TOWARDS AN INTERMODAL ROUTER FEATURING CYCLE SAFETY IN BERLIN

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Abstract

Different ongoing activities in Berlin promote cycling as a valuable alternative to private car use. An innovative approach of trip routing based on ITS technologies is presently under development and testing addressing not only car use and public transport but also walking and cycling. The goal is to provide cyclists the safest routes by taking into account additional cycling relevant parameters and data sources such as availability of the different kinds of bicycle lanes, type of road surface, traffic signals and accident hotspots. The relevance of the different parameters for cycle safety can be directly gathered from the users. The user will be able to evaluate the data sets and information provided. Based on crowdsourcing mechanisms updated information will be assured regularly. Overall, the system and development will be tested and assessed in two iterations of pilot field trials.

1. Introduction

Calculations for Germany show that each percent which is being transferred from urban car transport to public transport (PT) results in a reduction of about 260,000 tonnes of CO_2 per year. A shift of 5% to PT would mean a growth of around 24% in public transport demand and lead to a reduction of up to 1.5 million tonnes of CO_2 [1]. Besides public transport cycling is a valuable alternative to get around in urban areas. Assuming that 30% of all car trips below a length of 6 km would be realized by bicycles a reduction of 6.6 million tonnes of CO_2 per year [1] could be realized.

Berlin observes a growing demand in PT and cycling. In this regard, the Berlin authority considers and supports the increasing number of bicycles within the city strategic infrastructure development plans. Appropriate street infrastructure developments are foreseen to enable cycling and intermodal “Bike & Ride” mobility together with PT opportunities. On the other side, Berlin has an alarming accident statistics with about 1.752 badly injured and 27 cyclists killed in the three year period (2009- 2011) [2]. This shows that broad activities are required to improve safety and to enable and promote cycling within the city.

Currently, any actions to control and influence the traffic situation are based on a reactive level, such as providing warnings over the radio or displaying updates on congested roads on information screens. Even rerouting suggestions are only general. Particularly cycling specific information is not available. New approaches are therefore required enabling a sustainable change in the mobility behaviour in terms of greener transport and safer traveling.
Therefore the objective of the R&D project STREETLIFE, co-funded by the European Commission, is to encourage commuters to shift to alternative modes of transport by providing them with updated intermodal transport information. New technologies and services based on ITS were developed and tested in order to realize the envisaged objective within the three different pilot cities of the project (Berlin, Rovereto and Tampere).

The main goals of the STREETLIFE Berlin pilot are threefold:

i. Increase the safety for cyclists
ii. Reducing the carbon footprint of a trip
iii. Improve the transport performance of the city

Changing people’s mobility behaviour is a very challenging task. STREETLIFE addresses this task by incorporating different kinds of data to provide intermodal routing information in order to plan a trip. Additional user preferences allow the user to change easily between different transportation modes and to gain travel comfort.
A conducted requirement analysis shows that people would use bicycles more often, if cycling becomes much safer. In this regard, the Berlin pilot partner VMZ faces an innovative approach by defining a routing algorithm which takes into account cycling relevant data such as the availability of the different bicycle lanes, road surfaces, traffic signals and incident hotspots.
To adequately integrate the different modes of transport a comprehensive design of the application is of high importance. The design requirements of a mobility App covering intermodal routing information and personalisation were analysed by Schaffer & Reithinger [3]. The authors argue that an increasing amount of available data sources, including cyclists safety data, and the possibilities to generate intermodal trip chains result in a growing number of options regarding the personalisation of routing requests. This development poses a challenge for the design of mobility Apps, as the complexity of interfaces usually increases with the number of options. With respect to this the authors recommend to focus on specific user groups. Furthermore it was revealed that valuable solutions for the presentation of the mode choices within a routing proposal have to be found. If the number of transport modalities increases, the presentation of routing proposals within a list may have to be adapted in such a way that the information is still easy to process for a user.
Overall, several important preconditions and requirements had to be taken into account in preparation of a cycle safety intermodal router.

The rest of the paper is structured in the following way: Section 2 analyses the requirements of such an intermodal router and gives an overview of the current state of Berlin´s system and technology. Section 3 describes the envisaged system, its current state and future development. Section 4 elaborates on the methodology for gathering relevant data and evaluating and assessing the systems benefits and user acceptance. Finally, Section 5 elaborates on the initial results (final results will ready after the 2nd iteration) and discusses the future work.

2. Current state of Berlin and the systems

2.1. Requirements

With respect to the service design a requirement analysis depicts three essential conditions, which have to be met during the first stage of the project: A new application must be able to support multi-modal route planning. The computation of actual necessary modes of transport should consider the user and the user should have the opportunity to state their opinion (crowd-sourced approach) about the calculated and presented routing results for further service development in the future.
In order to contribute to the overall target of CO_2 reduction by influence people´s mobility behaviour to make use of more non-motorized modes of transportation, the focus of the Berlin pilot has been placed on bicycle traffic. The evaluation report of the recent online survey [1] indicates that cycling safety is a very important issue for wide proportion of the Berlin population. [4] Within the online dialogue people were asked to name locations within the bicycle and street network that they perceived as being dangerous. More than 27.000 single web site visitors have named more than 5.000 locations. Thus the focus of the Berlin requirements is set on the cycling community, especially on the aspect of safety. Accordingly, a new routing service should integrate services for different transport modes and focus on bicycle routing by taking into account safety aspects.

2.2. Services in place

An analysis of existing systems and available data depicts several available components that could be built upon. The main actor for providing traffic information on behalf of the City of Berlin is the Berlin Traffic Information Centre (TIC Berlin). Presently, the TIC Berlin offers multi-modal routing services for public transportation, car, bicycle and walking. For this purpose the backend system utilises external routing services from the regional public transport association (VBB), TomTom, Google and Bbbike. – see Figure 1: Existing routing architecture.

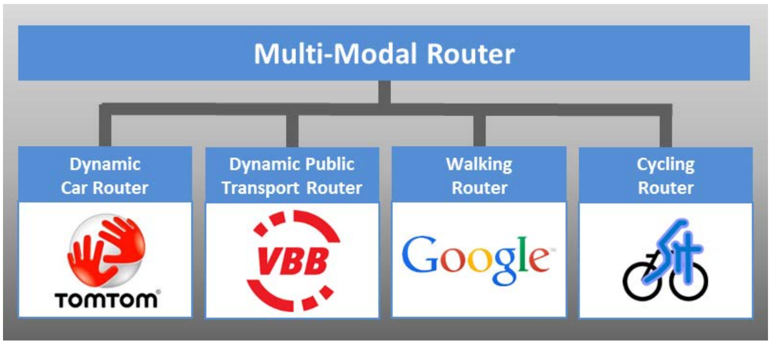

Figure 1: Existing routing architecture

In addition, VMZ Berlin provides real time data on bike sharing. VMZ has an interface connection to bike rental operators, which provide station based bike sharing services within the city centre. A data query of VMZ Berlin regarding the location of rental stations and bicycle availability is realised via a proprietary interface.

2.2.1. Technological Gaps

Not all requirements mentioned above are met with existing data and services. An analysis showed that a specialized router is needed to calculate:

- Trips for both private and shared bicycles.
- Intermodal trip combinations for individual transport - especially bicycle paths - and public transport modes, based on real time traffic information.
- Personalised trips with respect to cycle safety aspects.

An analysis of the mobility Apps available reveals that currently none of the existing solutions for Berlin

[1] Online Dialogue during the period of 12. November and 10. December 2013. More information: https://radsicherheit.berlin.de/

cover all of the stated requirements. Especially a mobility App that includes intermodal routing and safety aspects for bicycle traffic does not exist for Berlin so far.

3. System and technology

3.1. Backend

Service modules are separated in backend and frontend components. Regarding backend components, different underlying routing services are used for calculation of single routes, each for one mode of transport:

- TomTom router, to calculate routes in individual motorized traffic (private car)
- Google router to calculate walking routes
- VBB router to calculate routes within the public transport network
- Bbbike router to calculate bicycle routes

These routers are integrated in one VMZ router, to generate multimodal trip planning results. If more than one route is an option for a trip from A to B all route options are presented. The VMZ router obtains available real time traffic data which may have an impact on the trip results. Car routes take into account the current traffic situation (LOS[2]), as well as construction sites and road closures or similar events. Public transportation routes consider the real time departure times, including delays and further related information.

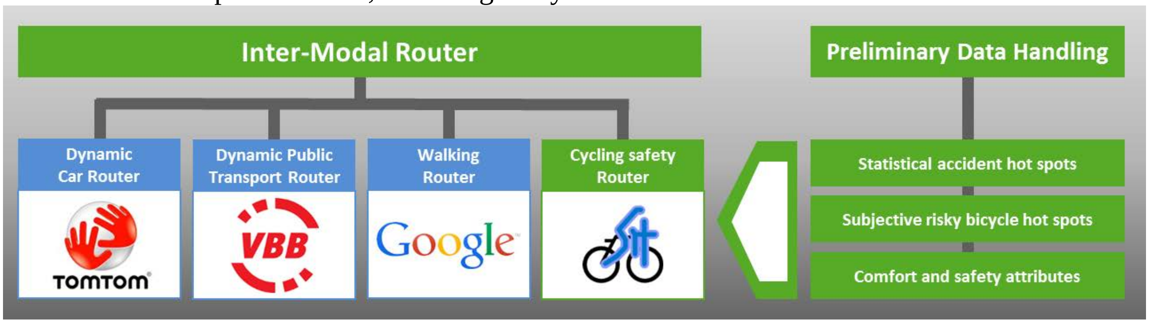

Figure 2: Extended routing architecture

Figure 2 shows the multi-modal router, extended to a multi-criteria intermodal router, which considers all routing criteria and personal trip preferences. If the route calculation results in an intermodal route, the trip will be presented accordingly, i.e. a trip could consist of at first a bike sharing part, followed by a public transportation part. For that, the entire component takes single routes from the external routers and combines them to intermodal trip results, being presented via the STREETLIFE app to the user.

In parallel, the cycling router will be enhanced taking into account safety and comfort aspects. For that a preliminary data handling is necessary. *Accident hot spots*, provided by the Berlin Police department, *subjectively felt points of danger* (based on the survey mentioned above) and *comfort as well as safety attributes* will be added to the routing variables. Furthermore other attributes regarding cycling safety will be taken into account: i.e. reference surface, quality road surface, traffic control at intersections, bicycle traffic at intersections or right-turn green arrow at intersections. All values will be analysed through a client based accident analysis through the tool ProVista[3] being an own development by VMZ.

In order to create a router that takes into account relevant cycling attributes we'd like know which information actually matters for the cyclists that contribute to safety. One step towards this goal is the survey conducted by the Senate department on the subjective dangerous cycling spots.

Considering that the data sets dangerous hotspots for cyclists and the quality of cycling routes are dynamic and subjective information, they need to be evaluated by the users and regularly updated.

Following the current trends in the domain of mobility, a crowd-sourced approach has been chosen as a mechanism for providing this data. Typically crowd-sourcing is used in the domain of mobility by tracking of travellers during their trip, for example using GPS tracks, possibly enriched with other context information coming from additional sources like public transportation systems, parking systems, ticket validation systems and so on. This information can later be used for personalized guidance during one's trip (when processed

[2] Level of service divided into "no delay", "moderate delay" and "severe delay"

[3] Provista Accident Analysis tool - Result of a Research Project 2009-2012

individually), or for deriving general mobility information (for example current average vehicular speed on a given road, as demonstrated, among others, by the popular Waze app[4]). This approach will be extended for the cycling modality by developing a context-aware crowdsourcing technique that collects cycling route quality information directly from the users as they travel.

Figure 3 illustrates the two basic components of the backend system - the intermodal router and the context-aware crowdsourcing component and their communication with the frontend and users.
Immediately after users complete their routes, the context-aware crowd-sourcing component generates route evaluation criteria depending on the context and pre-existing knowledge for the route (safety and comfort are given here as two basic examples). The system provides the users an opportunity to give their first-hand cycling experience, data which will be used to enhance pre-existing knowledge base with user-generated information.
This method will help us gaining knowledge on individual and general level. Through users' input the system will learn about their preferences and reflect this knowledge in the route personalization process. The crowdsourced data will also contribute in evaluation of existing knowledge about route safety as well as to gain information about new routes that did not appear in the previous surveys and do not exist in our knowledge base.

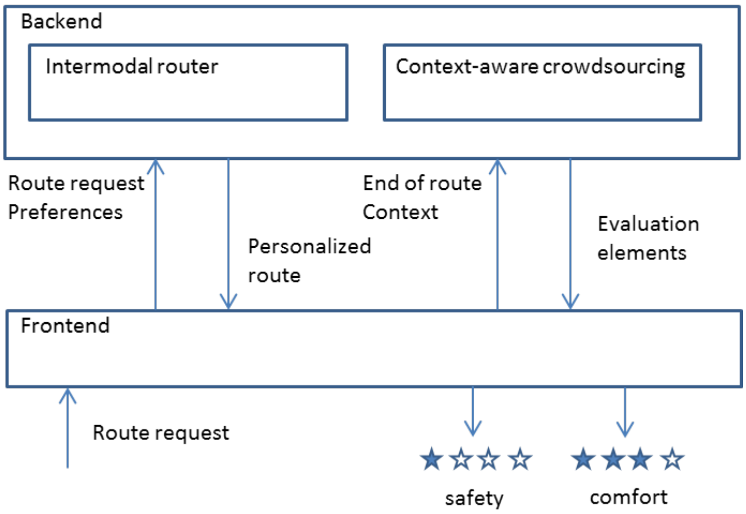

Figure 3 Backend and Frontend components

Our ongoing research combines both, selection of the right evaluation criteria and user interface design that will encourage and motivate user participation.

3.2. Frontend

As described above so far no mobility App exists fitting the stated requirements for Berlin. Therefore, a completely new App was developed. To ensure optimal user satisfaction, a user-centred design approach was chosen. Accordingly, user requirements were collected and use cases that should be covered with the service were described. Representing the core functionality of the system, the two main use cases 1) intermodal routing and 2) personalisation; were implemented in a first functional prototype employing MMIR, a Mobile Multimodal Interaction and Rendering framework using HTML5 as base technology [7]. The prototype is a smartphone application for Android devices.

[4] https://www.waze.com/

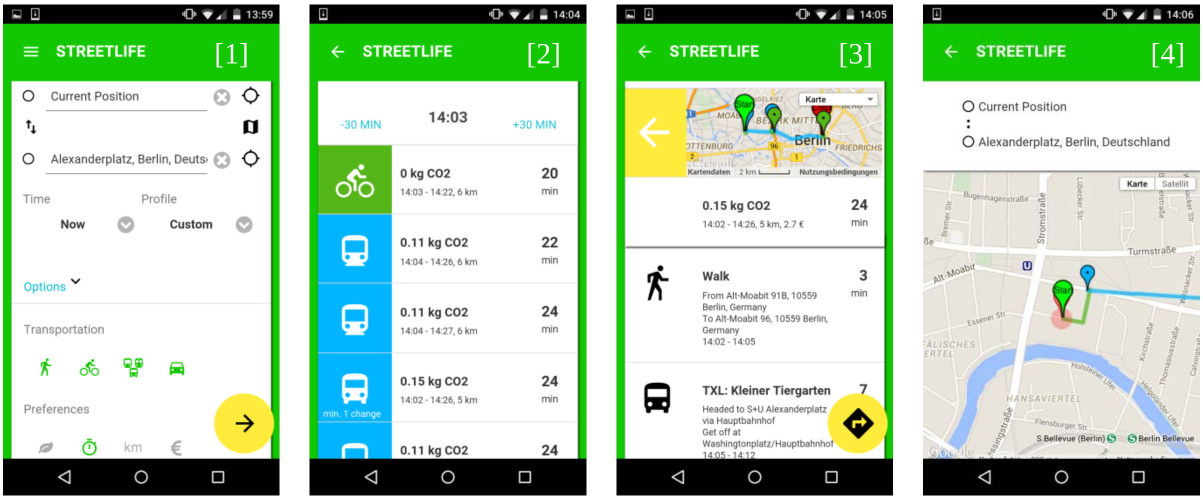

Figure 4 Mobility app screens: (1) basic routing information, (2) routing proposals, (3) navigation details for the selected result, (4) companion mode

Currently the mobility App for Berlin is connected to the intermodal router and provides an initial set of possibilities for personalization. The main purpose of the app is to efficiently support users stating route requests and help selecting appropriate itineraries. Figure 4 provides an overview of the most important features. Users can input origin, destination and further personalized routing preferences (screen 1). The latter refers along with the desired transport modes, to personal preference (greenest, fastest, shortest, or cheapest route) and settings concerning the maximum distance to be travelled for each used mode of transport. The routing proposals are presented in a list containing information about duration, distance CO_2 emission and main modes of transport within the itineraries (screen 2). If more than one mode of transport is used within an itinerary, a note is displayed under the mode icon. The colour code of the mode icons in the routing proposal screen gives a first idea about the eco-balance of the itinerary. The details of the itineraries can be viewed in textual format and routes can be visualized on a map (screen 3). By pressing the navigation icon in the lower right corner of screen 3a “Companion mode” is activated. During the companion mode the current position and the selected route are visualized on a map (screen 4).

As a next step specific features for cyclists will be integrated. These features will expand the personalisation options depicted in screen 1 of Figure 4, by adding a section for “Bicycle routing”. Within this section icons for “safe bicycle routes” and “comfortable bicycle routes” will be integrated.

4. Evaluation of the system

4.1. Methodology

The main goals of the STREETLIFE Berlin pilot are namely, i. Increasing the safety for cyclists, ii. Reducing the carbon footprint of a trip and iii. Improving the transport performance of the city, have been describe above.

In order to evaluate these objectives two scenarios and several use cases have been defined. The scenarios address on the one hand the end-user and on the other the traffic management.

Both groups play a major role while realising the objectives. The underlying concept in these scenarios is presented in the implementation cycle (Figure 5). In accordance to that the vision of the implementation cycle is the use of the mobility App through the citizen to find the preferred route. The route request and the related mobility data will then be integrated, stored and processed through the traffic management operator. On the next level the processed data will be aggregated and analysed with regard to required adaptations to improve the transport system and mobility services. Finally, the citizen benefit due to the described loop.

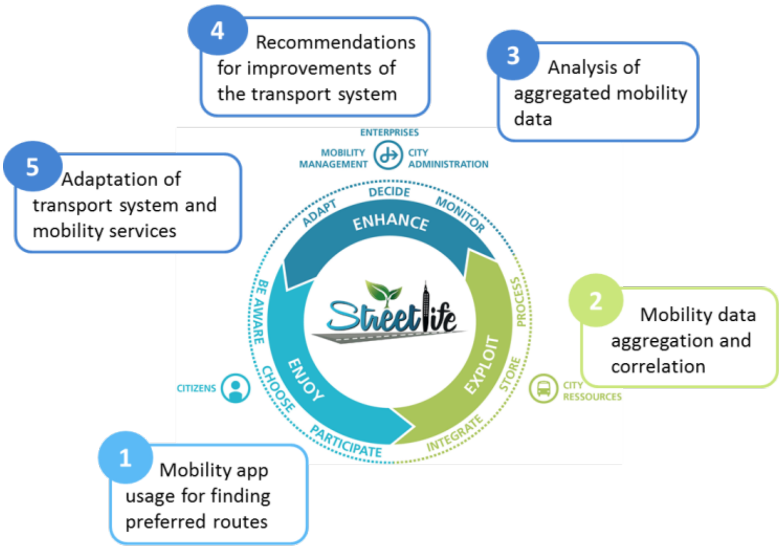

Figure 5: Implementation Cycle

With the aim of testing the implementation cycle and in order to identify the required data, software and tools and to realise the pilot objectives, a number of use cases were defined. A detailed description of the use cases can be consulted in the related STREETLIFE deliverable [5].
With regard to the evaluation of the implemented system an evaluation methodology has been elaborated addressing mainly the three impact categories:

I. User behaviour
II. Mobility
III. Environment.

Based on the defined objectives, research questions, hypothesis and indicators were defined. Relevant indicators with respect to the above mentioned impact categories are i.e.:

- Average changes in modal split
- Travel time per trip
- Users perception of comfort
- Service quality satisfaction
- User's safety perception

4.2. Methods used

In order to address the before mentioned three impact categories different methods were applied. To gather information in terms of user behaviour, two data sources have been used. On one hand a questionnaire has been approved as an adequate tool to provide valuable results. This questionnaire addressed overall relevant items but was also supplemented by additional questions to meet the local requirements and objectives. For the traffic demand analysis and the related impact analysis of carbon emissions, the microscopic traffic network simulations tool TAPAS (**T**ravel-**A**ctivity **PA**ttern **S**imulation) [6] was used. TAPAS is an agent-based modular simulation, meaning that special variable sets such as vehicle fleet, possession of public transport season tickets etc. can be modified without having to change the overall simulation. The simulation is restricted to a geographical area, e.g. a city or a county and allows a detailed illustration of travel behaviour and reactions on transport measures. Based on the TAPAS results an estimation of possible carbon emission savings are possible.

4.3. Test trial design

It was decided to test the system and technology in two iterations according to the defined objectives and the challenge to measure the impact of a newly developed system in a continuously changing environment. This decision allows improving permanently the system in terms of functionality and usability being able to mess with well-designed systems on the market. On the other hand long-term changes can be identified better. Overall, there will be two iterations of developing and testing whereas the 1st iteration is divided into three types of test trials. First, an initial survey was conducted with the purpose to reveal usability problems of the user-interface in an early development phase. This allows to uncovering many usability issues being able to fix them before the actual testing begins. Additional information about expected but missing features and further user requirements can be gathered. The gathered information is an important input for the development activities within the 2nd iteration of the project.

Second, a pre-test for baseline data acquisition was realised. The purpose was to gather trip and mobility data of STREETLIFE users about their daily mobility patterns. Therefore a tracking application was installed on Android-based mobile phones of 25 users. In a timeframe of two weeks information of the transport mode used for each trip could be derived. In order to gather more detailed information in terms of mobility behaviour, technology affinity and the user expectations of a multimodal route planer the pre-questionnaire was applied.

Following these two weeks, the pre-test trials for treatment data acquisition was conducted. In addition to the tracking application the STREETLIFE App was installed on the phones of the test users to test the system functionality and to test the defined methodology with its hypothesis to ensure that the appropriate data are collected. As the test has been carried out in an early development phase and technical problems were expected it was agreed to conduct these mainly with friendly user. After another two weeks of testing the STREETLIFE App the post-questionnaire was circulated to derive information with regard to the technology acceptance of the user and to compare the expectations with the made experiences.

Details of the questionnaires used can be consulted in the STREETLIFE deliverable D8.2.1 Initial Impacts.

5. Initial results and discussion

The results are mainly based on the user survey and cover topics of the user mobility behaviour, technology affinity and particularly the user requirements with regard to a multi-modal route planner.

As described in section “Methodology”, two test trial iterations are planned.

Although 25 friendly users participated at the test trials only 11 participants finished both questionnaires.

Details with regard to the evaluation process can be consulted in deliverable “D6.2.1 – City pilots planning and evaluation results (initial)”.

5.1. Impact Category: User Behaviour

5.1.1. Changes in mode choice

The analysis showed that people provided with an intermodal App are attracted to change the mode choice, in case alternative means of transportation are available. It could be observed that an increased usage of green transport modes such as Walking (less than 500m), Public transportation and cycling has been reported for the majority of trip purposes. Meanwhile, a decrease of car usage for private trips is indicated with the given data. Regarding car-usage a slight decrease of usage in general is reported. Here, especially cycling and walking benefits most of this change. In addition, a slight change towards a more intermodal mobility can be detected. As for the combination of different modes of transport, the test trial participants stated to combine different modes of transportation for their trips due to the information available.

5.1.2. Ease of use

The ease of use of the App is a crucial requirement, as it is the relevant user interface. Overall, the feedback received was very good. The given design was assessed as valuable as it enables the user to use the App intuitively. To navigate through the different functionality was easy to learn for most of the participants. However, also negative statements arose. For example the navigation through the App was rated very well but due to the system set-up the responding route request often took too much time compared with available Apps from the Google Play Store or AppStore by Apple. Here, we have to underline that a user centred approach is important but if the objectives of the trials focused on technical questions as it was the case in the 1st iteration, than the trial participants will identify these shortcomings.

5.1.3.Usefulness

Overall, the App was considered as useful in all test trials. The test trial participants rated the information provided as detailed enough. In some cases the user expected more and better comparable information with regard to environmental and economical traveling. However, most of the participants increased their awareness of sustainable mobility options. Apart from that, different planning criteria have been requested. It became clear that most participants favour “duration” as the most important trip planning criteria.

5.2. Impact Category: Mobility

In order to assess the impact of the implemented STREETLIFE solution the microscopic network simulation TAPAS has been applied. The input of parameters has been based on several assumptions as the user group was too small. This allows gathering comparable values which will be compared within the 2nd iteration by real user data. The simulation has been run for a representative weekday in Berlin with a 10% sample of the Berlin population to retrieve valuable and comparable results in the STREETLIFE context. The sample simulation includes 14,210 million trips per day and is based on assumptions of STREETLIFE affected trips. Due to the fact that STREETLIFE enables users to plan and find an alternative route, the bicycle mode benefits most, whereas the mode share for cars decreases. In this regard short trips normally conducted by car will be substituted by bicycle. Overall, the average trip length of public transport and walking did not significantly change.

Table 1: TAPAS simulation average trip lengths

	Average trip length in Kilometre for	
Mode	Baseline	Scenario
Walking	1.8	1.8
Bicycle	3.9	3.7
Car	7.4	7.9
Car Passenger	8.1	9.0
Public Transport	7.8	7.7

5.3. Impact Category: Environment

The approach applied is manly based on results described in Chapter 5.2. This approach uses the TAPAS microscopic traffic network simulation results in order to quantify the kilometre travelled and the transport mode used. In addition, the CO_2 values for the different transport modes have been considered for calculation. The emission factor is an average value considering the different vehicle categories (from mini to luxury cars) and types of vehicle propulsion (Gasoline and Diesel). A further distinction was not possible at this stage as detailed information were missing.
Based on the TAPAS output possible emission savings could be calculated. The result is shown in Table 2.

Table 2: Emission saving calculation

	Baseline		Scenario	
Mode	mileage in km	Emissions in t CO_2	mileage in km	Emissions in t CO_2
Walk	5,570	0	5,532	0
Bicycle	8,119	0	10,174	0
Car	31,536	5,550	29,099	5,121
CarAsPassenger	7,873	692	6,506	572
Public Transport	25,811	1,264	26,822	1,314
Total		**7,508**		**7,008**

The calculation of emissions is based on emission factors investigated for the city of Berlin in the EC FP7 project MOLECULES in 2014. This calculation incorporates the following emission factors: Car = 178g/km, CarAsPassenger = 88g/km. It is further assumed that the modal split for public transport modes bus, metro,

train and tram are equally distributed. Corresponding mode specific emission factors (bus = 118g/km, metro, train and tram = 26g/km) are averaged to 49g/km.
With the designed simulation scenario carbon emissions of **499,615 kg = 500 tons** could be saved per day for the overall Berlin transportation system. That would equate for about 6.5% of the road based transport emission (without logistics, busses). In fact, the potential of carbon emission reduction for a large city is very high when realizing a comprehensive cycling approach. A direct allocation of savings to STREETLIFE is not yet possible due to the small scale field trials.

6. Conclusion

With respect to the impact assessment of User behaviour, it can be stated that people provided with an intermodal App are more willing to change mobility behaviour while changing their mode choice, as long as alternative "green" transport means are available. It could be observed that also different modes were combined more easily due to the information available.
The impact category Mobility shows very good results. In Berlin a simulation-based approach was used to calculate the effects. The results show that share of cycling can be increased by 5% if cycling becomes more attractive. Specifically people who are travelling mid-range trips (<7km) are more willing to enhance their trip radius. At the same time it could be detected that the mode share for car use decreased by 4%.
With regard to the impact category Environment, the potential effect of STREETLIFE on carbon emissions has been assessed. The results provide a very good picture and underline the positive estimation.
In a large city as Berlin about 500t could be saved per day for the overall transportation system.

In conclusion, it can be stated that the impact assessment shows that ICT solutions can have real impacts in the transport related categories a. User behaviour b. Mobility and c. Environment. STREETLIFE could demonstrate that a change in the mobility behaviour can be realized with direct effects on reduced car-kilometres and a decrease of the carbon footprint of a user for a certain origin-destination (OD). Further research with a larger user group and a longer test trial time frame is planned for the 2nd iteration and will provide more valuable results in terms of significance and validity.

Acknowledgements

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