PILOT SYSTEM FOR TRANSPORT CONFIRMATION WITH LOCATION AWARENESS

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Abstract

Many Finnish municipalities have experienced an increase in the demand for logistics services. In addition, the requirements for energy efficiency and the goals of reducing traffic and noise pollution have created more costs for the municipalities and triggered a need for improvement and optimization. Nowadays there are various route and logistics optimization applications that can be used to replace routes previously calculated by hand. Automatically generated routes can increase the efficiency of logistics operations by lowering the overall costs and providing faster delivery of goods. These applications can be further improved by offering real-time information to those responsible for the management of the services, and also providing the people making the actual deliveries, e.g. the drivers the most up-to-date routes. The goal of the system presented in this paper is to combine the route optimization and tracking possibilities required by logistics managers with an easy-to-use mobile application, which utilizes location data and is targeted especially to the drivers making the deliveries. The paper describes the system architecture, and evaluates the usability and potential of the system from the perspective of logistics optimization. The paper is based on the pilot run of the system, and on the research done in co-operation with the City of Pori, Finland.

Keywords: mobile application, location awareness, geographical information, pilot system

INTRODUCTION

There are several factors that need to be taken into account when planning for municipal logistics services: delivery time windows; the number of vehicles used for deliveries and routes; vehicle capacity and capabilities; and potential special customer needs. Cost-effective routes should be planned on the basis of these factors, which can be a challenge if done by hand. The various tasks are generally not grouped together in the most cost-efficient and optimal manner. For example, the grouping could be based on a simple geographical task organization by zip/postal codes, or by grouping deliveries related to schools in one group, which may or may not be the optimal solution.

This research has been carried out in co-operation with the City of Pori (Pori, 2012) located at the west coast of Finland. Pori has around 900 kilometers of streets, which, in addition to normal road maintenance, require snow plowing in the wintertime. There is also a need to manage around 300 000 home visits (e.g. elder care), school and meal transport, and various mail and goods deliveries with multiple vehicles. Optimizing these activities can benefit not only in terms of lower costs, but also in better service quality.

The issues related to logistics management have been studied in various projects participated by the City of Pori for several decades, and the research field, in itself, is not a new one (for more detailed discussion e.g. Fisher & Jaikumar 1981, Solomon 1987, Laporte & Osman 1995, Fisher 1995, Laporte et al. 1997). However, the previous projects did not provide the results the City expected. This has been attributed mainly to the fact that most of the route optimizations were done manually without the aid of automated tools. In recent years attention has shifted to various software solutions, and to the use of location data in conjunction with mobile applications.

In preliminary studies made by the City of Pori, it was noticed that many of the old routes could be executed in a much shorter time, and in some cases it would be possible to combine multiple routes, thus requiring fewer vehicles for the logistics operations. These findings encouraged further studies, one of which is the project undertaken with the Tampere University of Technology, Pori Unit (TUT Pori, 2012). The goal of the two-year project – MOP (from Finnish: Mukautuvat OhjelmistoPalvelut, or “Adaptive software services”) – is to research the possibilities offered by location aware applications. During the project, a pilot system was developed for the logistics department of the City of Pori. The system can be used by both logistics managers and the personnel involved in the various day-to-day logistics activities. This paper describes the system architecture that was developed, as well as the implemented mobile application for the delivery and pickup drivers. In the context of this paper, if not stated otherwise, the term delivery is used to mean a logistics operation, which can be a pickup and/or a delivery of goods, mail or other similar items.

The structure of the paper is as follows: in the next chapter (The Requirements for Pilot System) we represent the basis and the starting point of the system development work. After that (Pilot System), we describe the structure and elements of the developed pilot system and the functions included in the mobile application in more detail. In the chapter Discussion, the developed system is evaluated and the next steps we are going to take in our research are also presented. Finally, the contents of this paper are summarized in the last chapter (Summary).

THE REQUIREMENTS FOR PILOT SYSTEM

The starting point of logistics planning is the proper analysis of customers' locations, travel distances and times, timetables, and the possible special requirements for the goods to be delivered. There are successful commercial applications (e.g. Kim et al., 2006) available that can be used to calculate the initial values. In addition, it is beneficial, if the system can offer suggestions on the vehicle types, and what kind of changes is required to the used vehicles if the order and delivery volume changes. The suggestions can be based on the pre-set properties (the capacity of the vehicle, driving speeds, working hours, driving cost per kilometer, etc.) of the vehicles. Based on the aforementioned requirements and properties, it is possible to calculate not only the optimal route, but also, to generate various alternative scenarios for future conditions and use cases.

For the pilot system the ArcLogistics (Arclogistics, 2012) route optimization application developed by Esri (ESRI, 2012) was chosen. The route optimization in ArcLogistics is based on Vehicle Routing Problem (VRP) algorithms. VRP is discussed more detailed by Solomon 1987, Laporte 1992, Fisher 1995, Laporte & Osman 1995, Laporte et al. 1997, Cordeau et al. 2002, Kim et al. 2006, Potvin 2009,). There were two basic reasons for this. Firstly, the application had all the requirements needed for the implementation of pilot system architecture based on the preliminary research work done by the City of Pori (Vanhala, 2011). Secondly, it has already been used by the City for test applications related on the optimization of personnel transport and wintertime road maintenance, for example snow plowing route optimization.

In addition to the requirements created by the route optimization, which are largely managed by the chosen third party application (ArcLogistics), there are other requirements, perhaps more directly related to the end-users, i.e. drivers of vehicles. In case of the deliveries, it is also important to acquire a confirmation. In practice, the confirmation process is usually implemented by a simple pen-and-paper signing process, where the delivery driver has a form, in which he/she fills in the details of the delivery, such as arrival time to the customer's location, and maybe asks for the customer's signature. This is the way the confirmation is often done by the regular courier/express services, and is also the way currently used by the City of Pori. This method, in its simplicity possesses a couple of risks. Firstly, there is always the possibility of human error, for example, mistyping the arrival time, or forgetting to ask the customer's signature. Also, this manual confirmation process lacks the real-time tracking that could be implemented with automated systems. There have been some minor problems, in which the customer has complained about the city's delivery services, claiming that the package did not arrive in time, or was not delivered as reported by the driver. These claims are very hard to verify or deny, as in principle, the customer and the driver both could be right, and thus it is hard to – definitely, and with proof – to say who made an error.

To enhance the confirmation process, we decided to design and implement a simple mobile application for the drivers. The main purpose of the application is to provide more solid confirmation process, and also to easily provide the details of the next destination. By using the navigation capabilities of the modern smartphones, it is also possible to provide directions to the next destination. In case of the regular and experienced drivers, these instructions may not be necessary, as the destinations themselves do not often change, though the order and amount of destinations per day can change. By using a smartphone application it is possible to automatically log the drivers' location and the time of arrival to destination. Additionally, by logging the departure time, the duration of the event can be calculated, which can be used to improve the optimization process. It is also important to note that the confirmation process is not only for the benefit of the logistics system, but also for the benefit of the driver, who will have a definite way of proofing his opinion of the matter.

As the mobile application is especially targeted to the drivers, this also creates additional challenges. It should not be assumed that all of the drivers are familiar with smartphones or feel comfortable in using the devices; it becomes crucial to design the user interface as simple and easy to use as possible. It should also be noted that we, as researchers, are not the ones doing the actual driving, it can be hard to figure out which features should be in the application, and what is only unneeded extra, or how easy the functionalities are to use in practice. For these reasons, it was important to do test runs with the actual drivers to get their inputs and opinions, and we decided to design a pilot system, which would first be tested with real transport routes optimized by the City of Pori. In the future, the system might entirely replace the delivery lists, which are often manually created and printed on paper for the drivers.

PILOT SYSTEM

In order to solve the aforementioned problems in logistics services, a pilot system consisting of a management server and a mobile application was created. The main goals of the system were to offer a semi-automatic management of delivery schedule and an easy interface for drivers to verify the completion of the deliveries. At the moment, the system is being piloted by logistics and transportation services of the City of Pori.

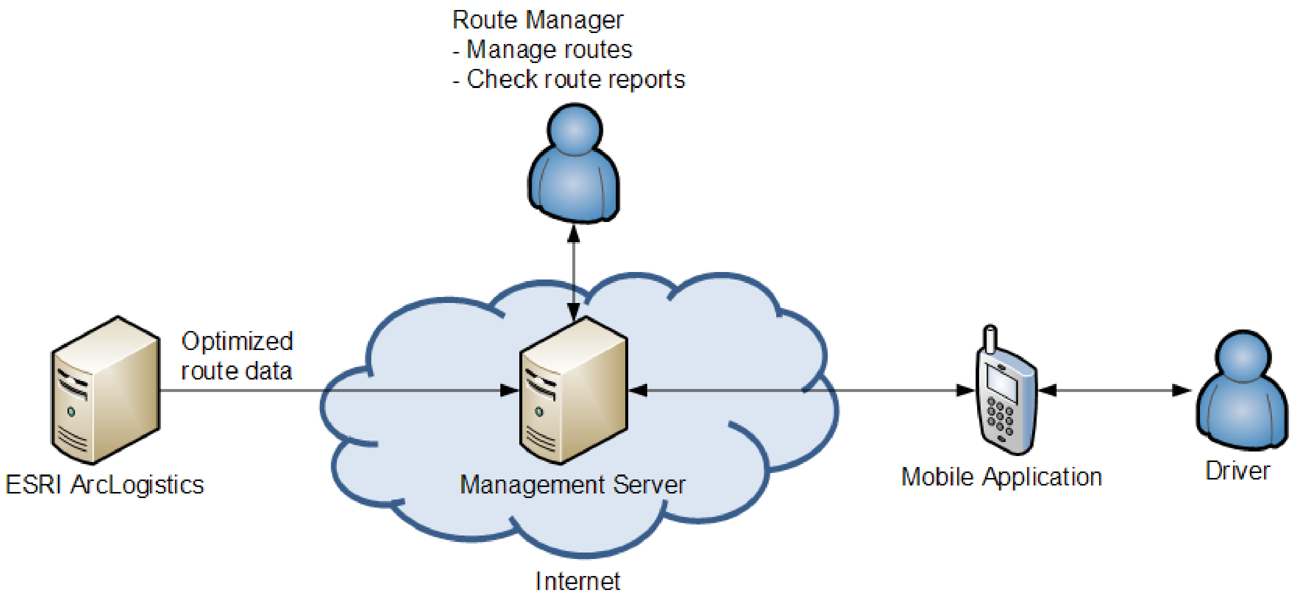

Fig. 1. The overview of the pilot system.

In Fig.1 is the overview of the pilot system which shows the relationships and directions of data flow between the different components. The *Management Server* is in a central role of the pilot system as it allows the route management, it generates real time route reports and it provides the newest data (i.e. route schedules) for mobile applications. The route management is carried out by uploading an optimized route data for each working day. Optimization, route management and upload require some amount of manual work. In the case of the City of Pori, there would only be five different route schedules for a each working day, and in general, the routes do not often change – and some of the routes can be valid as long as a couple of months. However, we agreed that this was an acceptable work load in the pilot stage.

Usually optimization begins by defining the preferred time windows, resources, destinations and other information of the routes. Once the initial data is defined, it can be optimized by hand or by any suitable application. In this case, we used the ESRI ArcLogistics for the optimization. The *management server* accepts the optimized data generated by ArcLogistics. This way the only remaining action is to upload a corresponding route data for each workday into the system.

The reporting web user interface allows the route manager to easily see in real time which delivery tasks have been finished and which tasks are still in queue. If there are network connectivity problems on the mobile device, the confirmations will be temporarily stored on the device. As soon as the network connection is re-established, the information is synchronized with the server. An example of a generated report is shown in the Fig. 2. The displayed data is for route with identification *ABC-123* for date *25th of September 2012*. The following data is shown for each task:

- Status of the task: queued, in progress, completed.
- Time window: earliest and latest time when the task should and/or can be completed.
- Customer's name and address.
- Timestamps of arrival to destination (*Arrived*) and departure from destination (*Completed*) confirmations. These are also links, which open a map with a marker of the confirmations.
- Duration between the confirmations.

In the generated report the first three tasks are marked as completed and the rest of the tasks are not started yet (i.e. *queued*).

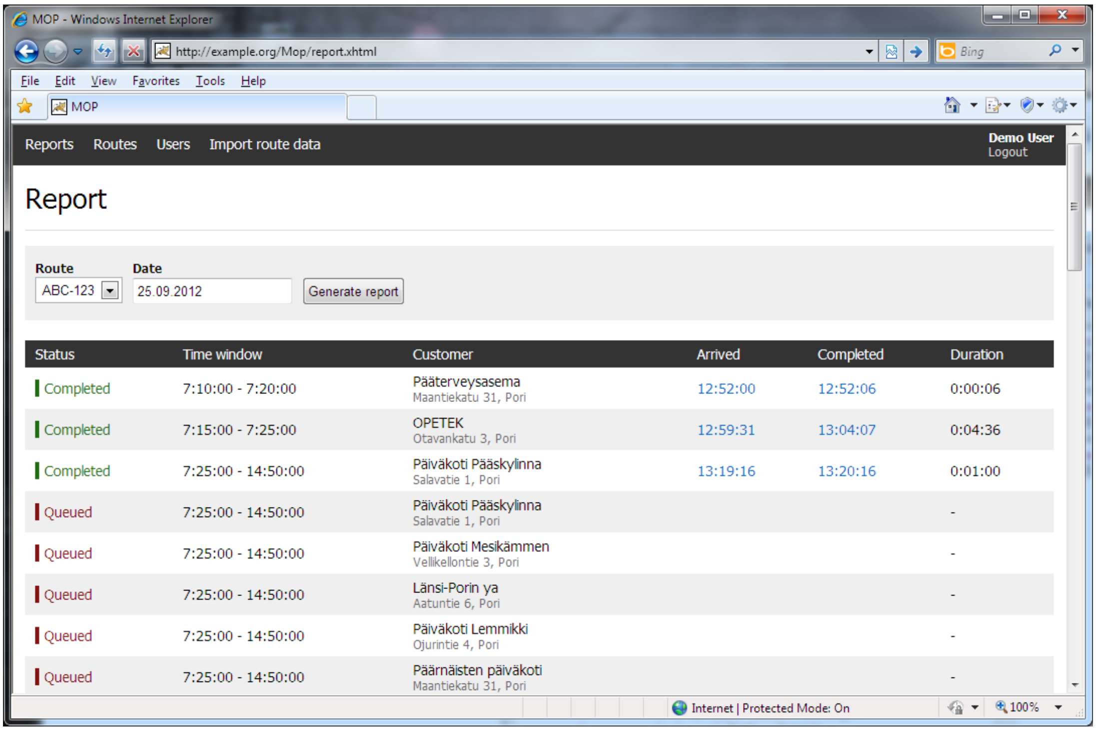

Fig. 2. Management view: Route report.

By clicking the time stamped link, a map window is opened. This map shows where the driver sent the confirmation by using his/her smartphone. A sample of this view is shown in the Fig. 3.

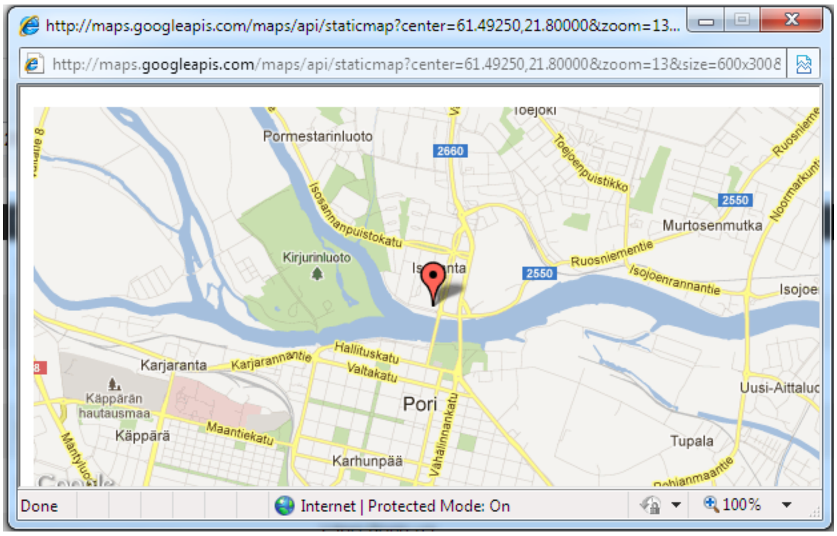

Fig. 3. Management view: Location of confirmation.

As the third main feature of the management server, it provides the most current route information for the drivers' smartphones. The information between the management server and the mobile application is exchanged in platform independent way by using Extensible Markup Language (XML) (W3C, 2008). This allows the developer to choose any modern target platform and development environment. In the pilot stage, we targeted Symbian platform (Qt framework, Digia Qt, 2012) as these devices were already used by the City of Pori. Because of the simplicity of the client software and of the chosen XML-based communication protocols, it is relatively straightforward to implement clients for different platforms, such as iOS or Android.

As the application is to be used in a car by a driver, or a co-driver, a special care for the user interface (UI) must be taken into account. The features must be easy to use with a touch-screen as an input device, simple enough for a user to understand and to learn. Finally, the user must receive an impression that the application helps to complete his/her job. Otherwise, the application may not be adapted as a new, and a natural part of the job. The mobile application provides the following main features:

- Task list. The application retrieves the current work list from the server (see Fig. 4. left side).
- Detailed information of the task. This view shows all relevant information of the task (see Fig. 4. center).
- The confirmation of arrival to the destination and departure to the next destination. With these features, it is possible to send information – such as GPS location and time stamp – to the server. This information can later be used to verify whether a certain task was completed on time or not.
- Map view with route drawing. This view allows seeing where you are and also a route to the task's location (see Fig. 4. right side)

The design of the graphical user interface is an attempt to combine a minimalistic layout with an easy readability and a touch screen friendly operation. The screen shots of the driver's mobile application are shown in the Fig. 4. Leftmost screen shot is the main view of the application. By using this view drivers can browse all tasks of the current date. In the example case there are four visible tasks. The first task, titled with customer name "*Pääterveysasema*", has a green tick and is partially opaque. The green tick means that the task status is completed. The next two tasks differentiate between each other by having different delivery types: pickup and delivery. The second task is a pickup task and has an icon of an unloaded truck while the third task is a delivery and it has a loaded truck as an icon. The type of the delivery can also be seen below the title. Estimated time of arrival is after the delivery type written inside parentheses. The destination address (i.e. customer's address) is the last piece of information that is seen of the task in the task list.

In Fig. 4. the estimated time of arrival does not adapt to the delays in the delivery schedule. The optimization process can use the time window value to allow minor delays in the schedule. In case of longer delays it is possible to send an automatic notification to the route manager who can contact the drivers and modify the task list or take other applicable action. In the figure, the time precision is shown in seconds for testing and illustrative purposes, but for a production environment a lesser precision can be chosen.

Fig. 4. Application screen shots: Task list (left side), Task details (center) and Map view (right side).

When a task is clicked, a view that is in the center of the Fig. 4. is opened. This view has the same information as the previous with a few additions. These are the *comments* field, and confirmation buttons. The comment field may include an optional text description that the customer or the route manager has deemed to be relevant for the driver. The confirmation buttons are used for verification of the task. By pressing the button *Arrived to destination,* followed by pressing the button *Departing to next destination* the task is marked completed. The confirmation information can be seen in the management view seen earlier in the Fig. 2. If the confirmation was mistakenly done, the driver can *cancel* the confirmation. The cancellation can be done by using the cancel button which will replace the confirmation buttons in the task details view (not visible in Fig.4.).

The last view (Fig. 4. right side) is the map view which can be accessed by pressing the truck icon while in the detailed view. The map view can give the overview of the task by calculating a route from current location to the destination. A few markers can be seen on the map. A blue “S” (top part of the figure) marker is the starting point which shows the location of the previous destination (if available), and a green “E” marker (i.e. end marker, in the bottom part of the figure) is where the destination is. The recommended route is shown between these two markers, and it updates automatically while navigating to the next destination. While navigating, a green square marker will show the driver’s current location. The green marker is barely visible in the figure, under the “S” marker. The map can freely be panned by using the touch screen. The map also provides a way to zoom by using the buttons “+” and “-“. The “car” button in upper left corner will recalculate the route if needed. Button labeled “E” pans the map to show the destination. Pressing the button on the bottom left will center the map to driver’s current location, and follow the car’s position on map.

The previous chapters explained the main features of the developed pilot system, and described a general use case scenario. The following chapter evaluates the usability and feasibility of the system, its applicability to logistics domain, and more specifically, to delivery tracking and confirmation from the municipality’s point of view.

DISCUSSION - PILOT SYSTEM EVALUATION

Today, both private and public sectors are faced with the somewhat conflicting and ever increasing needs for new improvements on their operations. There exist a continuous demand for both tight cost control and high quality services in all functions of the organizations. At the same time, new applications based on the information and communication technologies are introduced to markets almost every day. Re-engineering, or in other words, changing the existing business process somehow, is not necessarily a low hanging fruit, but rather a risky business. In terms of resources and calendar time, it usually consumes both of them, although the success is not guaranteed. In order to avoid a failure, it is usually a good practice to run a pilot project on the new approach before making almost irreversible decisions on new technology. That was the case, when the City of Pori decided to co-operate with Tampere University of Technology, Pori unit (TUT Pori).

Explorative usage of existing information at organization's legacy systems by developing new user interfaces for the new data types and new compositions of content is a common measure when organizations improve their processes. However, a poor or too complicated user interface of a new application is quite often a common scenario for failure. When the users are not willing to invest a lot of their time in order to learn the complex usage of an application, it will lead to the frustration of the users. That will be unacceptable situation, because in that case the deployment of the application is probably useless effort. For that reason we decided to focus on the easiness of the use of the pilot application. The developed graphical user interface for the drivers is quite minimal thus removing the drivers' need to worry about the usage of the application during the workday.

Before the deployment of the pilot system, there have been some minor problems, in which the customers of the delivery system have complained about to the City's delivery services. Some customers claimed that the package did not arrive in time, or was not delivered as reported by the driver. These claims are very hard to verify or deny. We considered about implementing automated arrival and leaving confirmations, but decided to leave that feature out of the pilot system. The reason was that automatic confirmation system may introduce undesired side effects that could be seen as major flaws by the drivers. From the programming point of view, the automatic confirmation system isn't too complicated, so it can be implemented if the pilot system succeeds and the users feel that they need that feature. Entirely automated process does have some other issues though. For example, there might be cases when it is absolutely necessary to inform the customer of the arrival of an important delivery. If customer's signature is required, that limitation cannot be removed, and at most the application can only remind the driver to ask for one. Another serious problem can be the accuracy of the positioning device. In a city with tall buildings the accuracy of smartphones' GPS (Global Positioning System) or network-based positioning can cause errors by reporting the location incorrectly, making it harder to confirm a visit solely by using simple geo-fencing. This is especially true when there are multiple locations close to each other, making it even more problematic to detect which location was actually visited at what time. In the case of nearby locations it is also possible that one of the destinations has not been visited at all, but this is impossible for the system to detect. It is also possible that the positioning source becomes unavailable (typically in the case of lost fix of the GPS signal). As it is hard to predict when and where the positioning errors may occur, the automatic confirmation should not be blindly trusted.

Because of these reasons, it was decided that a better solution would be a semi-automatic system, in which the application will provide destination information, and the key details of the required operation, but would not automatically confirm the delivery. In principle, a fully-automated solution would be preferable, but based on the initial tests, it was decided that the problems caused by the accuracy and connectivity problems can cause very hard to find errors, making the system perhaps in some way even more problematic than the traditional pen-and-paper confirmation scheme. Of course, with the mobile application, the list of destinations could be delivered directly to the driver's phone, and possibly updated on-the-go if needed, which would have been difficult with the old system, especially if large changes of the route were required.

The pilot is still ongoing, but the first results have shown that both the functionality and the appearance of the application's user interface are well balanced. There are some concerns still left which could limit the value of the system to the customer. The optimized routes have been quite fixed until now, meaning that there have been only limited amount of variation from day to day. This means that the procedure of making and deploying the new routes for vehicles do not happen very often and thus it is not routinized. Optimized routes may be valid for months. In the event that the situation changes, there is always the possibility that either the process of exporting the input data from ESRI to the management system or the deployment of the new routes to application fails for some reason.

Some topics for future research are new features of the user interface (bigger screens, signatures by electrical pen, contextual functionality, etc.), improvements for the positioning issues and explorative usage of the rich variation of geographic information produced and archived by the City of Pori (National Land Survey of Finland, 2012). Some of the positioning issues may also be solved in future by using preinstalled NFC (Near Field Communication) or RFID (Radio Frequency IDentication) tags on the destination. Based on the success of the first pilot, and the positive feedback and experiences received in the co-operation with City of Pori, we are now planning to use the developed and piloted service composition as a key component of the other mobile applications based on optimized routes and resources. Next candidates for new pilots are snow removal and several types of transport services to the homes of elder or handicapped citizens. In these new pilots we will also study the economical views, and continue to evaluate the customer satisfaction when compared to the traditional methods used by the City of Pori.

SUMMARY

The current trend towards energy-efficiency and effective utilization of all kinds of resources is reflected to an increasing degree in municipal services, too. In this research the subject was approached from the aspect of optimizing public sector logistics. The aim was to improve and streamline the transportation process through the utilization and combination of mobile and location aware technology. The idea was to improve transport verification and facilitate the work of the drivers during the transportation process. The initiative for the system development was to create an environment where logistics managers could monitor the transportation process, and where the system would have the capability to verify actions and resources, like the exact time stamps and locations of deliveries and pickups. Moreover, one of the starting points was that the system should support the drivers in their daily work. The research result, a pilot system with a mobile application developed during the MOP research project, was introduced in this paper. The presented system is one way to assist and support the transportation optimization, as well as reliably verifying the events that occur during deliveries. Furthermore, it gives one example of how the available technology can be utilized so that it looks and feels useful and is also very simple to use from the end-user's perspective. The next step will be to study the opportunities for expanding utilization of the system to cover other fields of operation in the public sector, as well as studying the economical effects of the route optimization process.

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