Spider Maps for Location-Based Services Improvement

Joao Mourinho, Teresa Galvao, and João Falcão e Cunha

Faculty of Engineering of the University of Porto
4200-465 Porto, Portugal
joao.mourinho@fe.up.pt

Abstract. Location-Based Services(LBS) are information services which are available through mobile devices inside a mobile network and can take advantage of the location of the mobile device. With the majority of the world population living in urban areas and using complex transportation systems, they can be used to assist people to use the public transportation systems more effectively and efficiently. This research aims to contribute to the improvement of LBS through the use of a new kind of a schematic map, called *spider map* that brings together geographic information in particular in its central location, or hub, with a schematic information of the overall transport network originating in the hub, including for instance relevant stops and their locations. These maps present an innovative layout that includes context information relevant for the users. They can be used to increase LBS user satisfaction and therefore increase the intention to use Public Transportation Services.

Keywords: Location-Based Services, Spider Maps, Schematic Maps, Public Transportation, User Satisfaction.

1 Introduction

At the late 18th century, the industrial revolution brought a wide set of scientific, economic and social changes which pushed new developments in the transportation field. The geographical world has already been discovered but the transportation systems (railways, roads, airways, underground systems, high speed trains) have been growing till today, and they are expected to continue to grow. Large urban areas appeared and needed complex transportation systems, combining different transportation types. Nowadays, about 80% of the world population [1] and 60% of the European population live in urban areas [2]. Public transportation is crucial to achieve sustainability and efficiency in mobility and high quality of urban life [3] However, people do not use Public Transportation to its full potential, due to two main factors: time and money [4]. Nevertheless, beyond economical profit maximization functions and rational choice paradigms there are other kind of improvements that can be studied. Trip planning in public transportation systems is currently offered to users through the use of paper maps at transportation network hubs and stops. People carry an increasing number of mobile devices (smartphones, etc) which could be used to access services

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such as trip planning in Public Transportation. Those maps are being manually designed by teams of expert designers. This process is expensive, time-consuming and it results in an inflexible map which may not reflect the spatial context and the needs of the user. Our research aims to develop a new kind of maps called spider maps, depicted in figure 5, which can be entirely produced by computer. These maps belong to the domain of schematic maps, and therefore they are an abstraction and simplification of the reality. In this paper we describe how those maps can be used to improve the dimensions of the theoretical information model [5] of the location-based services, leading to higher user satisfaction levels and consequently increasing public transportation ridership, as the empirical evidences of the literature state.

The structure of the paper is as follows. The main concepts and related work regarding location-based services, quality of information in mobile services and schematic maps are presented in section 2. In Section 3 we present the spider maps and discuss how to implement them in the location-based services. In section 4 we discuss the contribution of the spider maps to the enhancement of the location-based services and to the intention to use public transportation. Finally, some concluding remarks and clues about future work are provided in part 5.

2 Related Work

This section describes the research work carried away by researchers in the areas of LBS, quality of information in mobile services and schematic maps.

2.1 Location-Based Services

Location-Based Services are information services accessible with mobile devices through the mobile network which have the ability to make use of the location of the mobile device [6]. This definition is also accepted by the international OpenGeospatial Consortium [7]. Some authors state that LBS are an intersection of several technologies as internet, mobile devices and geographic information systems (GIS) [8] [9]. This model is shown at figure 1.

LBS allows the establishment of two way communication and interaction: user tells the system his actual context, intention and/or preferences (or the system may obtain them in a pervasive way) which can help the provider of such location services to deliver information tailored to the user needs [10]. As it is also possible to observe in figure 1, there is a relationship between GIS and LBS. Both of the concepts have common features, such as the handling of data with geographical reference and spatial analysis functions in order to answer the questions *"Where am I?"*, *"What surrounds me?"* and *"Where can i go to?"*. Nevertheless, their focus is completely different: while LBS recent appearance targets large non-professional user groups, GIS can be seen as traditional "professional" systems to be used by a restricted group of expert people.

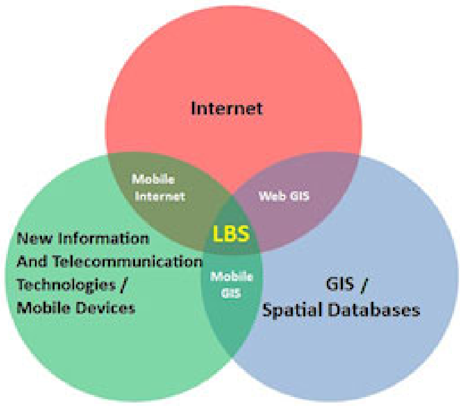

Fig. 1. LBS as an intersection of technologies [8]

According to Steiniger [10], LBS has the following components:

- **Mobile Devices:** The apparatus which serves as the physical interface for the user to access the service. It can be a PDA, Smartphone, mobile embedded systems or toll payment systems (ex: in automobiles).
- **Communication Network:** The network to transfer data between the service provider and the user mobile device.
- **Positioning component:** This is the component that determines the position of user. It can be a Global Positioning System (GPS) unit, or a triangularization technology that makes use of the wireless access points position (or GSM/CDMA antennas) to determine mobile device position, or any hybrid combination of both (as happens with assisted GPS (AGPS)). If this automation component is not present, the user has to specify its position by any mean.
- **Service and Application Provider:** The service provider offers a set of services to user.
- **Data and Content Provider:** Many times, the service and application provider need to obtain certain information it does not own, such as geographical information, event information, etc.

LBS applications need to be aware of a set of details, such as the type of mobile user, the context of the user, the user needs (can be gathered by questioning the user or by pervasive means, automatically), the search and spatial analysis, the user interface, the visualization properties of the device and a wide set of technological questions(how to transmit and store data, technical protocols and details). These details allow the user to effectively use the services.

Reichenbacher [11] enumerated five possible mobile actions users usually execute when using LBS:

- **Locating:** This is the most obvious action: user wants to know where he is.
- **Searching:** User may want to search for persons, objects or events

– **Navigating:** User may ask for the way to a location
– **Identifying:** Involves asking information about a location
– **Checking:** User may look for events near or nearby some location.

From this five possible actions it is easy to understand that all of them depend on the context. We can divide the context into three types of context [10]:

– **Spatial Context:** Where the user is,
– **Temporal Context:** When it is using the service,
– **User Context:** What is he using the service for.

Other authors [12] increase this list with other context types such as navigation history, orientation, purpose of use, social and cultural situation, physical surroundings and system properties. However, those context types can be viewed as subtypes of the three main context types proposed by Steiniger.

As it can bee seen, context is a main concept regarding LBS and as its importance is reflected in all the five kinds of mobile user actions, specially the spatial context.

2.2 Quality of Information in Mobile Services

Although mobile services are gaining popularity in contemporary life, there are some types of mobile services which are not effectively grasping their users. Public transportation services are among these services [13].

A comprehensive research [14] was made on how different dimensions of information quality affect consumers' satisfaction towards mobile information services and eventually the acceptance of these services. The fact that there are so many features which influence consumers' perceptions towards mobile services, called for a more precise theoretical framework. One promising way to consider the factors that affect the perceived quality of mobile information service from the consumers' point of view is the information quality framework of Chae et al. [5]. This framework identifies four dimension of information quality:

– **Context:** Although context was already mentioned in subsection 2.1, it is worth to mention a definition from Dey [15] adequate not only LBS but also generic mobile services context: *"any information that can be used to characterize the situation of an entity"*. Here an entity refers to a person, a place or an object that is considered important to the communication between the user and an application of the mobile service.
– **Content:** Content quality is the value and utility or usefulness of the information provided by mobile services [16]
– **Connection:** Connection refers to the link between the several components of the mobile service which allows the flow of information.
– **Interaction:** Interaction may be defined as the communication between a site and its users [17]. Mobile services achieve a high interaction quality if they are able to provide easy and efficient ways of interaction [14]. Being so, interaction is closely related to ease of use.

According to the framework, those qualities influence directly the user satisfaction. This influence has been proven by several studies [18] [19] [20] [21]. Based on the framework, Koivumaki *et al* [14] also show that all the four dimensions of quality in information services are positively related to user satisfaction. Another relevant conclusion of those studies is that user satisfaction is positively related to intention to use the service. The studies also state that although content quality is the most important factor, user satisfaction is affected by the set of the four factors, and consequently, the success of a mobile service depends on the form of all quality factors. Figure 2 shows the complete model.

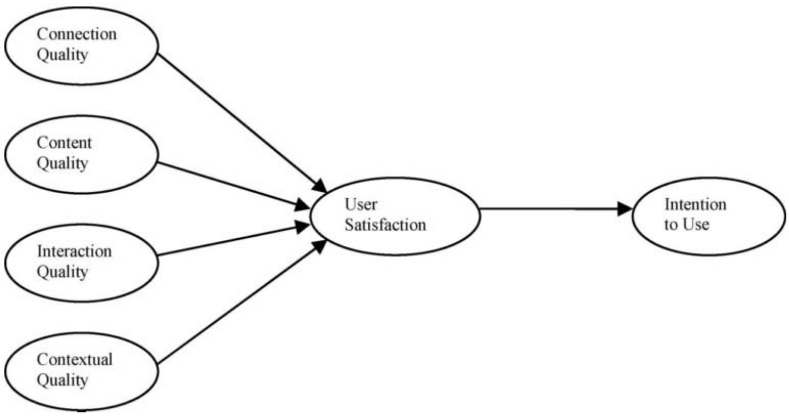

Fig. 2. The theoretical model of information quality, source: [5]

2.3 Schematic Maps

The onset of the industrial revolution brought a wide set of scientific, economic and social changes which required an increase of goods and people transportation. Large urban areas appeared and needed complex transportation systems, combining different transportation types. The need of highly efficient, easily understandable transportation maps pushed the evolution of the traditional maps, and new forms of cartographic representation have emerged. Among the new forms of cartographic representation that have emerged, the schematic maps were probably the most bold. One famous schematic map applied to a transportation network was the Harry Beck's London Underground diagram, depicted in figure 3.

Despite being bold and including some new and controversial features, this map was considered an innovation, as for the first time lines were drawn either horizontally, vertically or diagonally at 45. This map also uses a non-linear scale, so the central area of the diagram is shown at a larger scale than the extremities. It shall be noted that although it does not mimic the geography of London, this map gives the traveler some clues about the terrain features (ex: river) and his/her location. Avelar defines schematic maps as *"an easy-to-follow*

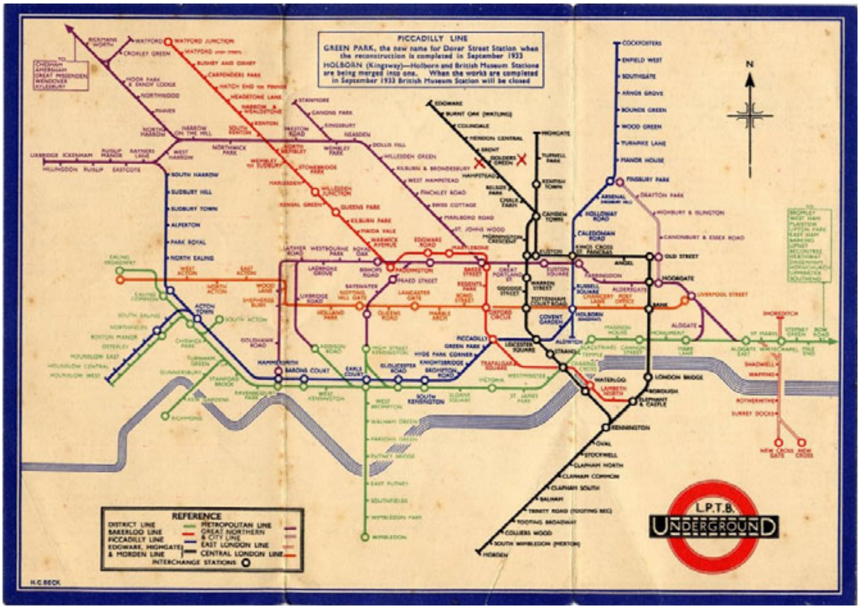

Fig. 3. London Underground Diagram by Harry Beck [22]

diagrammatic representation based on highly generalized lines which is in general used for showing routes of transportation systems, such as subways, trams and buses, or for any scenario in which streams of objects at nodes in a network play a role" [23]. The most important advantage of schematic maps is that they provide a quick view of the layout of the network by removing unimportant information like the detailed shape of the connections.

Schematic maps have been increasingly used in response to the need of better and simpler maps to describe complex transport networks. This apparent simplicity is achieved through a sequential process where choices are made regarding the level of detail and schematization choices. This process, called "schematization process", is still a manual process being carried away by teams of expert designers and cartographers, despite efforts in automating the process through the use of computers. The use of computers to execute the schematization process requires effective and efficient algorithms, to achieve in one hand high quality schematic maps which can be understood by people, and in the other hand a time efficient process. This process can also be used to produce schematic maps in soft real time, to support services such as transportation network load balancing through dynamic people routing across the network. Through schematization, certain map details are emphasized while others are deemphasized. It is fundamental, however, to present the smallest information amount the user needs to learn the map: the more information presented, the higher the learning time will be. Latto defends that information shall be reduced to its basic components to achieve that goal [24]. There are some studies regarding research the automated drawing of schematic maps [25] [26] [27] [28], nevertheless they do not analyze the schematic map generation a wide multidisciplinary problem as they tend to focus only in some areas of the problem. The automatic approaches for the generation of schematic maps mostly focus on the schematization process [29]. Nollenburg [30] [31] studies make an extensive research on the discrete mathematical foundations which are the basis of the algorithms used in the drawing of schematic maps and makes some brief considerations about their implementation. Nevertheless, his studies do not cover the human perception factors nor a concrete computer framework for drawing schematic maps. Silvana Avelar [23] presents a wider study, by including some human perception factors and makes a complete research on the schematic maps on demand, one of the components to be integrated in the new paradigm. She goes further on by presenting a framework for electronic schematic maps which can answer user queries and studies the automated generation of schematic maps. Nevertheless, the study of the human perception factors is limited to what she calls the aesthetic factors".

Most of the algorithms to design schematic maps retain a common structure [32]. They make use of a graph to model the transportation network, in which the vertices represent stops or turning points and the edges represent the paths between two turning points. Nevertheless, the automated generation of schematic maps is truly a multidisciplinary problem, which involves integrating knowledge from several science fields. Isolated studies of different areas of knowledge, such as cognitive psychology show that user centered maps have a better performance and allow users to commit less errors [33]. Hochmair, for example [34] studied the effectiveness in the context on route planning, more specifically, as a measure of how well the map information supports the map reader in planning the fastest route between trip origin and destination on a public transportation map.

As it is possible to see, the design of schematic maps is a complex problem. To solve it, there is the need to put together advanced optimization algorithms, transportation services knowledge, cognitive psychology and information systems engineering.

3 Spider Maps

Schematic maps are used nowadays as a vehicle for communicating transportation networks. The spider map, as a subtype of schematic map, can also be used for that purpose. But spider map features make it an enhanced tool for communicating transportation network information.

3.1 Definition

Schematic spider maps are a special type of schematic maps. As with traditional schematic maps, the stops and lines of the transportation network correspond to vertices and edges, respectively, in the spider map. However, they have enhanced features such a spider architecture, thus having a specific set of characteristics which sets them apart from the traditional schematic maps. Spider maps pay

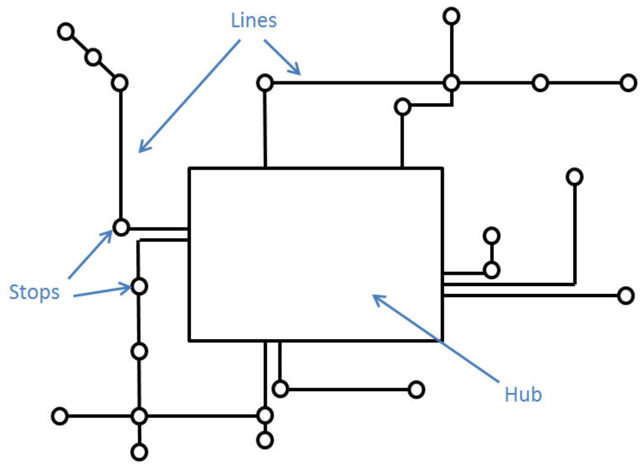

Fig. 4. Spider Map structure sketch

special attention to the context in order to enhance its learning by the users and it ease of use. The spider map architecture, depicted in figure 4, comprehends three main components []:

– **Hub:** The hub is the main part of the map. Describes the area in which the user is, as well as the surrounding area with a higher degree of detail (buildings, roads, etc). The hub, as it is the central part of the spider map, is the first component the user will look at, as it makes uses of *"focus and context"* [36] and detail focusing [24] techniques. The hub is the only part of the spider map which does not comply with the 0/45/90 degrees line orientation. It can also include landmarks to allow user to know important details about the place he currently is.
– **Lines:** The lines follow the orthogonal orientation of the traditional schematic maps, and describe the paths of the transport network where the user can go through while being at the zone depicted by the hub.
– **Stops:** The stops are the main destinations accessible to the user from the hub.

Figure 5 shows a Portugal real spider map of the the Sao Joao Hospital area for bus network service in Porto, produced with technology components developed by our investigation in the area in cooperation with OPT[1], FWT[2] and INEGI[3].

[1] OPT is an company based in Porto which develops IT infrastructures for Transportation Services. *http://www.opt.pt*

[2] FWT is a company based in London which produces maps for transportation networks. *http://www.fwt.co.uk*

[3] INEGI is a research institute based in Porto.

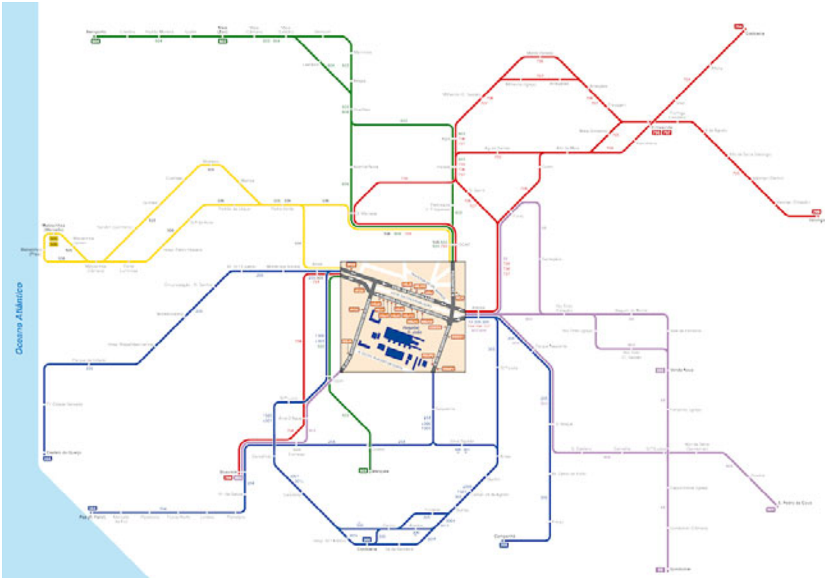

Fig. 5. Spider Map of the bus network service at Sao Joao Hospital Area in Porto, Portugal. For further detail on this figure please see http://paginas.fe.up.pt/˜ deg08005/index.html

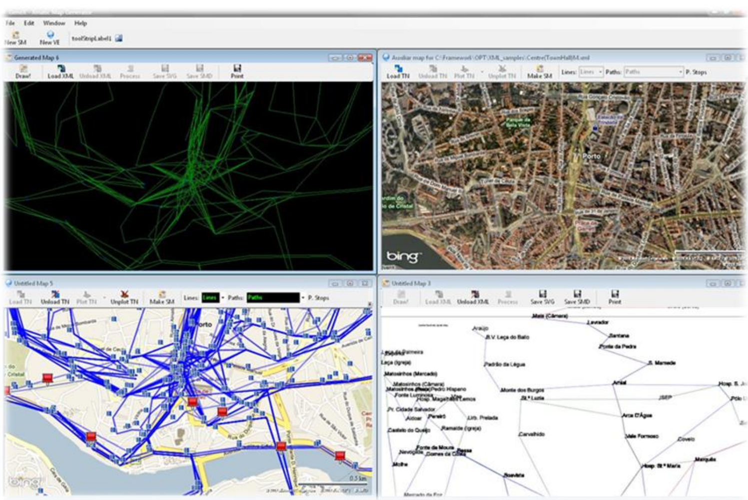

Fig. 6. The software framework, developed through our research. For further detail on this figure please see http://paginas.fe.up.pt/˜ deg08005/index.html

3.2 Electronic Spider Maps

Spider map advantages can only be fully materialized if automated means are used in their generation and use. This happens mainly in the communication of the user and time contexts: it is much faster to update an electronic map than a paper map, so an electronic map can be regenerated much faster than a paper map, enabling it to fit to a specific user context or time context. It is also better to generate user-centered maps through electronic maps [33]. The acquisition of context variables may be performed ubiquitously by seamless or autonomous sensors in pervasive systems which could directly affect in real time the production of spider maps. Space context could also be communicated more effectively and explored in many ways by using electronic spider maps. Our research has developed a software framework able to produce fully automated spider maps in soft real time [37]. This framework allows the visualization and generation of schematic (and spider) maps as shown on figure 6, serving as test lab for different schematization algorithms [38]. This is an excellent base to build user context-aware user centered spider maps in a bounded time frame, making them an ideal base for LBS.

4 How Spider Maps Can Enhance LBS and Public Transportation Ridership

If we look at the theoretical model presented in section 2.2 and depicted in figure 2, there are four dimensions of information quality which have a direct effect on the user satisfaction on mobile services. Regarding normal and schematic maps, spider maps present enhanced features to improve information quality in all the four dimensions.

4.1 Improving Context

Traditional schematic maps are not designed to pay special attention to the context of the communication act they are intended to support. Research on them has only approached syntax and semantics (ie. the symbols and their meanings in the layout of the map). Only recently the context (the third dimension of speech) [39] [40] has been given importance in the map design area. But as with any communication act, it also exists in the communication of spatial information. The spider map, due to its definition and features, is well suited to include context information. The map shall intuitively answer the user question *"where am I, and where can I go to?"*by providing him the correct space context to make the map more easily understood. The hub is a higher detail area which plays a fundamental role in communicating spatial context: when the user watches the map, intuitively it will look to the magnified area. This area shall depict the place where the user is at the present time, and the nearby stations, and all the relevant information for the user to understand that the hub represents the zone where he currently is. The zone can be only a point (a stop or station), an area (can have several stations, ex: city downtown), and shall be user-centered (the hub shall depict the geographical information accordingly to user's viewing perspective [33]). The lines flowing from the hub shall depict only the lines available from the station/stations inside the hub (not from the whole transportation network, thus reducing information amount and learning time and answering the question "where i can go to?"). The stations placed along the lines are the stations reachable from the station/stations/stops inside the hub. The hub also replaces the "you are here" statement, present at many maps, and allows the user to intuitively understand the spatial context where he is currently at. The spider map is also a good way to communicate user context. This is very important as there are different user types (at an extreme level, each user is inherently different from any other), with different intentions, needs and capabilities. Although there are many variables which could define the individual, when making transportation maps, the spider map shall be used to cope with different users, by changing its presentation (ex: high contrast schema for colorblind people, special hub and line definitions for children (ex: highlighting stations near schools and the lines which can take them there). Regarding time context, the spider map shall also change its presentation according to different times. For example, if at any instant, there is any problem in a line (obstruction, heavy load), the map shall regenerate itself in order to comply with that change. The same happens when special events that greatly affect transportation networks are taking place (ex: holidays, sport matches, celebrations). The challenge here is, this has to be achieved in near real time (which is already possible through the software framework we have been developing through our research).

4.2 Improving Content

Spider maps also provide enhanced content to allow the users to perform the five actions [11]. It allows the user to locate (through the hub), to search (as the spider map restricts the stops and lines presented to the ones the user can reach from its current location, it improves searching by eliminating superfluous information), to navigate (the user can easily know how to go to one destination through the schematized and simplified line layout). Identifying and checking are not the main objectives of the use of a public transportation network, but spider maps can be extended as other kind of maps to include content related to those actions.

4.3 Improving Interaction

Spider Maps have a higher degree of interaction quality. The use of the spider architecture is not a hit or miss matter. The spider map concept belongs to the domain of graphic organizers and mind maps. Spider architecture mimics the graphic organizers spider maps, which are proved to be improve learning and improve information recall as they represent knowledge in a similar way human brain does [41] [42] [43]. Being so, spider maps are easier to use and require less time for the user to learn them and therefore cause less errors and frustration, therefore increasing interaction quality.

4.4 Improving Connection

The use of Spider Maps cannot increase connection quality over a mobile service, as it can be easily understood. Nevertheless, the fact that spider maps can be produced in soft real time decreases waiting time for the user requesting the service.

4.5 Improving User Satisfaction and Public Transportation Ridership

As Koivumaki studies show, there is a positive relationship between the four information quality dimensions and user satisfaction, and between user satisfaction and the intention to use the service. [14]. Being so, if spider maps improve information quality in their dimensions, they will improve user satisfaction and consequently increase the intention to use the service. Dziekan [3] studies mention that one way to create high ridership in public transportation services is to strengthen their attractiveness by improving the quality of service. The author also presents the example of the city of Stockholm cooperation with the public transport authority in order to increase traveler numbers. This objective was also achieved by improving factors such orientation and information. Spider maps can play a fundamental role here in improving those factors, through their use in LBS.

5 Conclusions and Future Work

In this paper we have presented the theoretical foundations which support the assumption that the use of spider maps increases user satisfaction and intention to use LBS and therefore may increase public transportation services ridership. It is possible to conclude that the spider maps are a highly adequate vehicle to communicate transport network information in mobile services due to their higher information quality in comparison with normal or schematic maps. They improve the components of the information quality model presented by Chae [5] through the inherent advantages and innovations of their design. Their automated production through a soft real time makes them capable of responding in real time to changes in context, supporting what Steiniger calls *adaptative services* : services that dynamically respond to context [10]. Future work needs to be directed to test spider maps in real LBS of a public transportation service, to assess empirical evidence that spider maps increase user satisfaction, intention to use LBS and public transportation services ridership.

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