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(R)evolutions in route planners

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Abstract

With the advent of sharing more ubiquitous data and the personal possession of mobile devices, we see a clear trend in the availability of various sorts of route planners during the past decade. Developers are trying to devise solutions for end-users, whereas policy makers face various challenges in creating accessible and useful route planners. The success of a route planner is thus directly and highly dependent on its adoption by a large-enough community. Consequently, it is not a trivial task to create a good, usable route planner for the target users. This paper therefore explains what the basic ingredients for a good route planner are, and how the private and public transportation play a role in this. It then highlights the types of extra services that are added to modern route planners, and finally how development can be supported and Smart Cities contribute to the concept of Mobility-as-a-Service.

Keywords:

Route planning, intelligent and dynamic, public transport, ticketing management, integrated parking, mobility as a service

Introduction

With the advent of sharing more ubiquitous data and the personal possession of mobile devices, we see a clear trend in the availability of various sorts of route planners during the past decade. Whereas these planners were originally conceived as stand-alone PC applications, with people physically printing the routes, they have turned into apps for mobile platforms, such as smartphones. Furthermore, in addition to just providing navigation functionality for your personal car, they also have started including various other services, of which the incorporation of public transport seems to be the most important and pervasive one.

As the number of readily available route planners is more or less skyrocketing around the globe, we also notice how developers are trying to devise solutions for end-users, and how policy makers face various challenges in creating accessible and useful route planners. In this respect, the success of a route planner is directly and highly dependent on its adoption by a large-enough community. And consequently, it is not a trivial task to create a good, usable route planner that is suitable for the users in the target group.

Within this paper we first explain what the basic ingredients for a good route planner are and how the private and public transportation play a role in this. We then highlight the types of extra services that are added to modern route planners, and finally how development can be supported and Smart Cities contribute to the concept of Mobility-as-a-Service.

The role of public transportation

Nowadays, all regular route planners try to incorporate multimodality to various degrees. The archetypical example in this case is the inclusion of public transportation. There is certainly a clear need for this kind of information by travellers, as it makes an objective comparison possible of the alternatives to private transportation. As explained by Maerivoet et al. (2014), a case study in Belgium uncovered that only 8% of all daily trip chains (including one or more trip legs) can be ad hoc replaced by public transportation. We could state that in this case the public transportation is not up to par with the mobility needs of the population, but we rather argue that it just means that our current car-mobility behaviour is not adjusted to just being supplanted by public transport (wishing the same time comfort) and we need to change ourselves in order to cause a larger modal shift.

As such, public transportation becomes a necessary ingredient in a route planner. However, this brings along its own chair of challenges. In first instance, the data needs to be available. We are talking about schedules here, transition points, if possible an estimation of the encountered delays, et cetera. Given that most cities, regions, or countries have not a single public transport provider, this implies that in order to be successful it is a prerequisite to have the majority, if not all of them, aboard. This might go smooth as a breeze, or a developer might get entangled in lengthy negotiations about acquiring data. In some cases, developers need to specify a priori which information they want, and officially notify its provider. This is then followed by the developer having to sign a specific licence that governs the use and liability of the data. There are even cases were commercial use is excluded. Such worries are clearly not called for within the vision of a truly uninhibited use of open data. To summarise, this step can take quite some effort to pull off, as we can see for example with Google Maps, whereby they are dealing with each public transportation operator individually, to the degree that this is feasible.

Given that the data is available, the next question of course is to what degree the data is accurate and up-to-date. A route planner that gives incorrect, or just plain wrong advice will quickly be abandoned by its user base, thereby rendering the developers' initial investments void. In most cases, some data cleansing and fusing is necessary, and not to underestimate a lot of testing.

Beyond classic route planners

Looking at private car-traffic, a typical route planner is able to give you an estimate of the time it takes to reach your destination. These travel times are necessary in order to calculate what we call the *route with the least generalised cost*. The earliest route planners based their calculations on the physically shortest distance, after which this was replaced by the shortest theoretical travel time (which in turn was based on, e.g. the stated speed limit for each road segment). Later on, with the onset of statistics on available historical data, these estimations were substituted by the experienced travel times on each road segment. For a long time, most route planners remained actually stuck in this position. But with the appearance of more dynamical, real-time data feeds (like smartphone's GPS and Bluetooth tracking, Twitter feeds, …), this has totally changed the game. A good route planner can first and foremost detect the occurrence of congestion, which has a huge impact on the travel time. Based on historical data, this estimate can even be broadened to provide a range in which, say 85% of the to-be-experienced travel times fall.

Towards the next generation of route planning

And as revolutionary (and necessary) as this may seem, it still falls short of what we really need. Truly well-equipped route planners take into account *dynamic variations along* the route. We are not talking about the sudden incoming information of an accident, at which point the route planner plainly suggests an alternative route. Rather, we would like to stress the state-of-the-art in this respect, by which a route planner takes into account the changing traffic conditions as time goes by. So, whereas a classic route planner estimates the travel time based on the traffic conditions along the entire route at the time of departure, these new type of route planners predict traffic conditions as they change along the route and for the entire duration. In practice, this requires the implementation of either an underlying traffic flow model (that represents the propagation of traffic), or the dedicated statistical analyses of historical travel times on each road segment. An example of the former are the EC-funded FP7 MODUM[1] and CIP HoPE[2] research projects (see the following Figure), in which such a dynamic component is present. In contrast to this, TomTom IQ Routes[3] is an example of the latter.

[1] http://www.tmleuven.be/project/modum/home.htm

[2] http://hope-eu-project.eu/

[3] http://www.tomtom.com/page/iq-routes

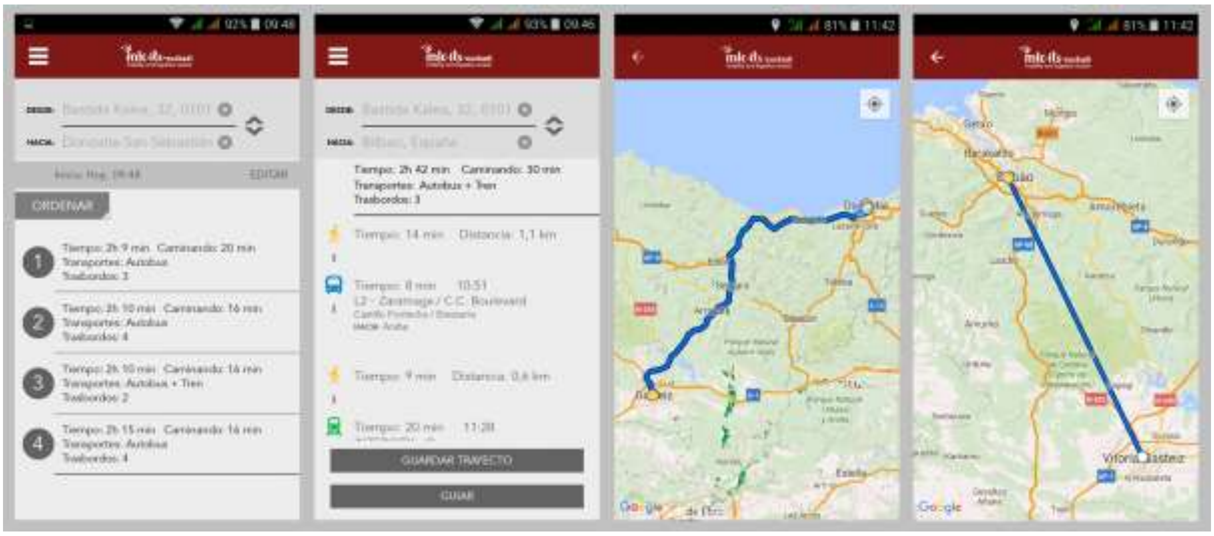

Figure – Real-life screenshots from the HoPE app running under Android during the field trials in the province of Gipuzkoa (Basque Country).

Furthermore, with the coming of more computational power and available data and models, these route planners can also make estimations of your energy consumption, for example expressed in the amount of CO_2 emitted during your journey. Via the MODUM field trials in Sofia (Bulgaria) and Nottingham (United Kingdom), Maerivoet S. (2014, 2015) were able to assess that users are not really aware of their CO_2 emissions, but that the provided information influenced their commuting behaviour (they switched from private car to public transportations as they used the new and more convenient routes offered by the system).

Figure – Screenshot from the MODUM app running under Android during the field trials in the pilot city of Nottingham (United Kingdom).

Striving for a system optimal load

Sometimes a route planner can lead to an at-first-sight counterintuitive result. Looking at how traffic flows settle on a network is similar to assessing how individual travellers behave when choosing routes as explained by Maerivoet (2006). The basic principles hereof were historically developed by Wardrop (1952), and are still used today. In his work, he stated two possible criteria governing the distribution of traffic over alternative routes.

- **User equilibrium (W1)**: "The journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle on any unused route."
- **System optimum (W2)**: "The average journey time is a minimum."

There are several assumptions regarding criterion (W1), mainly (i) that all individuals' decisions have a negligible effect on the performance of others, (ii) that they all have perfect information on the routes, and (iii) no one can improve his travel time by switching to another route. Aside from these, Wardrop (1952) also implicitly assumes that there is no cooperation between individuals, and that all individuals make their decisions in an egoistic and rational way as explained by Hagstrom (2001). In contrast to this, the (W2) criterion describes a system optimum. One way of achieving this is by implementing policies that let travellers also include the costs of the effects brought on by adding an extra vehicle to the travel demand (the so-called marginal costs). In any case, as some people will be better off in this social equilibrium, others will be worse off, but the transportation system as a whole will be best off (cf. the credo "You win some, you lose some"). A traveller that has for example the MODUM system to his avail, will be better informed than some other travellers and has an advantage compared to them. Increasing the penetration of this system within the population will naturally lead to more informed drivers, and thus closer to the conditions stated by Wardrop. Thus, what will happen if everybody uses the same system? However, contrary to what we may belief, this will not lead to another user equilibrium, but rather closer to a system optimum! The main reason is because the app is predicting traffic conditions for the near future, and it does this for all the travellers in the system. As such, the system will continuously try to generate the cheapest routes. If all users were (1) to choose the same cost function and (2) always follow the advice of the MODUM app, then the system will settle near an optimum. In this respect, the route planning system provides a new method for nearing a system optimum, while still remaining based on dedicated routing advice to individual travellers. It thus bridges the gap between traffic operators and individual travellers, by means of enabling more optimal routing and traffic control.

Service integration in the next generation of route planners

Whereas the previous sections described the main ingredients of all route planners, i.e. personal navigation of private (car) traffic and the inclusion of suitable public transportation, we now focus the attention on the extra types of services that are appearing in modern day route planners.

Tourist trip planning

A new market is opening whereby tourists in domestic or foreign cities are provided with real-time advice on how to plan their journeys, given their *interests* in the local shops, musea, … One method of doing this is by providing a route planner that gives it advice based on (i) a selection of interests by the traveller, and (ii) the opening and closing hours of the places where these activities take place. Furthermore, the advice can also be formulated the other way around, whereby a tourist gives its broad preferences of, e.g. socio-cultural activities, after which the route planner determines the optimal sequence of visits, taking into account the schedules of public transportation, walking times, and again opening and closing hours. An example of such a new mobility concept is the EC FP7 eCOMPASS[4] project.

Integrated fare management

As the push towards public transportation is on the rise in many cities and regions, the plethora of available ticketing options becomes quite overwhelming, especially for novel or foreign users of the system. In order to tackle this, companies are being founded that streamline the entire ticket purchasing process. With a single app, a traveller is now able to *buy and validate* his ticket for the chosen public transportation. Taking this idea one step further is the EC FP7 HoPE project mentioned earlier, in which route planning (for public transportation) is combined with integrated fare management, in a more holistic approach that focusses the attention on the 'bigger picture' and how all its parts are interconnected. The developed system asks a user to specify his (i) departure location, (ii) destination location, and (iii) personal travel preferences. It then calculates the quickest route (based on the dynamically changing travel conditions on the network as explained earlier, and the available public transportation schedules), and in the case of public transportation it provides the option of directly and securely purchasing all the necessary tickets (with roll-back options in case the journey should change). The ticket is then digitally stored on the smartphone, after which it can be validated at the vehicle itself, thereby relinquishing the need for a printed ticket. The project is furthermore piloted and tested in three European regions (Coventry city in the United Kingdom, Athens city in Greece, and the entire Basque Country), and applied to a wide set of local and regional means of transport (buses, undergrounds, railway lines, car-sharing, bike sharing, transport on demand, et cetera).

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4 http://www.ecompass-project.eu/

Pushing the boundaries with more services

Private (car) traffic, public transportation, and integrated fare management are not the only options that are directly available to end users. In addition, developers are including a whole other range of services, of which parking is the most prominent one. An earlier example of such a service was the iPark4U[5] project that, based on an on-board unit and smartphone with supporting software, gave information via in-car navigation on the number of available parking spaces in public parking garages. The system also provided routing to these parking spaces, and allowed the driver to pay for the parking costs via his navigation system or cell phone. As such, iPark4U became a system that combined navigation, parking, and payment as a whole.

> Note that there also exist a different kind of route planners, which do not per se provide a fastest route, but are instead based on the idea of *car and trip sharing*. Such an application can access a user's agenda and personal preferences, and try to match these against a real-time database of available rides. The user can then be picked up at a pre-arranged departure location, and subsequently be dropped off (in the vicinity) of his destination.

Another sought-after service in a route planner is the inclusion of the so-called *soft modes*, i.e. walking and cycling. In some state-of-the-art route planners walking is no longer a case of finding the physically shortest route, but rather of allowing the traveller to take a *nice* route that is *enjoyable* (and healthy!) to walk. Policy makers are also more inclined to support cycling activities within their cities, especially with the creation of dedicated bicycle-motorways and more prominently designed bicycle paths. More recently we also see how certain cities also include the perception of the available cycle routes. This implies that routes that mix or cross with (heavily congested) car traffic are avoided by the route planner, in favour of more greener, calmer, and healthier routes. Moreover, it is also possible to take road degradation into account, thereby adding a label of quality to a chosen route and taking this aspect into account in the decision making process by route planners.

Let us be warned though. The more features that are added to a route planner, the more difficult it may become for the end-user to understand them and use them to their fullest potential. Interface design, HMI research, psychological analyses, and feedback (e.g., via dedicated focus groups, Delphi panels, …) all prove to be a crucial step in this direction. And how to scale the use of a route planner from a modest group of early adopters to a more widespread usage by entire communities. This also ties in to the entire paradigm shift that is occurring with wearable devices and how humans interact with them.

5 http://www.tmleuven.be/project/ipark4u/home.htm

Supporting developments

Most research activities (be it by consortia of research institutes and private companies, or by individual companies themselves) are supported by various grants. In many cases developments are active by means of regional, national, and European funding. In this respect, the European Commission plays an important role, as it provides a cradle for innovation and international EU-wide cooperation (in the past by means of the Framework Programmes, which have now been succeeded by the extensive Horizon 2020 Programme).

Tapping into the data potential

Cities themselves are also going forward in their quest to get the most out of their data. Although this is not per se directly linked to the creation of route planners, it can provide modules that can be incorporated within route planners or the inception thereof. As Member States are by law being required to open up their data, by means of the EC INSPIRE Directive (2007/E/EC) and the EC PSI Directive (2013/37/EU, PSI stands for Public Sector Information) and their associated Delegated Acts, new sources of data are quickly becoming available. Whereas everything used to be sustainable in the past, we saw a shift that leads to smart being the new sustainable. Combining all this data with Big Data analysis techniques led to quite a revolution in the mobility landscape. Mining Twitter feeds can for example give insight into where in a city certain social activities are taking place, or how citizens behave mobility-wise, e.g. the commuter travel patterns. In order to tap into this large data potential, cities are opening up their data to the wider public (via Open Data Portals), adopt simple and straightforward licences that govern the (re-)use of this data, and organise workshops, as well as hackathons and challenges (to find the best concept, prototype, business model, or use of the data). The latter step is necessary because just making the data available is typically not enough to incentivise the market. In some cases a small fee is asked, but this is then mostly related to the fact that making the data available (and especially real-time feeds) requires some implementation cost on the side of the provider. Quality control is typically something that is outsourced, as we believe not every data provider should also be involved in this process (for which there are dedicated and specialised players on the market).

From Smart Cities to MaaS

As cities' data becomes available and used, some of them are already thinking a step ahead. Instead of letting people reinvent the wheel time and again, it is possible to re-use existing components. As an example, the city of Antwerp (Belgium) instigated their 'ACPaaS', which is short for Antwerp City Platform as a Service. The goals here are (i) to re-use components and prevent users from creating or buying them over and over again, (ii) develop the platform in cooperation with start-ups, and (iii) reach out via Meetups. As such, co-creation and innovation are explicitly stimulated by separate the apps' (changing) front-ends from their back-ends: the back-ends move into (stable) engines which then become accessible through published APIs. As such, everyone can participate in building a digital city. By adopting open standards (think DATEX-II, TMC, TPEG, RDS, UTMC, POSSE, …) and available geospatial data (think Open Street Map, Google GTFS, Bing, …) more ITS systems can be defined, leading to improved traffic flows, enhanced traffic safety, and reduced emissions. Combining all of this leads to Mobility-as-a-Service (MaaS) concept. The next generation of route planners thus frees the user from deciding all the hassle surrounding his or her mobility requirements. Rather, a service provider can take care of this and only requires the user to specify how many minutes in advance he or she needs ‘a ride’. This *package-deal* radically changes the entire concept of private (car) travel, whereby MaaS brings about a new transportation paradigm.

Conclusions

As more ubiquitous data is shared, personal possession of mobile devices increases, we see a clear trend in the availability of various sorts of route planners during the past decade. It is however not a trivial task to create a good, usable route planner for a group of target users. Looking at the necessary ingredients of such a route planner, we first focused our attention on the role of public transportation in multi-modality, and the share of challenges this brings along for a successful implementation.

We then introduced the concept of a generalised travel cost, making it possible for route planners to optimise their routes dependent on a whole range of user preferences. Special attention was given to the set of route planners that take dynamic variations along the route into account, including predictions of future traffic conditions, as well as how such systems can lead to a system optimum if they are widespread used.

As more services become available, we looked at how these are typically being integrated in the next generation of route planners. Examples of these are tourist trip planning, integrated fare management, and free parking space prediction, reservation, and routing. In this respect, we also considered the role of the so-called soft modes, and how this has transformed the routing advice given to pedestrians and cyclists.

Finally, we looked at some of the various ways to support active developments on route planners, considering the channels of European funding and how cities and regions can tap into the large potential of their data. This leads to the concept of Smart Cities, in whose formation the public takes an active role, and how this leads to a new transportation paradigm that embraces Mobility-as-a-Service.

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