management	
Smart plant	Working in a plant	Smart factories	
Supply Chain management	Tracking in Supply Chains	Supply Chain Integrity	
Crisis management	Olympic games 2012 (7 use cases)		
Entertainment	Personal sport & fitness trainer	Enhanced game room	Smart Museum
Healthcare and wellbeing	Elderly lifestyle assistant	Personalised healthcare	

Source: SENSEI project, deliverable D1.1 "SENSEI Scenario Portfolio, User and Context Requirements

Within each application space, two to four industrial partners are pooled in order to inject their expertise of the domain in the given scenarios. The work is done collaboratively through face to face or phone brainstorming and also permanently through a web based collaborative platform (for example, in SENSEI project, a wiki platform was used). The overall coherence of the portfolio is ensured by the work package leader who is involved in each application space to coordinate the advancement of the scenario elaboration.

Portfolio

The need for a variety of scenarios not only justifies a portfolio but there are important extra grounds that could also justify a collection of scenarios, even for application oriented projects.

The first reason is that the features of the designed system can consist in interfacing or networking several applications. This is the case with SENSEI project which key feature is *horizontalisation* of sensor and actuator networks (SAN) usages in a variety of application domains: concretely, a given sensor or actuator network will be accessible and used through the Internet by multiple users of diverse services []. It requires a

portfolio of scenarios to model the requirements of such uses and re-uses of the same technology brick (e.g. a Sensor and Actuator Network) in different application contexts. So the scenario portfolio as a whole is used to characterise the system architecture specifications.

The second reason relates to the time perspective of the project objectives. Besides the application spaces, it is important for the project to identify with the time scope of the future applications to be developed. In the case of application oriented projects, the time scope is likely to be the end of the project, so short and medium term scenarios are prioritised. However, anticipating long term application and technology update can justify envisioning as well as visionary scenarios. In the case of infrastructure focused projects, the medium and long term approach is necessary because of the amount of the investment and the structuring outcomes of the designed technology in many application domains and for numerous stakeholders. Beyond a particular scope (short/mid/long term), the project may require to roadmap the lifecycle of the developed system in order to anticipate its technology evolution and to derive requirements for its deployment and upgrades. This is particularly the case for innovation projects in the infrastructure and architecture of the Internet. Internet components are not design and then used: the design continues "at the runtime" []. In SENSEI, the scenarios depict Future Internet perspectives from short, mid, to the long term involving different levels of societal changes, business innovation and technical feasibility []. Table 2 describes the SENSEI applications lifecycle in the Future City application space.

Table 2 Scenario-based Road mapping in SENSEI project.

Timeline	**Now >>**	**New >>**	**Next >>**
Scenario	Smart places	Networked Inhabitants	City Information Model
Society	Evolutionary	Visionary	Revolutionary
Business	Vertical	Hybrid	Horizontal
Technology	Incremental	Innovative	Disruptive

Source: SENSEI project, deliverable D1.1 "SENSEI Scenario Portfolio, User and Context Requirements

Thus, user and functional requirements are characterised to design the system for change at runtime, accepted by the progressively involved stakeholders and in line with the society changes. In particular, it enables to characterise key high level design goals of the designed system that should be *scalability* and *evolvability*.

Elaboration of the scenarios

Within each application space, several scenarios are created. According to Carroll [], application scenarios are "use-oriented design representations": scenario based design is a methodological approach to develop applications for the technological innovation by anticipating the user experience through narrative techniques. Using narrative techniques makes it possible to capture information about the users' expectations, practices, social identity, situation and environment. Moreover, scenarios enable to picture hypothetical "what if?" situations in order to anticipate doubtful use cases, extreme usage situations, or even very conditional services and applications that require validating design assumptions through further acceptance studies.

Application scenarios are described from the user point of view and "may include sociological information, technological resources and characteristics, elements of commercial interactions etc" []. Thus, our scenarios approach integrates the business, user and technology rationales in the narrative artefacts. Each scenario captures the results of the collaborative work processed in three clusters: the user and society rationales, the business rationales and the technology rationales that are underlying the storyline. Each task force of the WP1 is involved in the scenario creation depending on its expertise. Task 1 coordinates the creation of the scenario portfolio. Task 2 involves the technology innovation and the expected progress beyond the technology state of the art. Task 3 provides an analysis of user expectations, expected society changes and benefits from the technology. Task 4 analyses the business roles, opportunities and potential new businesses that are likely to support value creation. The scenario creation is the result of a collaborative design from user, business and technology perspectives.

User and society rationales

Task 3 identifies and analyses the user and society rationales that motivate the design of the innovating technology or system. These rationales are both benefits in terms of quality of life (e.g. mobility, security, wellbeing, citizenship, environment, etc.) and challenges in terms of potential negative impact (e.g. privacy issues, ethics, healthiness). Each scenario is instantiating some of these user and society benefits or challenges. The scenario portfolio is covering all these rationales through a variety of applications and usage situations.

These rationales are also used as a metric to control the way the scenario-led innovated system is aligned with its objectives in terms of user and society benefits. Thus, the way the scenario portfolio covers these objectives can be continuously controlled by mapping the objectives with the scenarios. For example, a key rationale of the SENSEI project is to contribute to the evolution of the Future Internet. Thus the Future Internet dimensions and expected benefits have been identified (*Future Networks, Internet of Things, 3D Internet, Internet of Services, Internet of Contents*) and mapped to the scenarios as depicted in Table3.

Table 3 SENSEI project contributions to the Future Internet dimensions.

Scenarios/Future internet	Networks of the Future	Internet of Things	3D Internet	Internet of Services	Internet of Contents
Robot Taxis	Yes	Yes	**No**	Yes	**No**
Multimodal traveler	Yes	Yes	**No**	Yes	Yes
Sustainable transport	Yes	Yes	**No**	Yes	**No**
City info model	Yes	Yes	**No**	Yes	Yes
Smart places	Yes	Yes	Yes	Yes	Yes
Networked inhabitants	Yes	Yes	**No**	Yes	Yes
Intelligent home	Yes	Yes	Yes	Yes	Yes
Facility management	Yes	Yes	**No**	Yes	**No**
Tracking in supply chains	Yes	Yes	May be	Yes	**No**

Supply chain integrity	Yes	Yes	May be	Yes	No
Working in a plant	Yes	Yes	No	Yes	Yes
Smart factory	Yes	Yes	May be	Yes	No
Crisis management	Yes	Yes	Yes	Yes	Yes
Personal trainer	Yes	No	Yes	Yes	Yes
Enhanced game room	No	No	Yes	Yes	No
Smart museum	Yes	Yes	Yes	Yes	Yes
Elderly assistant	Yes	Yes	May be	Yes	No
Personal health portfolio	Yes	Yes	May be	Yes	Yes

Source: SENSEI project, deliverable D1.1 "SENSEI Scenario Portfolio, User and Context Requirements

Using the user and society rationales as a rule ensures that the scenario portfolio is aligned with its overall scope. Additionally it enables to identify the weaknesses or to choose the priorities. In Figure 1, it is clear that SENSEI project has decide to prioritise its developments to contribute to the Networks of the Future, to the Internet of Things and Internet of Services, while 3D Internet and Internet of Contents were not considered as priorities.

Business value scenarios

The different applications which enable delivering services have strong economical and business stakes that must be investigated further for a better setting-up of any IT system. It is necessary to identify what is required for the future services to be attractive for the users and be produced at an acceptable cost and sold at an acceptable price; what are the overall context in which the system will operate: how constraints may impact the business environment, such as legislation or regulation. The core is the notion of value, tackled with a usage (see above) and business perspective accordingly.

The business value analysis is twofold actually. In SENSEI, the first leg is grounded on the scenario roadmap towards the extended internet to new services, devices and protocols, nicknamed "Internet of the Future" []. This roadmap in the city, as the example presented here, draws a dynamic thread to link the different analytical elements: the rationales (or motivations to enter the business), opportunities and benefits (to make business), the main stakeholders involved have been listed from the different scenarios along with some key success factors.

The first case evaluates the situation in a shopping as it could be rolled out already today. It involves a set of services to users of a limited area (e.g. a shopping mall). From a technical point of view, this type of service needs only incremental enhancements. The second one is dedicated to city-dwellers in mobile life style. It needs technology innovation as it will also comprise sensing of various physical phenomena and it needs also interconnection and interaction of heterogeneous communication networks serving together the covered places. The last one is the most futuristic scenario, as it extrapolates the second case to city-area wide coverage and aims to network the whole city.

From a business perspective, the short term case involves shopping mall's stakeholders federated by a neighbourhood of business interest. It represents the least integrated phase when the infrastructure of a mall is used for applications dedicated to the

stakeholders of this place. In the second one, additional malls are connected together in order to offer a broader and ubiquitous scope of end-user services. It implies the deployment of connections between different and separate areas in the city and starts to integrate different entities in extension to the shopping mall (e.g. private residential infrastructure). The last case presents a dynamic increase of supply and demand as well as just-in-time provision. It also supports the trend to reduce stocks in stores and to increase uptake of kind of 'you shop, we drop' services. Micro transactions and demand for behavioural intelligence pulls data provision markets. New business actors such as the transport sector enter the network in order to provide a new generation of services to the citizens and to regulate the prices depending on energy savings and the carbon emissions related to clients' purchases.

Technology rationales

The scenarios are also developed and analysed in terms of relations to the technology challenges within each technical work package of the project. The list of challenges is provided by each of the work packages considering the project objectives and the technology progress they target beyond the state of the art. This is a way to control how far the scenarios are relevant to cover the technology innovation within the project. It enables the work packages to identify how far their developments will contribute to the application scenarios. This way, they can anticipate the application requirements when developing the required technology specifications.

Table 4 shows an example of the scenario technology rationales of SENSEI WP3 mapped towards scenarios during the project. It clearly shows that the first challenge of WP3 ("Enabling tussle based model") is not enough reflected in the scenarios, so the scenario creation has to improve this aspect.

Table 4 Mapping of the scenarios compared to WP3 challenges in SENSEI project.

Scenarios/WP3	Enabling tussle based model	Context services framework	Management of WSAN, gateway, framework	Hetero-geneous, mobile, trusted WSANs	Scalability/ Nodes, islands…
Robot Taxis	Could be	Yes	Yes	Yes	Yes
Multimodal traveler	Could be	Yes	Yes	Yes	Yes
Sustainable transport	Could be	Yes	Yes	Yes	Yes
City info model	Yes	Yes	Yes	Yes	Yes
Smart places	Could be	Yes	Yes	Yes	Yes
Networked inhabitants	Yes	Yes	Yes	Yes	Yes
Intelligent home	**No**	Yes	Yes	Could be	**No**
Facility management	**No**	Yes	Yes	Could be	Yes
Tracking in supply chains	Could be	Yes	Yes	Yes	Yes
Supply chain integrity	Could be	Yes	Yes	Yes	Yes
Working in a plant	**No**	Yes	Yes	Yes	Yes

Smart Factory	No	Yes	Yes	Yes	Yes
Crisis management	Could be	Yes	Yes	Yes	Yes
Personal trainer	Could be	Yes	Yes	Could be	Yes
Enhanced game room	No	Yes	Yes	No	Could be
Smart museum	Could be	Yes	Yes	Yes	Yes
Elderly assistant	No	Yes	Yes	Could be	Yes
Personal health portfolio	Could be	Yes	Yes	Yes	Yes

Source: SENSEI project, deliverable D1.1 "SENSEI Scenario Portfolio, User and Context Requirements

This is a typical example of how technology pushed innovation is concretised and combined with user and business constraints in such a project. The application scenarios are not only legitimate from a user and business point of view, but also they have to support also the technology innovation which is a key evaluation criterion for the industrials and scientific stakeholders of the projects, as for the project backers.

Storytelling and scenario artefacts

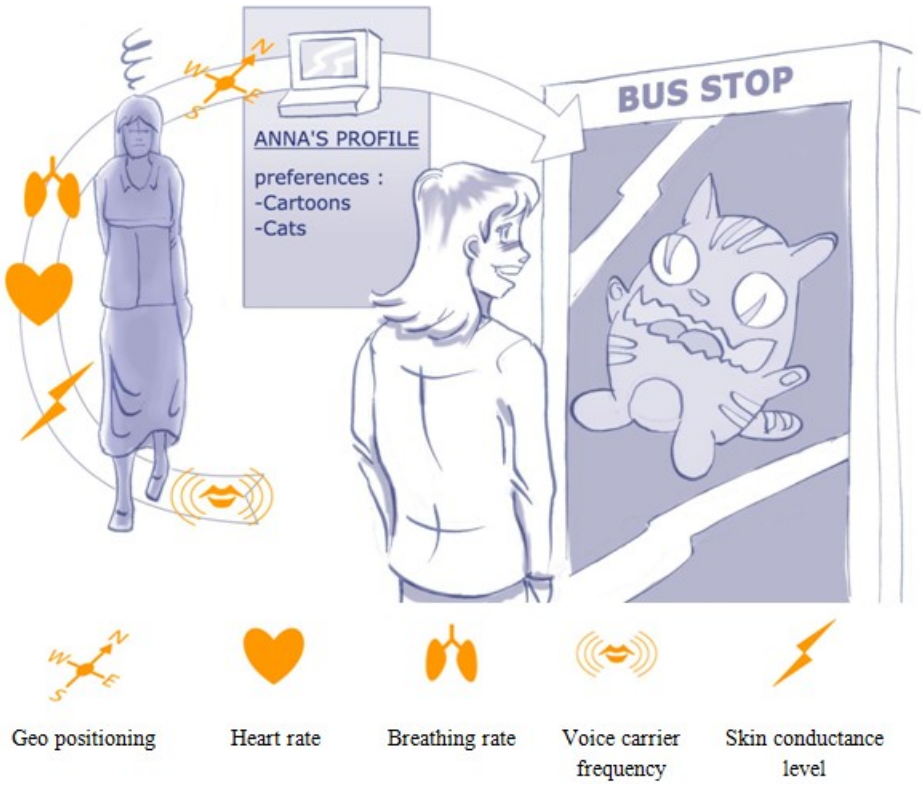
Once each scenario has been evaluated by the means of this framework and agreed as conform to the project scope (architectural vision, application space, user benefits, technological roadmap and business interest) it is wrapped up in a narrative and illustrative way in order to feed scenario portfolio. Below in Table 5 and in Figure 2 an example of a mood-based application scenario is presented as it can be seen in the e-SENSE scenario portfolio.

Table 5 Mapping of the scenarios compared to WP3 challenges in SENSEI project.

Happy Messaging - Anna is feeling depressed because of a recent argument with her boss. She normally takes the underground to go to work. On the way, her body sensor network (which is connected to her mobile phone) detects her negative mood, and activates specialised mobile services to cheer her up. Examples include jokes, family pictures slideshow, short funny clips, relaxing music, etc. Additionally, the application can trigger actions in the environment in order to adapt the surroundings to Anna's psychological needs (e.g., in the home environment, bus stop, shop, etc.).

Source: e-SENSE project deliverable D1.2.1, Scenarios and audio visual concepts, WP1, September 2006

Figure 2 Illustration of Happy Messaging scenario in e-SENSE project



Source: e-SENSE project deliverable D1.2.1, Scenarios and audio visual concepts, WP1, September 2006

This final wrap-up of the scenarios in a storytelling and illustrative manner support both the internal and external mediation role of the scenario-based design approach.

Internally, it captures the three-dimension pillars of the scenarios by synthesizing user, business and technology motivations and it is provided in the scenario portfolio along with these motivations. It also combines the industrial partners' expectations vision and it provides a common structuring reference for the project vision.

Externally, it conveys the project objectives, vision, challenges and contributions to the general public, industrial actors, scientific community and to the backers. Moreover, these narratives are to be submitted to the users and business stakeholders in order to evaluate the acceptance of the project vision and technology proposal and then to formulate additional design requirements and recommendation for prototyping and field trials.

In addition to the portfolio, some audiovisual artefacts, such as films or animated graphics, are created in order to support the presentation of the scenarios to the interviewed users and business stakeholders during field inquiries. It supports the dissemination and communication beyond the project through the website or during conference presentations.

For cost reasons, scenario artefacts cannot be done for all the scenarios of a portfolio. So the scenarios to be audio-visualised are selected according to multiple criteria:

- interest for testing user and society acceptance assumptions;
- interest for evaluation of innovative businesses;
- interest for representation of the technology innovation in the project;
- Interest for field trials, demos and prototyping: what we develop and demonstrate from a technology point of view is what we evaluate from a user and business point of views through the audio visual showcases.

Depending on the project objectives and worked concepts, different types of audio visual artefacts are created in order to optimise the presentation of the narratives, but also the presentation of the user, business and technology motivations that are underlying the designed system and its applications.

In the ADAMOS project we have created a ten minute movie telling the story of a day in the life of a archetypal user of the designed applications. The movie combines scenes in which the technology applications are demonstrated in appropriate situations. Each scene is presented through an ambivalent point of view: application benefits and assumptions about user acceptance such as privacy issues [].

In the e-SENSE project we made sixteen short movies combined with animated graphics. Each movie is demonstrating a specific context aware service in a particular application space []. It is split in two selectable scenes highlighting how the sensor-based system is perceptive to context variations, and the application reacts accordingly. Again, the critical user acceptance issues are considered and integrated in the scenarios through debriefing scenes in which the characters are expressing some reservation based on sociological assumptions to be evaluated.

In the SENSEI project we have created four audio-visual showcases using animated graphics. All scenarios are decomposed in three or four scenes and each scene is presented on four layers []: storyline, society rationales, business rationales and technology rationales that are underlying each scene.

In each case, these audio visual artefacts are realised in several languages in order to support further field inquiries with users in their natural language.

5 Scenarios analysis and requirements

In order to influence the technology developments, the scenarios have to be translated into functional user and application requirements held as a starting point for the system specifications in each of the work packages. This is the traditional justification of scenario-based design in software engineering which is involved in this approach and provided by task two. Decomposition into use cases and functional analysis of the scenarios enables to extract the high level requirements for the system design.

Functional analysis for application and user requirements

In SENSEI project, a set of system requirements has been synthesized from the entire scenario portfolio: the SENSEI framework must fulfil these in order to enable the creation of the services and applications in the context of the scenarios. As such, the system requirements outline the system functions in very broad terms, while not

imposing the technical choices or potential tradeoffs between requirements (specifications). To construct this list of system requirements, the scenarios and requirements are analyzed to identify specific system features. In the next step, these features are grouped into broadly scoped groups. So rather than, for example, specifying that "the SENSEI system should be able to sense temperature" (required in several of the scenario use cases), a more broadly scoped "Sensing Physical Environment of Sensors & Actuators" requirement summarizes the types of physical phenomena that might be sensed or actuated upon and broadly outlines different ways this can be done. The requirements are grouped into categories: Functional Requirements, Service Requirements, Network Requirements, Interaction Requirements, and Non Functional Requirements. Table 6 shows an example from the forty high level requirements synthesized from the scenarios. Each requirement is decomposed into tables that contain the following fields easily assimilated by the other work packages.

- Title (ID+name) - allows for easy referencing of the requirements.
- Type - unabbreviated requirement type.
- Priority - estimated relevance of the requirement for system applications. Some of the requirements are mandatory to indicate that this is a core SENSEI requirement. Other requirements are prioritized low, medium, or high to indicate their (more or less) optional status.
- WP holder: technical work packages where the corresponding developments are required
- Description - brief description of the requirement
- Rationales – arguments on the importance of the requirement from the application side.

Table 6 An example of functional requirement in SENSEI project

Title (ID)	**FU.9 – Locating sensor and actuator nodes or islands**
Type	Functional Requirement
Priority	Mandatory
WP holder	WP4 / WP2
Description	It may need to be possible to access the location of SENSEI islands or nodes within a island from the SENSEI framework.
Rationale	This is needed in some of the scenarios to correlate sensor information to physical locations or to identify the right actuators by location.

Source: SENSEI project, deliverable D1.1 “SENSEI Scenario Portfolio, User and Context Requirements

Functional analysis for context requirements

In e-SENSE project, the translation into functional requirements consisted in a top-down approach where each scenario were examined to extract context information building

blocks and then the latter were used to infer the system specifications []. Basically this functional analysis answers the following questions:

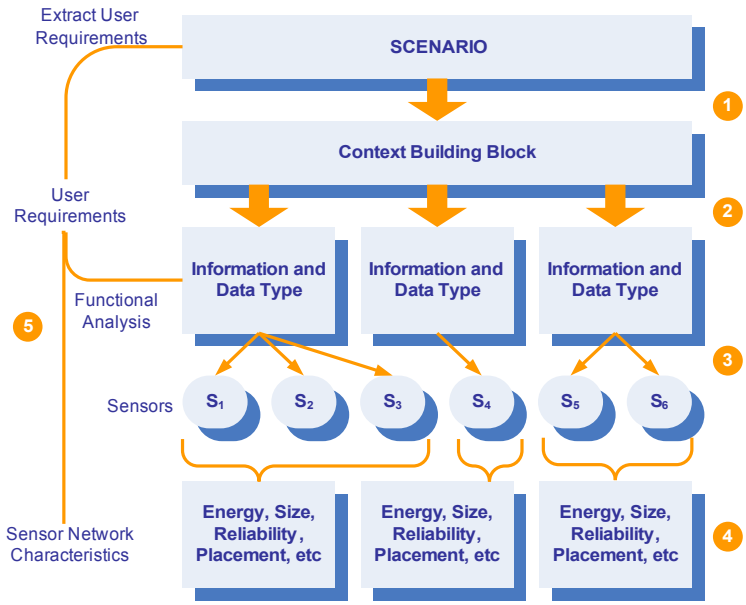
- What does the system have to be aware of within context?
- How can we describe the overall Context?
- What information is required to describe it accurately?
- When is the information required?
- The number of users (or more generally entities) connected to a given service
- Nature of environment (indoor/outdoor)

As summarised in Figure 3, the analysis framework is based on the derivation of a series of context information building blocks from each scenario, depicting their respective role in capturing context, and then decomposing each context building blocks into its possible components in terms of data and sensors involved for the capture. The scenario served as starting point, as it represents an instantiation of a given application of the e-SENSE system. It provides more descriptive rationales of how the user interacts with the system and how the user's tasks are carried out to achieve a certain goal.

By analysing the scenario, we derive the high level context elements (1), which contain the context entities and their current status. We refer to these high level context elements as context building blocks (CBB) because they are essential to the realisation of the scenarios and are in common with many other scenarios. Starting from these CBB, we identify the types of information needed to capture this context. Once the informational requirements are identified, we look for the types of data that lead to the definition of these types of information (2). Each data type hints at the sensor payload type (3).

Indeed, the results of analysis at each stage are summarised in a table where each context building block is associated with information and data types provided by the sensors. The sensors are grouped according to their classification (BSN, ESN, OSN) and are characterised in terms of quantifiable device characteristics (e.g. sensor lifespan, reliability, etc) (4). In parallel to this activity, user requirements are derived from the scenario (5).

Figure 3 e-SENSE analysis framework for context capturing requirements



Source: e-SENSE project deliverable D1.3.1, Functional Requirements for e-SENSE showcases, WP1, July 2006

Each functional requirement influences the characteristics of e-SENSE systems at two different levels: information and data level, and sensor network characteristics level (as indicated in the diagram above). The user requirements complement the above-mentioned top-down approach in that they help refine the characterisation of the system and provide justification to the design recommendations.

Scenario-based requirements for prototyping and system field trials

At last, the scenarios are not only used to influence the system design but it also contributes to the evaluation plan of the designed system through prototyping and field trials. In the SENSEI project this implementation phase corresponds to work package 5. Through field trials, the prototyping and evaluation plan aims at demonstrating the technology progress from the project and evaluating the system performances through small scale applications that are aligned with the scenarios. Thus the scenarios of the field trials are elaborated to demonstrate the key features of the designed system and the significant technology innovation from the development work packages.

As the prototyping and field trials are implemented at the end of the project life to demonstrate the research and development results, it enables to integrate also the results of the user and business acceptance studies from task 3 and 4 (detailed in next section 6). Actually, these acceptance studies make it possible to refine and to adjust the initial requirements with the real user and business stakeholders' assessment. Thus, it influences the prototyping and field trial demonstrations in two ways:

- It provides the user and business evaluation of the system with functions to be prioritised because these are crucial for the usages and for the business viability. Thus, among the initial design goals and functional requirements, it allows the field trials to select and to demonstrate the essential system building blocks have been

realised.

- It provides the user and business expectations in terms of performance level and quality of the services enabled by the system functions. Thus, it supports the prototyping task in drawing the scale of the field trials and in proof testing the appropriate parameters.

Through these final recommendations to the system developers the scenario-based process is able to support the system design until its final stage so that the outcome prototypes demonstrates the technology innovation for a system with business value and accepted applications.

6 User and business acceptance studies

The application scenarios synthesise a technology proposal to the users and business stakeholders. In parallel with the translation of the scenarios into functional requirements, it is necessary to evaluate this proposal from the real usage and business point of view. For that purpose, the scenarios are submitted to sample groups of users and business actors through audio visual artefacts. Then, interviews enable to get user or business actors' assessments that are in turn translated into additional or refined requirements for system design and prototyping as well as recommendations for the application release.

User and society acceptance study

The field of the user and society acceptance study strongly depend on the project objectives. For upstream and infrastructure oriented innovation projects, as SENSEI, the users to be in direct interaction with the designed system are professional and industrial users, in particular information and communication system engineers and designers who use the system to build some SENSEI-enabled application and deliver these through services to the end-users. For downstream and applications or services oriented projects, the users to interact with the designed technology are general-public or professional end-users. Thus, depending on the project focus, the sample group of the user acceptance inquiry will involve these different user categories. The specificity of a system user oriented inquiry is that the different user profiles in terms of technical expertise should be interviewed, e.g. engineers, service providers etc. In the end-user oriented inquiries, the standard social and occupational categories are investigated along with sociological user profiles towards technology [].

For both approaches and user categories, the user acceptance study consists in measuring to which extends the new high-tech system is matching the following criteria:

- Existing know-how and techniques;
- Their existing everyday or professional practices;
- Their user identity or professional role;
- Their social environment or their industrial sector.

These dimensions are evaluated through CAUTIC method (User Oriented Design for Technology, Innovation & Change) which is a sociological qualitative method for

investigating the user experience that is shaped to the study of user and social acceptance of innovative services and applications []. The CAUTIC method is based on a sociology of user experience tool derived from the sociological user centric studies [] []. Through user experience criteria, it enables to measure how the changes introduced in the user's existing way of life or professional activity will convert into continuity (evolution) or into break (revolution). The basic assumption of the sociology of technology usages is that revolutionary concepts are risky in terms of users' acceptance. The recommendations derived from the analysis of users' feedback to the concept presentation are aimed at reducing the risk of rejection on each acceptance criteria by identifying and adjusting the gaps between the new system characteristics and the users' ways of doing and working.

In the ADAMOS, e-SENSE and SENSEI projects this method has been applied to investigate the user experience of the designed innovation. The interview questionnaire explores the acceptance criteria and the interview analysis enables to identify the positive aspects (usage attractors) of the tested innovation, the weak points (usage inhibitors), and the usage conditions to the usage. The weaknesses and conditions are particularly interesting to elaborate the final recommendations to the designers in order to improve the system features. The positive points are also exploited to identify the level of quality and performance expected by the users on key features.

The specificity of the ADAMOS and e-SENSE projects is that the cultural factors have been considered by submitting the tested concept to sample groups in different countries. As the ADAMOS [] and e-SENSE projects were focused on applications for the end-users, it enables the designers to consider the cultural factors in the way they design the application depending on the cultural background. Table 3 synthesizes the results of the CAUTIC acceptance study in the e-SENSE project and shows the cultural variations between the three investigated countries. The acceptance is stronger in France and Spain compared to Germany. The reluctance of the users towards the e-SENSE concept is particularly significant on the *Identity* aspect: the qualitative analysis enabled to understand that this negative point was mainly due to privacy issues in the e-SENSE context sensing.

Table 7 – Sample groups' response to CAUTIC criteria in e-SENSE acceptance study

	1. KNOW HOW				**2.PRACTICES**				**3.IDENTITY**				**4.ENVIRONMENT**			
Criteria	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
France	**P**	**P**	**C**	**C**	**C**	**C**	**P**	**N**	**N**	**C**	**C**	**C**	**P**	**C**	**N**	**C**
Germany	**P**	**C**	**C**	**N**	**N**	**C**	**C**	**C**	**C**	**N**	**N**	**C**	**P**	**N**	**N**	**P**
Spain	**P**	**P**	**C**	**N**	**N**	**C**	**P**	**N**	**N**	**N**		**P**	**P**	**C**	**N**	**P**
Caption	**P**	*= Positive*			**C**	*= Conditional*			**N**	*= Negative*				*= Not encodable*		

Source: e-SENSE project deliverable D1.4.1, Report on evaluation of human impact, WP1, June 2007

Such a mapping of the user experience enables to provide design recommendations and to find out the appropriate system answers to optimise the usages. In addition, such analysis of the usage value is complementary to the analysis of the business value which is conducted in the parallel business field study.

Business fields study

The second phase of the business analysis may have different patterns, but they all aim at describing the business context, often called the "business eco-system" where the economical perspective is based on a biological metaphor []. The collection and definition of business roles and their relationships between each of them contribute to the analysis of business models that are viable for all IT applications.

In e-SENSE, the focus is drawn on the applications. Therefore, the investigation is carried on the stakeholders themselves, for whom the applications are designed. The business inquiry aims at positioning the various stakeholders into a value network that can bring value for all of them to ensure the equilibrium of the business ecosystem [ ]. In SENSEI, the objective is to describe the infrastructure level, in accordance with the very technical core: to built a "middleware", a kind of platform enabling services via applications. Key questions to consider include what are the different business roles, how do they relate to each other, and what are the different business rationales and incentives for engagement in this business ecosystem. The outcome is the description of a business value network.

In all cases, the objective of the business oriented scenario design is to grasp how global value can be created and shared among the different business stakeholders. The investigation phase is two-fold: first within the group (called "work-package") devoted to scenario design and analysis (see above); second, via interviews of targeted profiles. Actually, all phases are different aspects of an intertwined investigation as the project consortium is another field within which business issues are tackled during the design process itself.

6 Conclusion

The presented end-to-end scenario-based approach ensures that the technology innovation conducted by a consortium during a research and development project is continuously driven by the combined user, business and technology motivations. Since the user and business acceptance outcomes are considered in the prototype system features, the final result is a new set of scenarios that are reflecting the technology innovation, the business opportunities and user benefits. In SENSEI project, it is planned to push forward this scenario logic since final audio visual showcases will be created to capture the final results of the project: technology innovated, the accepted system applications and the viable businesses.

This approach enriches the existing scenario-based design methodologies by enabling a continuous internal and external mediation role played the scenarios: internal mediation by organising the project vision and technological proposal, and external by making the users and business actors' point of view considered in the design process.

This approach proposes the scenarios as a key tool for the management of collaborative innovation projects. It ensures a consistent but evolving and operational vision of the objectives and roles shared by the stakeholders. It provides a generic and flexible solution to support the evolution of the application scenarios from the initial idea to the user accepted, business proven and feasible technology. Thus, it does not imposes scenarios as a static vision all over the design process, but it enables a logical and co-opted evolution of the scenario(s) as "boundary objects" [] that carries the innovative vision throughout the design lifecycle.

Acknowledgement

This paper describes work partially undertaken in the context of the SENSEI project, 'Integrating the Physical with the Digital World of the Network of the Future' (www.sensei-project.eu). SENSEI is a Large Scale Collaborative Project supported by the European 7th Framework Programme, contract number: 215923.

In addition, the authors would like to thank their colleagues and the partners of e-SENSE and ADAMOS projects.

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