Research Article

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A Strategic Approach for implementing A Smart Pedestrian Network (SPN) System

https://doi.org/10.1515/comp-2020-0128
Received Mar 31, 2020; accepted May 25, 2020

Abstract: This paper presents a strategic approach for implementing a Smart Pedestrian Network (SPN) navigation System that is geared towards promoting sustainable mobility. The SPN system is being designed to reach multiple market segments by providing information on suitable walking routes aiming to satisfy potential users' needs, but also multiple stakeholder demands. The paper presents the main objectives of the SPN system as well as its system structure, application features, functions, and relevant data sources. The proposed strategic implementation framework deems necessary for scaling up so that the SPN system is successfully implemented in a variety of urban conditions. The framework emphasizes the element of adaptability, so that SPN can be adjusted where and when necessary, to deal with a variety of contexts and specific sustainable mobility issues, depending on the particular municipality conditions. The proposed framework combines elements of both the waterfall and agile software development methods, as well as, aspects of Open Innovation, Customer Involvement and Co-Creation taking a multiple stakeholder approach.

Keywords: Information and Communication Technology (ICT), Software development, Sustainable mobility, Smart Pedestrian Network, Open Innovation

1 Introduction

Software development for large scale applications must take into account the long term and adopt a strategic approach to systems analysis and design. In addition, emphasis should be given on project management and implementation issues considering application in a variety of contexts. Especially, if we aim at developing systems for smart cities which involve changing end-user behaviour, it is imperative that implementation issues should be given great attention. For successful system development and implementation we need to bring together multiple stakeholders, so that we integrate views and gain acceptance. In this context, software development becomes a co-creation process that could borrow techniques from Open Innovation, Customer Involvement, and co-creation [3, 11]. Such a software development process case is the Smart Pedestrian Network System (SPN) [14–16]. In this way, SPN software should consider aspects of urban planning and development. Specifically, the SPN system should be analyzed on the social, economic and environmental levels.

In the case of SPN, a clear problem statement is necessary so that the extent of its domain is properly analysed. The SPN system development can then be justified with the fact that Information and Communication Technology (ICT) can act as a catalyst for promoting active mobility. Clearly active mobility could alleviate problems with air pollution. It is estimated that there are 4.2 million deaths each year directly attributed to air pollution [20]. With over half a million premature deaths in Europe it is evident that there is a huge problem to deal with. As air pollution mainly stems from high levels of vehicle use alternative modes of transport such as walking and cycling would have a significant impact in tackling the situation. Further, current ecosystems and ocean life are also being adversely affected by CO2 emissions and the resulting climate change. Via a Smart Pedestrian Network system we can develop and promote sustainable transport modes in order to reduce pollution and global warming. In this way, we can significantly mitigate the climate change crisis by maintaining cleaner air in our cities, preserving our natural environment and land, and therefore, conserve the planet for ourselves and future generations.

In the current transport model used in our cities, we see that we heavily rely on vehicle use and current Intelligent Transportation Systems (ITS) solutions mainly support mo-

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torised vehicles [10]. Sustainable urban transport policies can be enhanced with the use of ICT to substitute vehicle use with active means of transport. On the other hand, this is not an easy solution to implement as people still opt to take the presumed more convenient and easier route, which is using a motorized vehicle instead of engaging in active mobility. This can be attributed to lack of awareness of appropriate walking routes, as well as the lack of knowledge of the many benefits that active mobility can have both to ourselves, and to our planet. There is a lot to be gained if we embark on more active means of transport, such as simply walking. With walking, we can have a plethora of benefits for ourselves and the environment. The key to this sustainable mobility transformation, is not only to encourage and convince, but also support people when engaging in active mobility. All of these can be supported by the provision of relevant information.

Current advancements in ICT and Artificial Intelligence (AI), create a significant opportunity to support the active mobility vision [2]. For example, a smartphone application system could be developed so that people are informed about appropriate walking routes, but also give feedback via crowd-sourcing, to municipal authorities on issues regarding the pedestrian network conditions. Even though several applications may give general information on the pedestrian network environment, they are not necessarily geared towards suggesting appropriate and enjoyable walking routes, and thereby encouraging people to walk more. Also, they do not provide information on safer routes, and are unable to inform users about amenities such as water fountains, public toilets or resting places that certain user groups such as elderly people may particularly need.

Even though SPN presents an innovative proposal, that on its own does not guarantee a successful implementation. It is important to consider the use of an appropriate framework for properly implementing SPN. As shown later in the literature review, current methods for software development, which include the Waterfall Model and the Agile Model, do not adequately address these implementation issues. We investigate such issues and suggest a road map for successfully implementing our SPN system.

In the next section we examine past literature and software development methods and the potential for mobility navigation systems. We also discuss the effectiveness of methods to support the successful development of software systems.

2 Methods

According to research studies, as of 2018 [12], a majority of smartphone owners use a navigation application to help them in tracking a suitable route for their journey. The Manifest study [9] surveyed more than 500 smartphone owners to understand how people are relying on technology more to get from point A to point B. Their findings were as follows:

- Over three-fourths (77%) of smartphone owners regularly use navigation apps.
- Google Maps (67%) is the most popular navigation app by a wide margin. It is the preferred navigation app for nearly 6x more people compared to the second-most popular app Waze (12%).
- One-quarter (25%) of smartphone owners say they use their preferred navigation app because they believe it offers better directions.
- Over one-third (36%) of smartphone owners use navigation apps prior to leaving their location.
- 34% use them en route, and 30% use them both prior to leaving and en route equally.
- An overwhelming number of respondents (87%) use navigation apps for driving directions.
- People use navigation apps for non-driving directions such as public transportation, walking, or cycling twice as much in the Northeast than in other U.S. regions. This might be due to cultural reasons and better infrastructure conditions.

From the above, we can derive several implications for the development of navigation systems suitable for pedestrian use. The fact that an overwhelming 87% of respondents use navigation applications primarily for driving directions, is a disturbing fact. This fully supports our argument that there is an extremely high level of vehicle use in our cities. Furthermore, it provides evidence that vehicle use is proving to be a major contributing factor to environmental detriment and the deterioration of human health.

As a result, there is a lot of potential for people to use navigation systems for active transportation such as walking and cycling. This showcases that indeed not only is there demand for such products, but that this demand could be enhanced further if an appropriate smartphone app is developed that appeals to the public. Hence, there is a potential market granting our SPN app the opportunity to achieve its goal in promoting higher walking levels and reducing air pollution.

Such findings may suggest that the reason so many individuals use navigation applications for vehicle use,

Table 1: SPN Competitor Apps

Application	Waze [18]	CoPilot GPS [19]	Google Maps [7]	Komoot [4]	inRoute [1]
Best for	Dodging Traffic	Offline Maps	Ultimate All-Rounder	Great Outdoors	Road Trips
Turn-by-turn voice directions	Yes	Yes	Yes	Yes	Yes, with Premium & Pro upgrades
Route Type	Driving routes	Cycling & walking	Cycling, walking & public transport	Cycling, hiking, road biking, & mountain biking	No
Traffic reports	Yes	Yes, free for 12 months then $9.99/month	Yes	No	No
Offline maps	No	Yes	Yes, with some limitations.	Yes	No
Add Stops	Yes	Yes	Yes	Yes	No
Price for end-user	Free for Android, iOS on waze.com	$9.99 for Android, iOS and more options on copilotgps.com	Free for Android (preloaded), iOS on maps.google.com	$3.99 - $29.99. Available for Android iOS	Free for basic use, $14.99 for Premium upgrade
Pros	Accurate, up-to-date traffic info and good rerouting to get you around severe traffic	Excellent search feature for places and addresses; a comprehensive navigation interface that shows ETA, next turns, and overall route; offline use means minimal drain on your smartphone battery	Excellent integration with other Google software. If you use the Chrome browser on your smartphone, you can search for a place, then tap the map result to open it directly in Maps. Android users can mark routes and locations on custom maps in a web browser, save them to My Maps, then access them in the smartphone app	World is broken in Koomot regions that are purchased individually, reducing purchase cost	Can plan looping routes that hit up various destinations before ending up back at your starting point -gas stops, breaks and sleeps included
Cons	Some of the user-submitted info isn't comprehensive or edited (for example, place names might not be capitalized).	If you don't often drive where you can't access the internet, CoPilot may not offer much more than the free Google Maps	No speed camera warnings	Area defined by a Komoot "region" isn't large, so if you're an infrequent hiker, the cost of purchasing extra regions might not make sense	You have to upgrade to get directions and the app only gives you one route. However, you can export your route to another navigation app, such as Google Maps or CoPilot, if you upgrade

is because there currently does not exist in the market a satisfactory application designed specifically to promote sustainable mobility. Even though some applications have been developed for this purpose, these failed to take off and become widely used. Table 1 provides an analysis of the main applications found in Google Play. Existing applications fail to completely satisfy particular pedestrian user needs such as getting information on amenities, safe routes, comfortable mobility etc., when engaging in active transportation.

Further, in a market research and concept study for SPN [13], it was shown that there is demand for such a smartphone pedestrian network app so that people are informed about the various aspects of the pedestrian network including comfortable mobility, safety, convenience, and connectivity. Furthermore, it was found that successfully implementing SPN would be challenging, as high levels of investment and commitment from the side of the municipal authorities are required. Therefore, new business models that involve the element of sponsorship and co-creation should be considered.

Therefore, what is important to also stress in this section, is that for the SPN system to be a success, it must be properly implemented using an appropriate framework. This is discussed in the following paragraphs by reviewing the most widely used methodologies for developing information systems. These include the waterfall approach and the agile method.

The waterfall methodology model [6] is a sequential software development process where progress flows steadily toward the conclusion - like a waterfall - through the phases of a project. That is, analysis, design, development and testing. The nature of the Waterfall methodology insists that each phase be completed and perfected before the start of the next phase. This involves fully documenting a project in advance, including the user interface, user requirements, and all the features' variations and outcomes.

A detailed investigation and full research into a product feature are conducted up front, eliminating (most) project risks. With the bulk of the research done in advance, estimates of the time required for each stage are more accurate, thus providing a more predictable release date.

During the analysis stage, the product development team analyses the requirements, and fully understands the problems. This is a research phase that includes no building. The team attempts to ask all the questions and secure all the answers they need to build the product requirements. In the design stage, the software developers create a technical solution to the problems set out by the product requirements, including scenarios, layouts and data models. This phase is usually accompanied by documentation for each requirement, which enables other members of the team to review it for validation. Once the design is approved, technical implementation begins. This is often the shortest phase because research and design have been done in advance. Upon completion of full implementation, testing needs to occur before the product can be released to customers. The software testing team will use the design documents, personal and user case scenarios delivered by the product manager in order to create their test cases.

Very early on, Royce [17] in a study about managing development of large software systems criticized the sequential nature of the waterfall method. It was asserted that software should not be developed like an automobile on an assembly line, in which each piece is added in sequential phases. In such sequential phases, every phase of the project must be completed before the next phase can begin. There are criticisms against this approach in which developers first gather all of a project's requirements, then complete all of its architecture and design, then write all of the code, and so on. Specifically, this approach has been opposed due to the lack of communication between the specialized groups that complete each phase of work.

This is where the agile method comes in to fill in the gap, as an improved method of software development. According to McConnell [6], the agile methodology is an iterative approach to software development that is performed in a collaborative environment by self-organizing teams which produce the final product version in a sequence of multiple product releases. The methodology produces high-quality software in a cost-effective and timely manner to meet stakeholders' changing needs.

Every product release begins with a list called a "backlog", which consists of a list of prioritized requirements which are dynamic and can change at any time. Determining the next product release, a smaller number of requirements can be chosen from the backlog list. The work involved in the next product release is called "iteration (or sprint)". Each iteration has a short time frame which usually lasts from one to four weeks, depending on the team's experience. A key element of an iteration, is that the priorities regarding which requirements should be built, do not change within the iteration; this list should only change from one iteration to another.

The Agile methodology accepts that project change is inevitable. The use of small iterations allows changes to be absorbed quickly without inflicting significant project risk. The system to be developed can be adjusted as business priorities evolve. With the next iteration, the software development team can adapt to the new priorities.

It is easy to see how the "waterfall" methodology is far from optimizing the final software solution compared to

the agile methodology. First of all, it assumes that every requirement of the project can be identified before any design or coding occurs. But in truth, this is seldom the case. This is an impossible task that makes the waterfall model inadequate for effectively developing software solutions. On the other hand, the waterfall model provides structure to software development which is essential for complex projects such as SPN.

Therefore, a combination of the waterfall and agile methodologies would be ideal for the case of developing the SPN information system and smartphone app. We have attempted to follow the waterfall methodology in outlining a roadmap in order to analyse the SPN structure, and future goals we hope to achieve within a given period of time. This was also done for the SPN design, implementation and testing phases. In order to add flexibility and effectiveness in developing SPN, we incorporated the dynamic approach as suggested by the agile methodology model. Therefore, an integrated approach that combines the waterfall and agile models is proposed as shown in Figure 1. Note that the approach involves multiple iterations with elements of co-creation and open innovation.

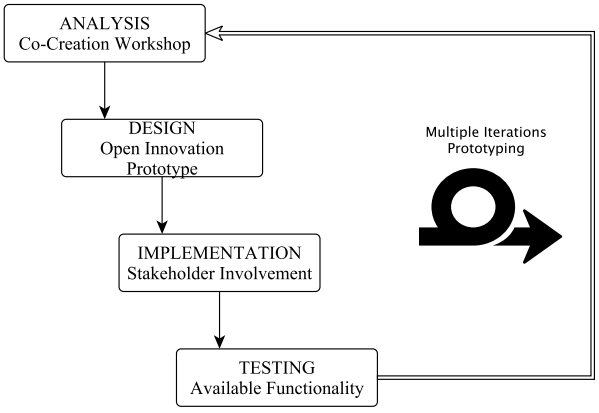

Figure 1: Integrating the Waterfall and Agile methods with elements of Co-Creation and Open Innovation

Further, we see that current methods for developing software interactive systems, such as SPN fail to effectively consider implementation issues. As we see further on in this paper, we explain how the proposed approach can deal with such matters, which involves making the system ready for the market via testing, adaptation, feedback and adjustments, to improve the chances of successful implementation.

3 Results

We are currently in the process of developing the SPN system which provides real time analysis of the actual physical and virtual environment that exists in a specific area within the pedestrian network. Furthermore, the SPN system assists pedestrians in formulating their interests, preferences or goals at any given moment in time regarding walking routes, specific attributes, objects of interest and their properties. SPN is able to calculate alternative routes based on pedestrian preferences, topography, and actual status of the objects in the physical and virtual environment in real time and present a holistic vision of the route options to pedestrians on-demand. Additionally, it records walking routes, measures relevant statistics, collects updates regarding actual status and properties of route objects, and presents it to pedestrians.

SPN offers re-routing upon calculation of (unfavorable) changes in the status of particular objects along the route and deviations from the initial route plan and schedule by time, distance, physical condition, health, degree of fatigue, etc. It has also been devised to support final assessment of route results by the pedestrian. This is achieved by collecting important data for statistics, analytics, prediction and feedback. Finally, SPN could process the results and update statistics regarding the particular city condition, and pedestrian experience based on personal profiles.

3.1 SPN System Structures & Data Sources

The SPN system structure comprises of the pedestrian profile, preferences, filters on key journey information, rules for route suggestions, data sources and specific smartphone app functions.

There are static data and dynamic data that we can utilize. Static data comprise of attributes such as distance, land metrics, traffic infrastructure and so on. Dynamic data on the other hand, comprises of things that are changing over time such as on-going events, maintenance work and changes in weather conditions. Most static data are currently available from open sources such as MAPS.ME [5] and OpenStreetMap [8]. Both static and dynamic data sources could also be given from the local city mapping services.

3.2 SPN System Features

The SPN system has some important features which are discussed as follows. For example, the SPN app takes into consideration weather conditions, available amenities in

the area and safety conditions during the night. In addition, the SPN app is able to calculate the number of steps and provide rewards when the user achieves specific milestones. There is to be an audio option for those who are visually impaired. A sharing journey option creates a sense of community which is available through the smartphone app. In this direction, a chatting service could also be available in order to promote walking together with friends.

Further, in collaboration with local cafes, restaurants and retail stores, rewards would be given to those who walk more. Also, information about the effect of walking on CO_2 reduction is to be provided. Moreover, the SPN system is able to handle the uploading of information by the end-users, thus implementing crowd-sourcing schemes. For the promotion of a sense of community, it could easily be linked to Facebook or other social media platforms. We outline in further detail the main features the SPN system as follows:

- Time of Day, Weather & Location Detection: The SPN accounts for weather conditions and time of day when considering appropriate walking routes. It also detects the user's location.
- Amenities: The SPN is able to suggest appropriate walking routes depending on a list of amenities users wish to have along their journey.
- Safety: The application provides the safest routes especially for those travelling alone or during the night.
- Number of Steps: Users are able to view the number of steps they have made on a journey per day or week. They could also track their progress over time. The number of steps could also be combined with a free drink in a local café, or other rewards.
- Audio Guidance: Users would have the option for audio guidance, particularly for those who may be visually impaired.
- Save Option: For frequent journeys taken, users would be able to save their journey and store it. They would also be able to share these saved journeys with others.
- Group Walks & Chats: This option would enable users to form groups with friends and families to walk together. A chat would also be available for people to interact with each other. They can use this to arrange meeting points etc.
- Estimating CO_2 Levels: It should be able to estimate levels of CO_2 reduction from walking.
- Point Collection: To give incentives to individuals for walking more, the proposed SPN application can potentially collaborate with cafes, stores and other enterprises to reward individuals who walk more. For instance, for every so many steps taken in a month, individuals may be entitled to discounted drinks or food specific products such as discounted pair of shoes from sponsor companies.
- Crowd-Sourcing: The SPN system would be able to collect information after users upload data and inform municipalities on problematic areas of the pedestrian network. Users would be able to upload such information via images or location tags.
- Linking SPN system to Social Media: For easier use and to share between friends and family SPN can be linked to social media platforms, such as Facebook or WhatsApp.

3.3 SPN Application & Functions

The user would be able to first state their preferences and make their identity known (i.e. if they are a tourist or local, or perhaps disabled). The SPN application system collects pedestrian preferences using the User Interface functions. Once the information is submitted by the potential user, the application would respond according to the user's profile.

The system then identifies the user's location. Based on this, the proposed SPN application will list the best routes for users along with media data such as metrics, analytics, pictures, video and recommendations. In this way, the SPN can reveal to the user, the most suitable route options for them. The user then is presented with an "option" button where they are able to choose the walking route they wish to take. The SPN system enables pedestrians to download and store their local routes as well as trace them. This also allows the users to re-open any saved walking routes whenever they wish even when they are off-line. This of course, would be particularly useful for those who have difficulty accessing their mobile data or have no internet connection.

If any changes are to take place - either along the selected route or from user preferences, then the SPN system would be able to notify the user of these changes and provide alternative routes. In addition, SPN would provide continuous updates to users so that they will be notified of any changes that occur and hence, affects their selected walking route. These updates would be carried out in real time, so that accurate and reliable information is given to users. In such a case, an alternative walking route would also be provided. If the user deviates from their selected route, SPN would inform users about this deviation.

Furthermore, users will be able to evaluate routes and the quality of objects, such as amenities along their walking routes. Such feedback can then be collected by SPN, via the Smart City Monitor (SCM), which collects information

from all data sources in real time. This is an important component not only for the users but also for the developers. In this way, we will be made aware of any shortcomings of SPN. By collecting such constructive feedback, any issues can then be rectified. What is more, the data collected can also provide us with great insight into what particular services or features our potential users want to see in the navigation system. Therefore, evaluating such data can also allow us to incorporate these desired features, and thereby, improve SPN.

3.4 Developing SPN prototypes

Prototyping is very important for understanding user experience, monitoring the user's journey from point A to point B, their reactions and taking notes on any feedback. The prototype would include main features of SPN such as:

- Time of day, weather and location detection
- Amenities
- Safety levels
- Number of steps
- Audio guidance
- Save option
- Group walks & chats
- Point collection/Incentives
- Point redemption for coupons and free goods
- CO_2 reduction levels from journey taken
- Linking SPN to social media platform
- Calories burnt

For the prototype, the IT team would also provide a visual representation with a given example of how a pedestrian would get from point A to point B. This will include:

- Instructions and images showing to register/login
- How the user can input information about the destination they want to reach
- How the user can choose from and view the various SPN features as mentioned above
- How the SPN will direct the user along their journey
- How the user can view their amenities and sites around them.
- How the user can provide feedback and rate the SPN app.

The SPN prototype can then be given to testers who can experience first-hand the SPN app. We as developers can also use it to evaluate SPN performance, observe any drawbacks or improvements that can be made to SPN. Prototyping is an excellent method to assess SPN, how pedestrians react to it, if they feel it is useful, if we have correctly identified our market audiences, and if we have managed to add value to the market by satisfying pedestrian needs. We can then organize a co-creation workshop to test the reaction of the users to the prototype. We will also be able to monitor the user experience and observe how pedestrians interact with the SPN app. This will be an important workshop that will give us a lot of insight and a strong indication of what the prospect of SPN is for a successful launching. Therefore, we must also ensure that the prototype is as close to the final SPN app as possible.

As the experience prototype is used in any medium to understand, explore and communicate what it might be like to engage with the SPN system, we would organize a workshop that can involve asking people to use the prototype to get from a point A (allocated by us) to point B (again allocated by us). This will also make the workshop more fun and get the potential users more involved. We can offer a prize to add to the enjoyment of the workshop. In this way, by designing a scenario of sorts where we set the scene with props, we are observing how the users will also adopt the SPN app in practice and heighten user experience.

3.5 The Proposed Strategic Implementation Framework for Scaling Up

The proposed framework for implementing SPN is based on an integration of the waterfall model and the agile methodology. It is comprised of two phases. Phase 1 presents aspects of implementing SPN in one particular city, while Phase 2, examines the issues of implementing SPN in multiple cities. In Figure 2 which depicts Phase 1, we show the very beginning of implementing the SPN system. To secure funding and support from municipalities and investors, it is necessary to properly present our business plan. Explanations should be given to our potential stakeholders, why SPN is worth investing in, how it will benefit society and our environment, and how we will get people interested in using SPN. Also, explanations should be given on how the budget is prepared and utilized. Once having attained the necessary support and funding, part of it, would be allocated for all the necessary tools, equipment and technology that is needed to make SPN successful.

Once an initial version of the SPN system is agreed upon with stakeholders, the next step is to test it. Testing is to be carried out with the cooperation of the municipal authorities in order to adapt SPN to the context and needs of the particular city. Municipal authorities and a group of end users would be required to use the system for a given number of weeks, after which they will provide their feedback. We can use any positive feedback to further promote

SPN. For any shortcomings, we will make the necessary adjustments and changes to satisfy particular needs of end users and municipal authorities.

Having had first-hand experience with implementing SPN in Phase 1, we will proceed to Phase 2 as depicted in Figure 3. In Phase 2, the SPN system is ready to be launched in the multiple municipalities that are interested. Priority

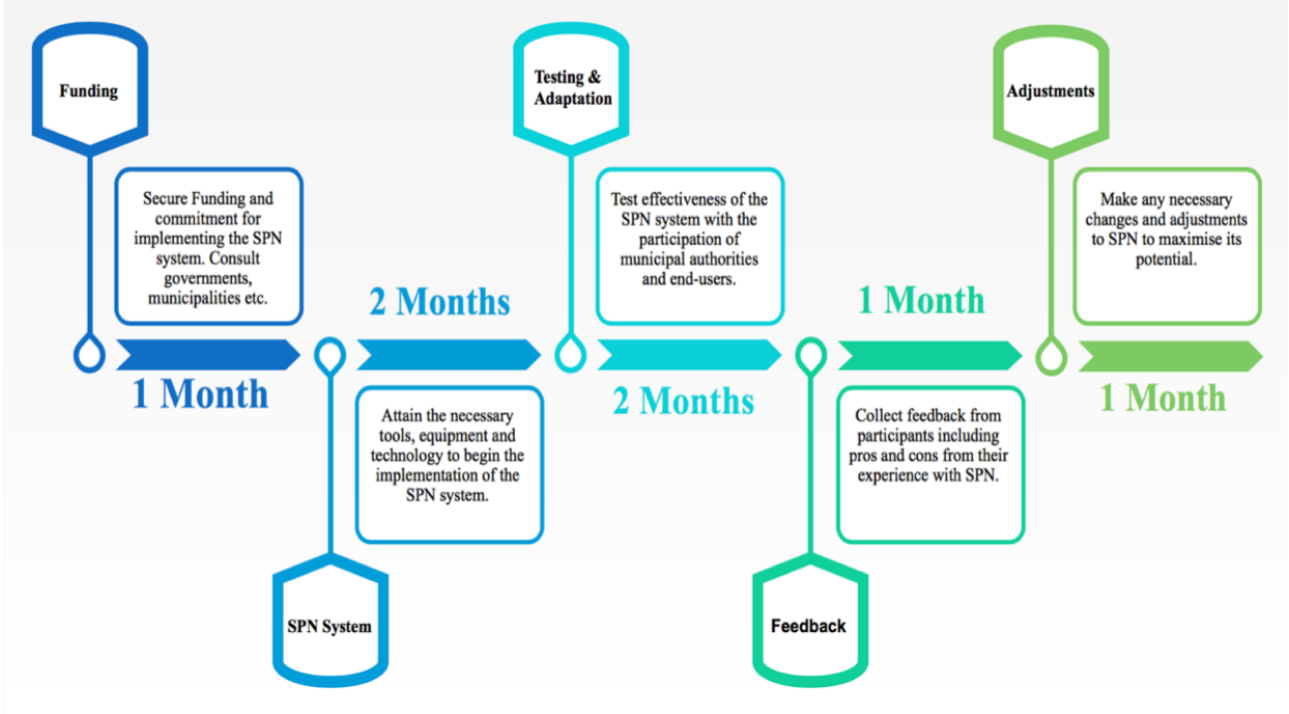

Figure 2: Roadmap Phase 1

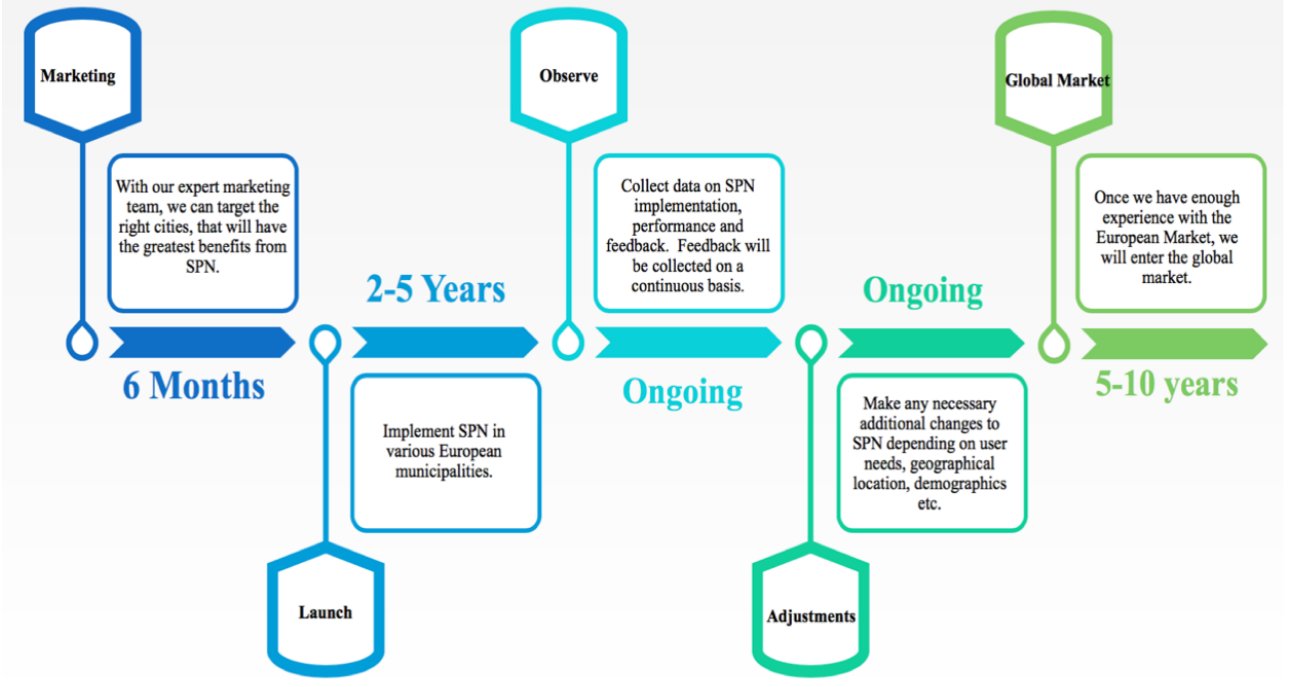

Figure 3: Roadmap Phase 3

would be given to municipalities in various European countries. We could begin with the countries of the associated organizations/institutions, which are part of the SPN partnership. These countries are: Austria, Cyprus, Italy and Portugal. In this way, we can better monitor the SPN system's performance.

All necessary data and feedback from stakeholders should be collected. This will be used to assess various factors including:

- how frequently the SPN app is being used on average;
- SPN application performance;
- which markets are using the SPN app more;
- number of weekly/monthly downloads, ratings;
- if the market is increasing via widespread use;

and other factors that deem necessary for monitoring a successful SPN implementation.

This information is to be used in order to notify governments and municipalities about various issues regarding the pedestrian network. Successful collaboration with governments and municipal authorities is essential in order to invest in improving infrastructural conditions, walking paths, providing amenities etc. It is important to consider feedback from stakeholders as this will help in improving the SPN system. Feedback will be taken into consideration and any necessary changes or adjustments will be made to meet and satisfy users' needs.

4 Discussion

This paper presents our experiences from developing a smart pedestrian network (SPN) system, which aims at promoting walkability in urban spaces. Even though the system considers effectively the variety of user needs, that does not guarantee its successful implementation. Going through a literature review on the main methods of developing information systems, we found that there are gaps when it comes to supporting the implementation of interactive information systems, such as the SPN case. As a result, we have developed an implementation framework for SPN that would also be useful for other similar interactive systems development. The proposed framework integrates aspects of the waterfall model and the agile software development method.

Especially by means of prototyping, valuable information may be collected ensuring that the system to be developed is in accordance to end user needs. In addition, stakeholders' views could be taken into consideration with the use of an appropriate prototyping method. Moreover, a co-creation approach should be implemented as in the case of SPN, where developers, stakeholders and end users will meet in organized workshops to share their views on the current prototype. Such views and opinions could then easily be integrated in an improved prototype until the final system development.

Further, the need to take a multi-stakeholder approach in software development becomes even more important nowadays. In the current critical situation with the COVID-19 pandemic, ICT and software development take a new, prominent role in our lives. Urban interactive systems development, such as the case of SPN could be further developed into integrated social smart city systems to manage the COVID-19 crisis. However, software development becomes a very complex process, that requires new tools and approaches, such as the ones presented in this paper.

Finally, software development should make use of ideas and concepts of open innovation. Open innovation principles would enhance the requirements engineering process but also system analysis and design. In the case of SPN, such an approach is implemented to emphasize testing, adaptability and feedback in order to give room for adjustments to be made based on future demands.

Acknowledgement: The research presented in this paper is co–funded by the Republic of Cyprus and the European Regional Development Fund as part of ERANET Cofund Smart Urban Futures (ENSUF) Joint Programming Initiative (JPI) Urban Europe, through the Research Promotion Foundation, protocol no. KOINA/ΠΚΠ URBAN EUROPE/1215/11. This framework is supported by the European Commission and funded under the HORIZON 2020 ERANET Co–fund scheme

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