"Smart" as a key component of the sustainable city development

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ABSTRACT

Smart City Initiatives are aiming on creation of a sustainable model for cities with the aim to improve quality of life of their citizens. A smart city represents an interdisciplinary field requiring high level of cooperation among experts from different fields and a contribution of the latest technologies in order to achieve the best results in the city's key areas. Such approach requires an effective cooperation across many fields, from technical or economic through legislation to social areas. Success of the smart city concept is not thinkable without an effective engagement of the end users, i.e. citizens of the smart cities. The traditional systems engineering methodologies fail and new approaches are urgently needed. A new Hybrid-Agile Methodology (HAM) is introduced and its advantages with respect to smart city projects are discussed. However, application of methodologies cannot be successful without principal changes in how are all engaged parties thinking.

Keywords: Smart City; Sustainability; Systems Engineering; SCRUM; Agile

1. INTRODUCTION

A smart city is a phenomenon of the last years. The main reasons for the emergence of Smart City Initiative are to create a sustainable model for cities and preserve quality of life of their citizens [1]. There is still not existing one commonly accepted definition what the smart city is. For instance, the official definition of the smart city according to the IEEE is: *„A Smart city brings together technology, government and society to enable the following characteristics: a smart economy, smart mobility, a smart environment, smart people, smart living, and smart governance"* [2].The main purpose of the Smart City Initiative is to provide a framework how to ensure the sustainability of cities, quality of life and safety of their citizens, and maximum energy efficiency, all of those in the six key areas: economy, environment, mobility, people, living, and governance, with the contribution of the latest technologies.

The smart city is, similarly to systems engineering field, an interdisciplinary area that requires a high degree of cooperation between experts from many different fields. Contrary to the statements of some technological companies, the topic of the smart city cannot be seen only as a technical discipline, but it is necessary to involve economic, social, legal and environmental aspects. Different systems within the smart city must cooperate closely together and share information and other resources in order to achieve their objectives.

2. "SMART" AND "SUSTAINABLE" DEVELOPMENT

City development is understood as 'smart' if investments in human and social capital, city infrastructure and services for citizens is generating sustainable economic, environmental and social development [3].

Business development usually carefully stresses its economic sustainability measures and due to its nature, business can easily get in a dominating position within all mentioned measures. Environmental activities gained strong enough position, as well. Communities identified that they can profit from environmental activities, especially if the environmental emphasis are reasonably balanced with the other discussed factors.

Therefore, social aspects might get the weakest position among the other ones. Improvement of a human quality of life can be accepted more like proclamation than the tangible measures directly implementable in the decision processes. However, smart cities solutions are (should be) designed for citizens [4] and social inclusion and diversity in smart city solutions should represent very important role. Social inclusion is hardly reachable without effective physical proximity. Relevant solution and feed-back control granularity must be adopted to reach effective evaluation of response of the real end-user, i.e. touched by smart city project citizens.

Technological aspects are frequently presented as the key to the smart city development. This can result in overestimating of their influence and significance on the proposed solution. It is important to point out that using of a state-of-the-art technological solution does not automatically mean it is the smart one. New solutions can be smart one only in case if their implementation is smart as well, and most importantly if they are aiming on the objectives of smart city initiatives Smart implementation represents complex process typically with directly engaged citizens. Citizens should be educated and carefully prepared to be ready to accept any new solution. Each new implementation process needs careful justification - even a small insensitive upgrade step can generate citizen's hesitation to accept it.

Economic, ecological and social development should be kept in careful balance. Dominance of any of these measures in the decision processes will generate significant problems in the future.
In order to balance the different aspects of smart cities sustainability, we concentrate on project development methodologies, with the aim on better balancing the key aspects in reaching the smart cities sustainability.

3. PROJECTS DEVELOPMENT METHODOLOGIES

Many different methodologies and approaches have been developed over the years to address systems engineering. Let us look at the different software development methodologies provided for example by Whitten [5]:

- Category I:
  - Structured Design
  - Waterfall Development
  - Parallel Development
- Category II: Rapid Application Development
  - Phased Development
  - Prototyping-based Methodology
  - Throwaway Prototyping-based Methodology

- Category III: Agile Development
  - An Extreme Programming-based Methodology
  - SCRUM

The selection process depends on many different and project specific aspects, such as a complexity of the system to be developed, time constraints, need for visibility of a schedule, experiences of the development team or even the level of customer's involvement.
In this paper we want to present two different approaches covering the width of system development methodologies. The first approach is based on the traditional approaches from Category I – Waterfall Development, particularly s-called Systems Engineering Management Plan (SEMP). The second approach belongs to the category of Agile development.

3.1. SYSTEMS ENGINEERING MANAGEMENT PLAN (SEMP)

In the previous section, the need for a standardized systems engineering approach was discussed and different approaches were briefly presented. At this section we focus on one particular approach used especially at systems consisting of software and hardware together. Typical examples of such systems are intelligent transport systems that have closely related to the smart city initiative. A detailed handbook explaining the principles, steps, deliverables, responsibilities and providing additional resources is provided by Federal Highway Administration – Californian division (USA) [6]. The usage of systems engineering management for ITS systems was provided for example by [7] and is a mandatory document for the Ministry of Transport in the Czech Republic.

The Systems Engineering Management Plan presents the V model. Its main purpose is to provide detailed information on the processes, deliverables, roles and quality gateways used. A version adopted from [8], which aimed on pragmatic application of the general SEMP Framework is depicted in the Figure 1.

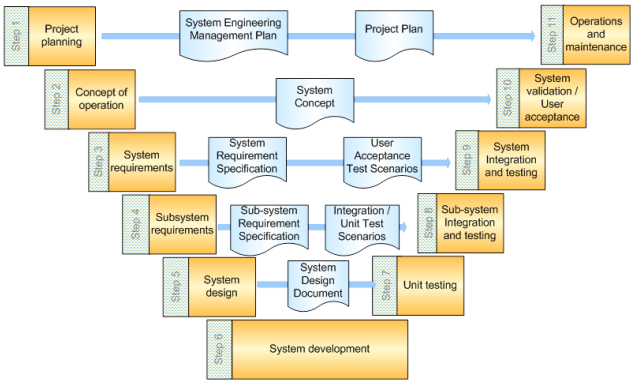

Figure 1 – The Systems Engineering Management Plan Framework [6]

The SEMP defines not only the particular steps, but more importantly also the deliverables of the particular steps as well as the quality requirements and checklists.

This SEMP has several advantages, among others clarity, the fact that it is understood by different stakeholders and in the way in which the customer is involved: first through requirements management which form basically a contract between the customer and the developer and at the end of the process through user acceptance testing proving meeting of the customer expectations.

However, the smart city initiative introduces new aspects, which are not addressed by the standard SEMP [9], which include:

- **Cooperation among experts from different fields** – Smart cities cannot be solved through traditional focusing on particular engineering disciplines, such as transportation, energy, ICT and others. There is strong need to address problems jointly through an interdisciplinary team. Sharing of resources - in smart cities, the different processes within a city must access the same resources in order to use them effectively. This covers information, energy, infrastructure and many others.
- **Focus on soft measures** – also contrary to traditional approaches, a city can be smart only when the citizen's feel happy in it. This is something that cannot be always expressed through a clear objective function where an optimum can be found. Terms such as happiness, quality of life, habitual behavior and feelings are very important.
- **The control and management systems are not strictly hierarchical** – in the traditional control or management systems, there are a clear hierarchy and clear rules. For example in transportation, there is a local traffic controller responsible for the signal timings, an area controller responsible for orchestrating different local controllers, main city control center responsible for traffic information and general strategies and typically a national traffic control center mainly responsible for collecting traffic data and providing traveler information. Such distinction is no more possible in smart cities and internet of things. Each element can be understood as an agent (in the multi-agent system theory – [10]), which exchanges information with other agents, but can make an own decision and follow own objective functions based on trustfulness of the other agents, environment and current as well as the past states. Such agents do not communicate only with agents from the same field (e.g. transportation), but also with others. This can mean that for example a street lighting is not only affected by the time of a day or environmental sensors, but for example also by the traffic density or the presence of a pedestrian on the side walk.

Such new aspects make it very difficult to use the traditional SEMP. In such SEMP, the tasks and problems are firstly divided into separate subsystems/sub-problems and interfaces are defined. Each subsystem is then solved with a dedicated group of experts. However, this approach is contrary to the key specifics of smart cities such as cooperation, sharing, or the amount of different heterogeneous agents' communication across different fields. We need to change this traditional perception if we want to build smart cities effectively. This is also the main motivation for this paper. A modified approach to Systems Engineering must be defined in order to achieve.

3.2. AGILE METHODOLOGIES

SCRUM is the next approach discussed in this paper, the approach from the class of Agile methodologies. The Agile methodologies were originally designed for developing a software based on iterative and incremental development [11]. In 2001, Manifesto for Agile Software Development was published and 12 basic principles of Agile were also presented. These principles are shown below and are defined for software projects [12]:

1) A customer satisfaction by early and continuous delivery of useful software
2) Welcome changing requirements, even late in a development
3) Working software is delivered frequently (weeks rather than months)
4) Close, daily cooperation between business people and developers
5) Projects are built around motivated individuals, who should be trusted
6) Face-to-face conversation is the best form of communication (co-location)
7) Working software is the principal measure of progress
8) Sustainable development, able to maintain a constant pace
9) Continuous attention to technical excellence and good design
10) Simplicity - the art of maximizing the amount of work not done - is essential
11) Self-organizing teams
12) Regular adaptation to changing circumstance

According to these methodologies, verifying the accuracy of the system only by means of quick development, presenting to customers and incorporating directly the customer feedback. Agile approach is not only limited to programming, but also found its application in business intelligence and marketing planning [12]. It helps teams respond to unpredictability through incremental, iterative work cadences, known as sprints. Agile methodologies are an alternative to waterfall, or traditional sequential development.

The shortcomings of Agile approaches are that customers like their contracts fixed in time and budget. In the case of Agile development, it is not possible to state exactly how much it will cost in advance, because it depends on the requirements expressed during the entire duration of the project and the discussions with customers. This could be a problem in terms of public contracts, because every voter wants to know how much will cost contract execution. The next shortcoming is that a poor customer participation directly affects product quality. It means that customers must be directly involved in the whole development process and closely cooperate with the development team. Another well-known problem of Agile methodologies is originally designed for small software projects, but there are alternatives for large projects now.

Scrum is a particular application of Agile methodologies in practice. It defines a flexible strategy for product development, where the development team works as a unit to achieve a common goal. A key principle of the Scrum is that customers can change their minds about what they want and need (often called "set of requirements"), and that unexpected tasks cannot be solved simply traditional forecasting and planning during the project. Scrum uses an empirical approach in which the problem cannot be fully understood or defined, and therefore focuses on maximum team's ability to deliver quickly and respond to new requirements [13].

There are 3 key team roles in the whole Scrum process:

1) A **development team** is responsible for the delivery of potentially shippable increments (PSIS) product at the end of each sprint (sprint goal). The team is typically composed of 3 to 9 individuals, who are doing the current work (analysis, design, development, test, technical communication, document, etc.) [14].
2) A **Product Owner** represents stakeholders and the voice of the customer. He is responsible for ensuring that the team will add value to the business. The Product Owner shall understand the customer needs and expectation and clearly state those to the development team, evaluates particular working tasks and assigns them a priority, and adds them to the product backlog. The Product Owner is on the business side of the development, and can never interact with the team members during the development apart from scheduled meetings (sprint meetings) [15].
3) A **Scrum Master** is responsible for the removal of barriers of the team on product delivery goals. The Scrum Master is not a traditional team leader or project manager, but acts as an intermediary between the team and any negative effects. The Scrum Master ensures that the Scrum process is used as planned and team members shall comply with agreed processes. Meetings are organized often and encourage the team to improvements [16].

A **sprint** (or an iteration) is the basic unit of development in Scrum. The sprint is a time boxed effort; that is restricted to a specific duration [17]. Each sprint starts with a sprint planning event that aims to define a sprint backlog, identify the work for the sprint, and make an estimated commitment for the sprint goal. Each sprint ends with a sprint review and a sprint retrospective [18]. Each day during a sprint, the team holds a daily Scrum. The overview of the Scrum methodology is shown in the Figure 2.

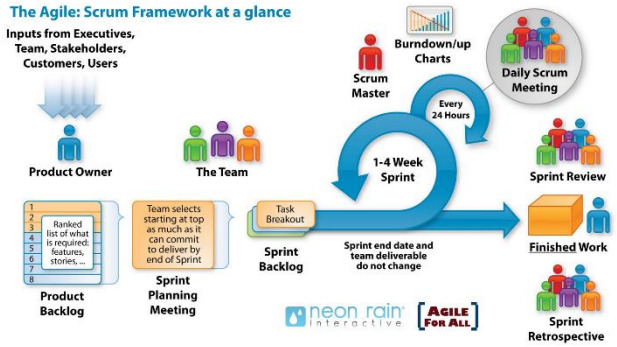

Figure 2 – The Scrum Framework [19]

3.3. HYBRID-AGILE METHODOLOGY AS AN ALTERNATIVE FOR SMART CITIES

In this paper, a short overview of different development methodologies needed for any system development process was presented. However, none of the existing methodologies are appropriate for the challenges linked to smart cities. Therefore, this section introduces a new approach called the *Hybrid-Agile Methodology* (HAM).

When approaching the smart cities procurement process in terms of a public contract, a new hybrid methodology combining the Agile principles with the SEMP principles is needed. It is clear, that meeting the challenges of smart cities require a major shift in our thinking and in approaching problems must be performed. This new hybrid approach is based on the 12 basic principles of Agile with certain adaptations, which are part of our proposal. First, we have to specify various roles throughout the process. The roles are based on the Agile methodology, but their definition can differ.

A Product Owner (PO) is the most crucial role. S/he should understand the customer needs and expectations, understand the technical terms and be able to make certain decision on regular basis at the same time. It is difficult to place this role to a

customer as the customer can hardly have the required technical knowledge. The Product Owner located by the solution provider cannot have the decision making power and would have to validate the decisions by the customer. Therefore, there are two Product Owners in the *Hybrid-Agile Methodology*: the first by the customer (PO-C) and the second by the solution provider (PO-P). They have to work together and cooperate very closely with each other. This is the first and very important difference between the Agile and the *Hybrid-Agile Methodology*. It is important that the Product Owners are fully integrated with the entire process and also have a key role in communication between both sides. Their joint negotiations always result in requirements that are followed by the team.

The development team is performing in a similar way to the standard Agile methods.

The Scrum Master is also supporting the development team in the traditional way.

The basic principles and changes to the standard Agile methodologies are provided below:

1) **The customer (municipality) shall be fully involved** during all project steps in, i.e. not only to prepare a tender and select proper solution provider, but also during the implementation by providing feedback to the developers and making decisions. The Product Owners on both sides are fully responsible to gather the requirements to specify them and to present them to the team during regular meetings. This is not an activity performed once at the beginning, but the ongoing activity. When questions are presented, the Product Owner on the customer side (PO-C) must be able to make decisions.
2) **The requirements** (often in the form of a request for proposal or tender materials) **play still an essential role in the development process.** This is one of the major differences in comparison to the standard Agile methods. Since the municipality/government organization must be able to manage the project in a transparent way, the scope expressed must be known through requirements from the beginning. However, this hybrid approach minimizes the major problem with requirements – they are rarely written in a form that allows direct implementation and ensures that the customer gets what is expected. We depend not only on the System Requirements Specification (SRS) document, but we combine it with the knowledge and decision making of the PO-Customer. With such combination, we can prepare a project plan and manage the project while at the same time minimize the discrepancies in expectations between the customer and the solution provider.

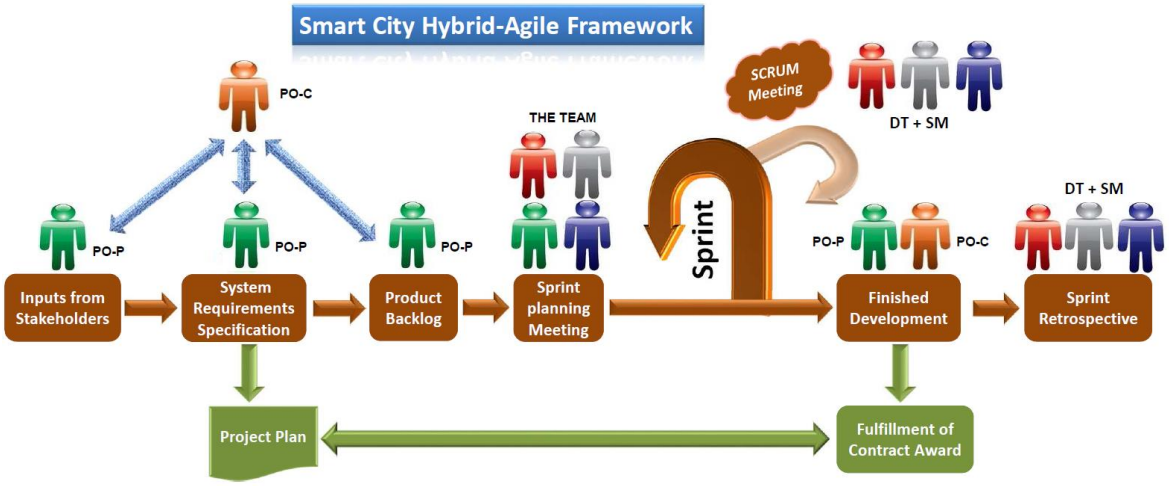

Figure 3 - Hybrid-Agile Methodologies Framework

3) **The entire contract is divided into short cycles** – Scrum sprints (recommended one to four weeks) can respond quickly to any changes. The Product Owner collects requirements and is entered into the Product Backlog, where they are further processed by the development team. At the beginning of each short cycle (sprint) is a sprint planning meeting, where is specified when it must be done. The major advantage for customers is that the progress is monitored regularly – at the end of each sprint. The aim of these sprints is to provide a detailed review as well as planning of next steps during a following cycle.
4) **Not being afraid to change specifications and requirements**, if it turns out that it is more efficient and cheaper, even if it is in the implementation phase. This point is one of the more important and also the most difficult since it requires a complete change in the mindset from the procurers and the developers as well as other stakeholders. Based on the fact that in the process of planning and early execution of the contract, it is not knowm exactly what the customer wants and it is not possible to predict what may during the implementation to appear (new technologies, change of an assignment for streamlining the entire implementation). This principle says that both the customer and the developer not worrying about come up with completely new requirements and specification during the implementation if this should help to streamline, simplify and cheapen the entire process. However, this does not necessarily means a problem in tracking public projects. Since the PO-C is closely linked to the development process and must understand all the reasons for change, s/he must be able and ready to justify them to general public.
5) **Close daily cooperation between representatives of cities or countries and developers.** There is necessary especially daily communication between both Products Owners who should communicate and gather the requirements and put them to the Product backlog. A Face-to-face conversation is the best form of communication (co-location). This is a fairly simple rule that says that the face-to-face communication is preferred form of the

communication before for instance emails. The reason is that the verbal communication is better understood by both sides what the other party requests them. Since the communication is in generally the key success factor in the system development, a lot of focus must be dedicated to the communication in general and to this rule in particular.

6) **The fulfilment of the contract award is the measure of success**. The destination success is a final completion, which meet the individual steps that are given by requirements through the Product Owner. Therefore, as the measure of success can be taken to carry out tasks that are always entered in the individual sprints. Of course, the Agile methodologies are based on changes during the process. Therefore, it cannot be taken as a failure if certain task is changed during the development. However, the changes should contribute to better performance of the system.
7) **Sustainable development able to maintain a constant pace** is necessary for the duration of creating a contract award and the subsequent implementation sets a pace that will be sustainable throughout the project. If it does not manage to the process, requests should find out why prosecute are meet. The primary task of the *Hybrid-Agile Methodology* is obviously the fastest performing a given task, but the rate should never prevail over the quality and fulfilment of the task.
8) **Simplicity - the art of maximizing the amount of work not done - is essential**. This is the key principle of the Agile methodology. Do only what is necessary. This principle says that the Product Owner and the development team should quickly and accurately analyze whether the task needs to be done in order to achieve performance completion. It is also necessary to assess whether such a step will help us in some other saves. This is extremely complicated and it is directly dependent on the experience of the whole team.

If we analyze the HAM principles described above, we find out that the application of the *Hybrid-Agile Methodology* to smart cities procurement process has the potential to solve major shortcomings of two dedicated methods discussed above. The detailed overview of the proposed HAM is shown in the Figure 3.

The first disadvantage was the inability to determine a fixed final price and delivery date in advance. Through combination of the Agile approaches with strong focus on documenting requirements, this is not the case anymore. Additionally, the project progress is monitored regularly and the customer is informed about any new developments or challenges through regular sprints. The major advantage of applying the *Hybrid-Agile Methodologies* is in achieving the cooperation and the communication among the developer, the customer and other experts throughout the implementation. This is the key requirement in order to achieve the best possible results in the shortest time and meet the objectives of smart cities such as sharing of resources. Since we have the role of *Product Owner – Customer* and *Product Owner – Provider* with strong focus on the face-to-face communication, the cooperation is supported in the best possible way.

The danger of appearing extra project costs during the project lifetime due to misunderstandings between the customer and the provider are minimized. The general scope and directions are set from the beginning through the requirements. However, they are clarified via the Product Owner.

4. CONCLUSION

This paper discusses the necessity to improve balance of three different aspect of smart cities sustainable development. We identified potential of the social sustainability aspects underestimation, even though smart city affords should lead to higher quality of citizens´ life. One of acceptable possibilities to keep the fragile balance stable is identified in more effective integration of soft parameters like quality of life in project decision processes based on direct integration of the customer/citizen. In order to overcome the existing limitations, the new *Hybrid-Agile Methodology* was proposed in this paper.

This HAM is based on principles of the Agile development and basically uses the best characteristics of the Scrum methodology and the Systems Engineering Management Plan. An application of this **new methodology requires a major shift in thinking of all parties engaged in projects** and puts new requirements especially on municipalities or governmental organizations representing with relevant granularity real citizens being touched by such projects.

As [20] stated, “a city cannot be smart without smart citizens” we additionally claim [21] **that a city cannot be smart without smart government**. This paper provides guidance how a smart municipalities or governmental organizations can improve the development process with smart cities.

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