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Sakari Luukkainen, Mikko Karjalainen, Juha Winter and Mehrdad Bagheri Majdabadi

Sakari Luukkainen is Senior research scientist at the Department of Computer Science, Aalto University, Espoo, Finland.
Mikko Karjalainen is based at the Department of Computer Science, Aalto University, Espoo, Finland. Juha Winter is based at the Department of Computer Science, Aalto University, Espoo, Finland. Mehrdad Bagheri Majdabadi is based at the Department of Computer Science, Aalto University, Espoo, Finland.

Abstract

Purpose – *The aim of this paper is to identify promoting and restraining factors of a novel mobile service in the pedestrian safety area.*

Design/methodology/approach – *This paper uses the case study methodology that focus on analyzing a specific case of mobile safety services in depth. A case study is especially suitable for an emerging case, such as pedestrian safety, where the aim is to identify relevant influencing factors of the particular case and not to generalize the findings. To gather data for case study analysis, several expert interviews were performed. Because they provided a large volume of data, the Service, Technology, Organization, and Finance business model framework was used as a way of structuring the analysis.*

Findings – *The main restraining factors are end-user value proposition, battery life, accuracy of GPS positioning and the revenue model. However, the service could improve traffic safety considerably and it should be introduced first locally in places, where many accidents take place. There is a great interest on driver data, which could be the main advantage for this service in the future. Integration to navigation products would complement the service significantly.*

Originality/value – *Current traffic safety-related literature covers mainly technical issues, and there are only few papers related to business model issues on that particular service. Observations of the various factors affecting the related evolution at an early phase of the life-cycle support further service design process.*

Keywords *Case studies, Business development, Mobile communications systems, Cloud computing, Traffic safety, Telecommunication services*

Paper type *Research articles*

1. Introduction

Traffic safety is one of the most promising applications for Internet-connected vehicles. Most of the previous attention on traffic safety through vehicular networks has focused on vehicle-to-vehicle (V2V) communications for collision avoidance and road hazard alerts using WiFi-based communications technology. However, the associated DSRC/802.11p technology has major limitations in mass market adoption. The transceiver units are being rolled out by automotive original equipment manufacturer (OEMs) very slowly – it is likely to take still several years before the fitment rate is significant in new cars. Older cars still in use are unlikely to be retrofitted with this technology, which makes it largely uncertain whether other cars around you support V2V. Additionally smartphone manufacturers have shown limited interest in implementing DSRC/802.11p transceivers in their devices so far.

Ideally, road hazard alerts would also be sent by roadside units (co-located with, e.g. traffic light poles) directly to approaching vehicles by means of direct 802.11p communication with the vehicles (V2I, vehicle-to-infrastructure or vice versa). Roadside units could also serve to monitor traffic and receive safety-related messages and probe data. However, building the roadside infrastructure is expensive and dedicated V2I transceiver units supporting 802.11p are required.

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Smartphones and cellular technologies could provide a more commercially viable communication method for traffic safety applications. Although mobile technologies are not originally intended for vehicular networks, there is recent evidence of their feasibility for this need (Araniti *et al.*, 2013). They provide high mobility support, bit-rate, coverage and capacity. Also the latency of cellular networks has improved to reasonable levels since the introduction 4G Long Term Evolution (LTE), and 5G technology brings even further improvements. Some of the vehicles already contain embedded cellular connectivity, but otherwise, the smartphone could be used as an alternative. Mobile network infrastructure is already there and traffic safety could be only an additional application and revenue source for mobile operators while leveraging existing investments.

Although pedestrians are among the most vulnerable road users in fatal accidents (WHO, 2011), most of the attention on traffic safety via vehicular networks has concentrated on vehicle-to-vehicle accidents and thus improving pedestrian safety has not been extensively addressed. Related personal injuries are a significant cost for the insurance companies. Integrating pedestrians into the vehicular networks by means of their smartphones would enable development of innovative applications like vehicle to pedestrian (V2P) collision avoidance (Bagheri *et al.*, 2014). Proactive safety and prevention of such accidents could also be kept in mind as opposed to reactive safety measures like automated emergency call.

Currently, most pedestrians and drivers carry a smartphone that has a Global Positioning System (GPS) receiver suitable for collecting probe data: location, speed and direction of travel, from which prospective collisions can be detected. In the future, similar probe data can be collected directly by the base stations, which can be used to complement GPS. In a cloud-based system, smartphones can be utilized together with cellular technologies as the only communication method. Cloud-based intelligent safety systems could provide alerts on potential road hazards and other special conditions to drivers and pedestrians if they are connected and using proper software applications.

Most literature concerning mobile traffic safety applications has dealt with technical issues, while the body of research examining the related business view is scarce. That is why the research question of this study is the following:

RQ1. What are the critical business model issues relevant to deploying a mobile safety services in pedestrian usage?

Identifying the drivers and restraints of the related evolution at an early phase of development will increase understanding of the prerequisites for successful mobile safety services.

The paper is structured as follows: first, a description of methodology and theoretical framework for the study is presented. After this, related literature is described, which is followed by the actual business model analysis of the mobile safety service. The analysis and its results are summarized in the discussion and conclusion sections. Finally, recommendations for future research are given.

2. Methodology

Business models have existed for a long time, but only the adoption of Internet brought the term into common usage. Even with common usage, there is a lack of one clear definition for the term. One way to look into business models is to look what they are composed of. Among the first to analyze the term were Linder and Cantrell (2000). They identified seven components: revenue model, pricing model, value proposition, organizational form, commerce process model, channel model and Internet-enabled commerce relationship. Alt and Zimmerman (2001) were some of the first to perform a review of earlier definitions in the literature and found that six specific components were often mentioned: structure, mission, revenues, technology, legal issues and processes. After them, there have been several different listings, one of them by Chesbrough and Rosenbloom (2002). They defined that a business model has to be able to fulfill six functions: market segment, value proposition, competitive strategy, value chain, profit potential and cost structure and value network.

We utilize Bouwman *et al.*'s (2008) Service, Technology, Organization and Finance (STOF) model for this study. It is a theoretical framework developed for designing business models, originally meant mainly for mobiles services, making it well suited for analyzing our case of mobile traffic safety applications. The STOF model places emphasis on holistic evaluation of the business model, considering all of the domains mentioned above and value created for all members of the value network, including the customers. It allows holistic evaluation of the model even at an early stage, thus enabling detection of critical issues far in advance. Early identification of these issues simplifies reacting to any problem and helps with market adaptation. Additionally, it gives more weight to the technical issues, which is especially relevant for our analysis. Finally, the STOF model can be used to analyze connections between different domains, which is missing from several business model frameworks (Zott *et al.*, 2010).

The service domain is concerned with the most obvious part of a service: the value provided to the customers of the service. The main concern is the value proposition and how it compares to similar existing services. Additional concerns in the domain are, for example, customer segmentation and usability of the service. The technology domain analyzes the technological requirements and possible architectures and applications inspired by the requirements of the service domain. The whole technological implementation is considered here and as such also security, management of user profiles and possible devices for deployment. The organization domain is concerned with the actors required for the service and the value network created by them. All these actors act to fulfill their own goals and analysis of the network is the main purpose of the domain. Important here is to ensure that value is divided to all members of the network. Finally, the finance domain describes the financial side of the value network. It is concerned with how different actors aim to profit from the service and how an equilibrium can be created where all actors benefit financially from the service. Thus, the domain is interested in revenues, capital, associated risks and who should carry these. Clearly, all these four domains are linked to each other, beginning from the service specification that affects all others through, for example, value proposition affecting perceived value for customers.

To figure out what are the critical business model issues relevant to deploying a mobile safety service, we analyze the specific case of a mobile alert service using the STOF model. We are performing an intrinsic case study (Stake, 1995) with our analysis being based on expert interviews and a literature review. We conducted nine recorded expert interviews with Finnish organizations in the area of mobile traffic and mobile communications. The interviews were mostly conducted on the interviewees' location and took, on average, one hour. All interviewed people were in managerial positions in their respective organizations and were selected based on their familiarity related to traffic safety or mobile services. The interviewed organizations included a mobile network operator, information technology service providers, traffic authorities and an insurance company. The interviews were conducted as semi-structured (Hirsjärvi and Hurme, 2004) with same overall topics in all interviews structured by the STOF framework. Some questions were tailored for each interviewee to ensure relevant themes for their area of expertise while still covering the general questions. The interviewees were first shown an initial model of a V2P service to acquaint them with it and to give a reference point for the interview.

3. Literature review

Works such as those of David and Flach (2010); Sugimoto *et al.* (2008); Tornell *et al.* (2013) and Liebner *et al.* (2013) use existing infrastructure and devices for pedestrian road-safety. They use mainstream smartphones together with either WiFi *ad hoc* networking or cellular-based Internet, or a combination of both. It should be noted that, experiment and evaluation (Vandenberghe *et al.*, 2011), (Araniti *et al.*, 2013) show that utilizing WiFi only (not the amended 802.11p) is not practical in all collision prevention scenarios. The reason is that, unlike IEEE 802.11p, WiFi suffers from limited communication range (100 m) and weak mobility support (e.g. sensitivity to Doppler effect due to its 20 MHz channel width). On the other hand, although cellular technologies (e.g. 3G and 4G LTE) are not designed for vehicular networks, evaluation (David and Flach, 2010), (Araniti *et al.*, 2013) and experimentation (Sugimoto *et al.*, 2008), (Liebner *et al.*, 2013) show their potential for this purpose. This is because of their high mobility support and high bit-rate, communication range and communication capacity.

Regarding communication in road-safety systems, European Telecommunications Standards Institute (ETSI) categorizes the exchanged messages into two main classes (ETSI EN 302 665, 2010):

1. Cooperative Awareness Message (CAM) that is time-triggered (periodic) and conveys information related to the geolocation of vehicles. Data traffic can be heavy and frequent which might result in high energy consumption or considerable data exchange charges by operators to drivers and pedestrians.
2. Decentralized Environmental Notification Message (DENM) that is event-triggered and conveys hazard warnings.

Example of a DENM message for pedestrians is traffic light violation warning on their smartphones. This type of message needs less data traffic and has a limited lifetime. ETSI specifies maximum allowed latency of 100 ms for CAM and DENM messages, as well as the time interval between CAM messages ranging from 100 ms to 1.0 s depending on the use case (ETSI TS 102 637-2, 2011). For this purpose, LTE has a fair enough performance with a maximum latency of 100 ms (Araniti *et al.*, 2013). In addition, practical experiment (David and Flach, 2010) demonstrates feasibility of using earlier cellular technologies such as Universal Mobile Telecommunications System (UMTS) and high-speed packet access (HSPA).

Regarding computation, the predictive algorithm, pedestrian detection and collision prevention can be performed in one of the following three architectural arrangements (David and Flach, 2010) and the choice depends on which method provides a better performance and energy efficiency:

1. all computation performed on smartphone;
2. all computation performed on vehicle on-board unit (OBU); and
3. all computation performed on back-end servers.

In this paper, we adapt and use only the last method (cloud-based server). This method has the advantage of having access to road information such as maps which, in turn, allow performing more precise calculations and better predictions. However, utilizing map data for collision avoidance is outside the scope of this paper.

As mentioned before, there are a few previous works which use wireless communication and smartphones to develop pedestrian road-safety systems. David and Flach (2010) and Sugimoto *et al.* (2008) investigate different architectural arrangements, utilize smartphones on pedestrian side and use a hybrid communication method using both cellular connectivity and 802.11 (WiFi-based *ad hoc*). David and Flach (2010) address the non-structured mobility behavior of pedestrians by using filters to identify and ignore pedestrians' non-risky movement patterns. Sugimoto *et al.* (2008) developed a V2P prototype and performed simulation. A cellular network (3G) is used to send GPS data to a server which performs initial and predictive calculation. In case this calculation concludes a risk, vehicle and pedestrian are notified to start a direct WiFi-based V2P communication.

Anaya *et al.* (2014) use only WiFi as the communication medium, analyze requirements of V2P collision avoidance system and implement a tablet-based prototype for the pedestrian side. Tornell *et al.* (2013) implement a WiFi-based protocol and a smartphone app for vehicular communication scenarios. However, as mentioned before, WiFi may not perform well in road-safety scenarios because of its limited communication range and high speed of network nodes. Wu *et al.* (2014) integrate DSRC without any hardware or chip upgrade into mainstream smartphones carried by pedestrians. Smartphone is used only on pedestrian side, while vehicles use dedicated hardware. However, Wu *et al.* (2014) do not thoroughly investigate the feasibility of using the power-hungry DSRC (Tornell *et al.*, 2013) on smartphones. Using only cellular communication, authors of Liebner *et al.* (2013) experiment and analyze the accuracy of GPS information provided by smartphones, and feasibility of using 3G Internet in terms of latency.

Unlike previous solutions, we analyze the road-safety system from the business point of view and examine the critical business model issues relevant in deploying a mobile safety service in commercial usage. In addition, unlike David and Flach (2010) and Sugimoto *et al.* (2008), our system design uses a cellular network for communication in all cases, and no switching is performed between cellular and 802.11p (or regular WiFi) when a risky situation is detected by the cloud-based server.

4. Case analysis

4.1 Service design

Typically, only the newest premium car models have advanced traffic safety features, such as radars integrated to automatic braking and head-up display alerts. The average practical lifetime of cars, e.g. in Finland is about 11 years (Trafi, 2013). Thus, most of the car population will not have sufficient safety mechanisms for a long time. Furthermore, radar detection requires line of sight and the reflector range of the pedestrian is limited. Risk of accidents increase in the dark time or when a pedestrian appears suddenly from invisible places on the path of vehicle.

The traffic safety application would send early collisions avoidance alerts to the mobile phone to activate the vigilance of driver. Pedestrians and cyclists will also contribute GPS probe data for purposes of their own safety and collision avoidance with vehicles through a smartphone-based solution utilizing cellular communications developed for this purpose.

Most critical issues within the service domain were found out to be end-user value proposition, market penetration and customer retention.

4.1.1 End-user value proposition. The value proposition for the end-user is mainly composed of three separate points: increased safety, discounted insurance and bundled application. Increased safety is the most obvious added value of a system such as this, but most interviewees saw that it alone is not big enough an incentive for large-scale adoption of the service, thus there is a need for additional value propositions. One possible source for value is insurance companies, which could provide discounts for drivers using the service. Additionally, GPS probe data of willing drivers could be shared with their insurance companies, making them eligible for further discounts. Finally, the service can be bundled with other services, such as the navigation applications and ridesharing.

Some incentive is needed for the pedestrians, too, to provide GPS probe data via a mobile app that they would be willing to keep running regularly. Thus, at least for pedestrians, the service should be free of charge. Very often, pedestrians or joggers wear headphones and listen to music and they cannot hear the approaching vehicles or they are just concentrating on using their mobile phones. Thus, the system could give collision alerts also to the pedestrian if it recognizes that the user's terminal is active. Additional alerts could also be transmitted to nearby drivers approaching crosswalks or other areas with considerable pedestrian activity.

Statistics of the generated alerts can be used in road-safety planning. The service provider could sell the alert statistics to the transport authorities, which can then improve the traffic safety of the roads. The system could also give automatic alerts based on the earlier statistics of the most dangerous places.

4.1.2 Market penetration. It is essential for the service that a large enough number of users in a given area are using it. If there are low chances of communication as with V2V techniques, the service is not attractive for users. Therefore, the service should be piloted in highly local conditions, small cities or neighborhoods where a lot of accidents take place and where the community together wants to increase traffic safety. Then, it is easier to achieve sufficient penetration for the service. Thus, local drivers, pedestrians and cyclists are the target group for the service. Local public transportation, taxis and other professional drivers are then possible extensions to this.

Ensuring an adequate numbers of users is also critically important during expansion, so that new users do not drop the service because there are too few users in their area. Thus, even after the initial pilot, a slow expansion around the same area was seen by the interviewees as the best way to increase the user base. The service can be promoted annually in the beginning of the school semester or the dark time of the year as the issue of road safety rises during these times.

4.1.3 Customer retention. Most interviewees stressed the issue of customer retention and in addition to market penetration, ease of use and lack of false alarms were seen as the critical features to ensure this. Market penetration is essential for retaining the end users because the lack of other close-by users renders the service essentially useless.

The interviewees brought up two ways in which ease of use is critical. First, the mobile application has to be such that it is always and automatically on. It is not feasible to expect the end user to remembers to turn it on every day or even whenever the device is switched off and then on again. Second, as the app will be ideally used by a sizeable portion of the population, it has to be as simple to use as possible.

Lastly, constant false alarms were seen as something that would drive most end users away and avoiding these would be essential.

4.2 Technology design

In such a traffic safety system, the technology design is based on mobile cloud computing, where servers perform the data processing and computation and end users (drivers, pedestrians, cyclists) only send update messages to the cloud. These probe messages contain speed, location and direction of travel. This information is enough for the system to anticipate possible collisions.

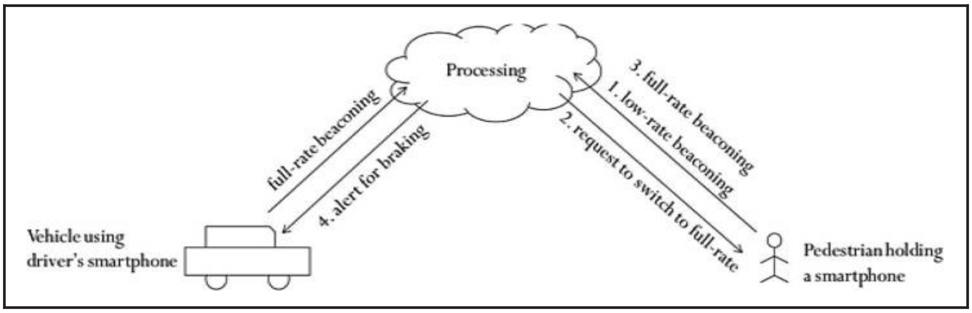
In case a possible collision is predicted, the server informs the vehicle's smartphone, triggering an alert. There are two models for implementing the alerts. They can be either very prominent and loud alarms with the intent of forcing the driver to brake immediately or they can be subtler with the intention of only increasing the driver's awareness in a potentially dangerous situation. The case for more prominent alarms is clear: if there is little time for the driver to react, the alarm must be noticed quickly. However, the increased awareness from the subtler alarm is often enough. For example, a considerable benefit of the subtle model is the lack of distraction, which was deemed as a likely problem in a service like this by several interviewees.

The application could also be integrated to, e.g., a popular navigation application. In the case of GPS-based positioning data and various backend applications, a public cloud could be used as computing platform.

The most critical design issues in this domain were found to be battery life and accuracy of the GPS signal.

4.2.1 Battery life. The limited battery life of smartphones is one bottleneck in the realization of such a system when using GPS. To predict accidents, terminals need to constantly, and with a high frequency, send location updates. These periodic messages can, even when

Figure 1 System work flow (Bagheri *et al.*, 2014)



sending a small amount of data, drain the smartphone battery quickly. To save electrical energy in smartphones and thus enable running the pedestrian safety system, an adaptive multi-level approach is proposed which changes the messaging frequency according to traffic density and level of risk (Bagheri *et al.*, 2014).

The associated method saves energy by reducing unnecessary network traffic that is caused by constant radio-level beaconing. Figure 1 illustrates the system workflow. Mobile terminals perform the beaconing while the cloud performs the more frequent and energy-consuming operations of listening as well as calculations for collision prediction.

Pedestrians in risk-free situations, e.g. when they are walking along streets without crossing or when they are not in sufficient proximity to any road or vehicle will be considered as a risky situation. In such risk-free situations, a constant full-rate beaconing is not required. For this reason, the system can contain low and full-rate modes of operation for the pedestrian. The pedestrian's terminal works in an energy-saving mode in risk-free situations where the beaconing frequency is kept at a lower rate. A predictive algorithm is running in the cloud at the same time.

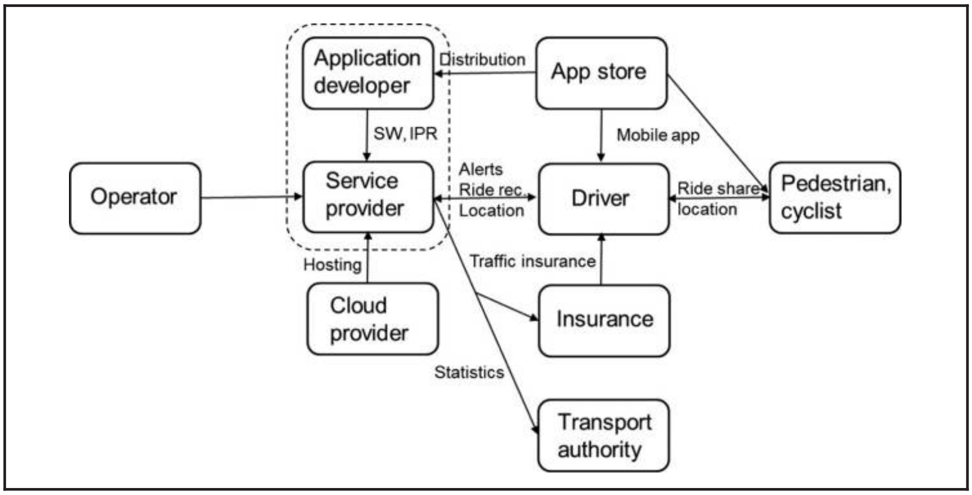
When a riskier situation arises, such as when the pedestrian approaches the road to cross it or reaches certain proximity of vehicles, the predictive algorithm recognizes the change of situation and adapts the system accordingly. It then sends a push message to alert the pedestrians' terminal to switch to full-rate mode. Additionally, the system could recognize situations when a pedestrian user is inside a vehicle. Then beaconing would automatically stop in order to avoid wrong alerts.

The driver's terminal works in full-rate mode all the time. It can be assumed that it is plugged to vehicle's electricity system using a car adapter. However, if such arrangement does not exist or the driver forgets to plug the smartphone, the system could alert the driver about this problem. As soon as the distance between a vehicle and pedestrian and their movement direction and speed indicate a risky situation, the system starts a full-rate communication to perform further processing.

4.2.2 GPS positioning. The accuracy of the GPS signal was a common theme in all interviews and an important question in general for all traffic safety services based on GPS technology. Most interviewees thought that the accuracy would be enough in general, especially if a good movement prediction algorithm would be used in calculating potential collisions. Few also argued that the quality of the predictive algorithm might be a more significant constraint than the accuracy of GPS positioning itself.

Cities were seen to be the most significant challenge for GPS positioning, as they combine the need for precise location data and several obstructions in the form of buildings and other structures. Concerns were also raised about the dampening effect of clothing as people generally keep their smartphones in their pockets during daily activities.

Figure 2 Traffic safety case's value network



4.3 Organization design

The value network for the service can be seen in Figure 2. The service provider operating the traffic safety system is the central actor in the value network. However, the roles of the actors can vary. The roles of the service provider and the application developer can be combined, even though they are considered in this design to be integrated. That is the reason for dotted lines used in the picture. Experience in developing software for traffic applications would be very beneficial for the application developer as there are issues not found in typical mobile applications, such as the importance software stability and service availability.

A public cloud provider is needed to provide an additional hosting platform for the system. The application store provides the application developer with the distribution channel and billing platform for the mobile apps. The service provider provides the car insurance company with the lists of active drivers using the system and possibly information about their driving habits, e.g. whether they follow speed limits. To increase market penetration, it is essential to work with most insurance companies in the serviced area. Additionally, the service provider delivers statistics about locations of frequent alerts to the transport authority that can use this information to its benefit in road infrastructure and traffic planning.

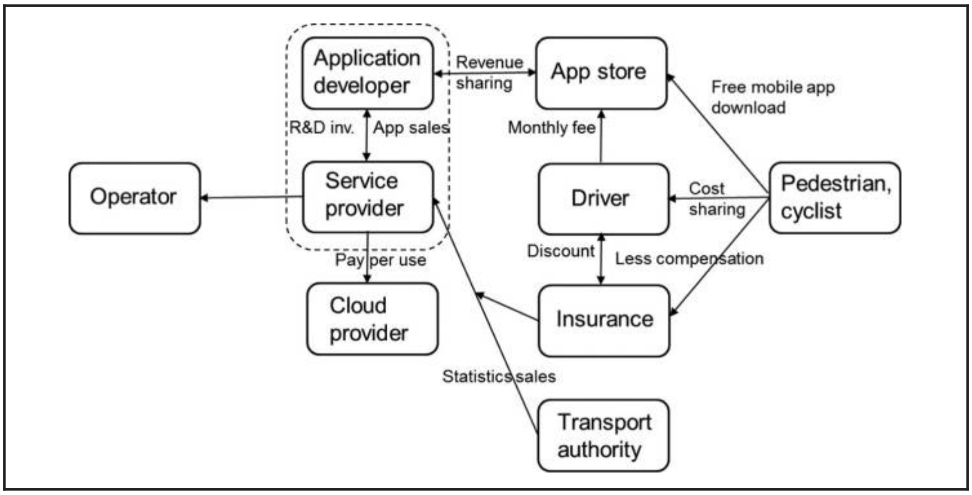
The end users of the system, drivers, pedestrians and cyclists, send their probe data to the service provider and, in return, receive collision alerts and recommendations of ridesharing or location of free vehicles in car pools.

4.4 Finance design

The actors gaining most value in the network are the end users and the insurance companies. There are two reasonable options for the service's revenue model, either most revenue is collected from the drivers or from the insurance companies.

In the first model, drivers will pay the through the app store a monthly fee of €5. This price is set to match the price of the 5 per cent discount of car insurance. The insurance company could give additional discounts to drivers if their driving habits are considered safe. The insurance company's compensation costs of accidents are supposed to increase in the future. The app store takes 30 per cent commission for each app download by drivers and also the monthly fees charged as in-app purchases. The app is free of charge for pedestrians and cyclists. Possible new sales could come from OEM contract with

Figure 3 Traffic safety case's revenue streams



navigation application provider. The collected data could also be sold to the traffic and road safety authority and insurance companies. (Figure 3)

In the second model, the app would be free of charge also for drivers and the revenue would be collected mainly by selling users' data to the insurance companies. It would probably see wider adoption among end users than the first model. The data collected by the service can be used by the insurance companies to make better predictions and thus there would be an interest in buying it from the service provider. This model would also avoid sharing revenue with app store, increasing profits for the service provider. Again, the collected data could also be sold to the traffic and road safety authority.

The R&D investment cost of both mobile application and server side is expected to be around €400,000. The service provider has to pay for the public cloud provider annually on average €15,000. However, this is a variable cost relative to the usage of the cloud platform. The service operator also needs personnel for maintenance and marketing. So, the service operator incurs around €300,000 annual operating cost.

If the service will be promoted in small communities by around 8,000 driver customers, the break-even point could be reached, and annual sales would then be around €380,000.

5. Discussion

Mobile safety services, as proposed, offer tremendous new opportunities for businesses. The most significant difference, when compared to often proposed systems using, e.g., wireless 802.11p technology, is the lack of need for new hardware, whether handheld or in-vehicle devices. This considerably simplifies and facilitates deployment, making it faster, more efficient and cheaper for the service operator.

Our analysis found significant challenges that still need to be addressed for a service such as the one proposed to work reliably. First are the obvious technical issues: GPS and battery life. There has been some research into the viability of GPS positioning in such services (Liebner *et al.*, 2013). They found that at the time of testing, GPS was accurate enough for a GPS-based mobile safety service, at least when considering only the longitudinal direction. However, storing the mobile phone in a jacket pocket degraded the quality of positioning considerably. Additionally, Bagheri *et al.* (2014) concluded that their algorithm lowers battery usage in this use case to more practical levels. Other solution could be to use location information directly taken from the base stations without GPS. The related concept of Mobile Edge Computing provides application developers real-time access to radio network information like location of terminals. In the service domain, as large-scale adoption is necessary for the usefulness of the service and the value of the service has been found to be critical for adoption of mobiles services (Mallat *et al.*, 2009), the end-user value proposition is seen as one of the most critical issues.

Overall, there are several positive factors encouraging mobile safety services. First, there seems to be a clear social expectation for some kind of a mobile safety service, as all interviewees found the basic idea of such a service to be valuable and saw that it should at least be tested at a larger scale. Second, the initial costs and operating expenses are minimal thanks to the lack of required special hardware, which has been seen as a problem for the swift adoption of other proposed systems. Third, the interviewed insurance company expressed enough financial interest in the data collected from the drivers to warrant further research.

6. Conclusion

In this paper, we analyzed a GPS-enabled mobile traffic safety business model. The approach was a case study concentrating on an earlier technology proposed by Bagheri *et al.* (2014). We evaluated the service using the STOF model based on expert interviews and literature review of earlier research. Several critical business model issues were identified and discussed in detail.

The main issues included concerns about end-user value proposition, battery life, accuracy of GPS positioning and the financial design. However, the interest shown by the insurance companies toward driver data collected by the service shows that there is basis for a profitable venture in the area even if the revenue is not collected from the end users. The safety service should also be integrated with other services like navigation and ridesharing.

Mobile safety services like the one presented could improve traffic safety considerably, but if there are low chances of communication between pedestrians and vehicles, the service is not attractive. Thus, the service should be introduced first locally in places where accidents take place and where the community mutually wants increased safety.

7. Future research

Although most interviewees saw that there would be potential interest from the end users, this is a critical area for future research. As mass adoption of the service is required for effective operation, a large-scale pilot should be conducted to gauge the viability of the end-user value proposal. Simply having an increased level of pedestrian safety may not be enough for all end users, and additional incentives may be required. Determining these incentives through direct end-user feedback surveys, interviews or other means would be a key next step.

Another important focus for future research is a pilot to study the technical challenges, mainly battery life in continued usage and feasibility of GPS tracking. Additionally, research into how integration with Mobile Edge Computing could benefit the system should be explored. Lastly, a comprehensive survey into insurance companies' financial interest in the collected data should provide critical information for the financial viability of such services.

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Corresponding author

Sakari Luukkainen can be contacted at: sakari.luukkainen@aalto.fi

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