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EFFECTS OF REAL-TIME TRAFFIC INFORMATION IN CAR NAVIGATION – RESULTS FROM A CASE STUDY IN ERFURT, GERMANY

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Abstract. The inclusion of real-time traffic information (RTTI) in navigation systems is commonplace nowadays. The data sources for the RTTI can be manifold: It is mostly floating car data obtained either by the application users or via a specific fleet of cars (e.g., Taxis). At the same time, cities around the world are also collecting information on the traffic situation via different sources such as induction loops in the streets. The data source collected by the cities can have higher quality, due to more and more precise data collection points, and can also be enriched with information on construction sites and road closures from the cities' road authority. In the FaMoS research project, a prototypical navigation app was developed, which directly uses the RTTI provided by the cities via the "Mobilitäts Daten Marktplatz" (MDM), a German mobility data exchange platform. The performance of the navigation app was tested in a study with 417 trips in Erfurt, Germany. For comparison, the FaMoS navigation app was tested against a default app using the same routing algorithm but without the city's RTTI. It was found that the FaMoS app with the city's RTTI was on par with the default app (HERE WeGo) on all routes. On select routes, the FaMoS app statistically significantly reduced the average trip time by up to 12.6%. Further studies over a longer time period with more users and routes are needed to prove the trend seen in this study. Nevertheless, the data from this first case study can be a starting point for the further development of RTTI inclusion in navigation apps and systems with the goal to reduce congestion.

Keywords: traffic management, real-time traffic information, navigation system, navigation app.

JEL Classification: R41.

Introduction

The inclusion of Real-Time Traffic Information [RTTI] in navigation systems is commonplace nowadays. They are usually considered to be part of an Advanced Traveller Information System [ATIS] (Ackaah et al., 2016, p. 471), which itself is part of Intelligent Transport Systems [ITS]. The data sources for the RTTI can be manifold: It is mostly floating car data obtained either by the application users or via a specific fleet of cars (e.g., Taxis). At the same time, cities around the world are also collecting information on the traffic situation via different sources such as induction loops in the streets. The data source collected by the cities can have higher quality, due to more and more precise data collection points, and can also be enriched with information on construction sites and road closures from the cities' road authority. So, is it possible to give traffic participants access to the cities' traffic data and what benefits could it have?

1. Theoretical background

The possible benefits of the inclusion of RTTI into car navigation have been in discussion for many years. Kim et al. wrote in 2005: "Our primary conclusion is that real-time traffic information incorporated with historical traffic data can significantly reduce expected total costs and vehicle usage during times of potential heavy congestion while satisfying or improving service levels for just-in-time delivery." (Kim et al., 2005, p. 26). As a possible hurdle for the implementation, they saw the, at this time, high effort for the implementation of real-time information (Kim et al., 2005). The technological developments of the last one and a half decades have eased the problem they described, at least from an IT perspective. Van Essen et al. (2019) conducted a study on the likelihood of changes in route choice when RTTI was present. Their experiment was conducted as a real-world case study. They found, that "travellers follow the 'advice' from received travel time information in 72% of the cases. This

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suggests that a majority of travellers tries to minimize its travel time with help of received travel time information." (van Essen et al., 2019, p. 1739). A trend to switch routes when RTTI was available was also reported by Gokasar & Bakioglu (2018). Tsirimpa & Polydoropoulou (2014) researched the effects of RTTI inclusion and the effects on drivers. They found that: "the biggest impact of traffic information is reflected in route changes and rescheduling of activities. These two have a direct effect in the reduction of traffic, while causing a redistribution of travel demand. The impact of the activities re-scheduling may have on the network conditions and on the environment are of major importance." (Tsirimpa & Polydoropoulou, 2014, p. 16) This highlights the transformative potential of RTTI inclusion in navigation apps can have on urban transport. The potential for including RTTI via a mobility data-sharing platform was described by Stieler et al. (2015). They especially highlighted the mitigation of the negative effects of unwanted route choices (e.g., taking a shortcut through the residential neighbourhood) and the potential of informing traffic participants of road closures and congestions (Stieler et al., 2015, p. 206).

2. Project description

2.1. General

The FaMoS (Fahrzeugnavigation auf Basis multimodaler strategiekonformer Mobilitäts- und Situationsinformationen im Verkehrsmanagement) research project addresses the development of methods, tools and processes for improved access to existing data sources, the development of new data sources and the improvement of their usability using the example of large cities and their surrounding areas. As an example location, the German town of Erfurt (pop. ~213.000 (Landeshauptstadt Erfurt, 2021)) was chosen. The aim is to support the implementation of data-based applications in the field of transportation. A transferable solution approach for multimodal strategy-conform mobility and situation information in Traffic Management [TM] was developed, which is fed into vehicle navigation systems via the Mobility Data Marketplace [MDM] (Mobilitäts Daten Marktplatz, n.d.), a data-sharing platform operated on behalf of the German Ministry of Transportation. The FaMoS project addresses the complete chain of effects for the acquisition, refinement, linking, provision and use of data. The data is based on data from the areas of the traffic situation, parking, construction sites, events, public transport as well as environment and meteorology. The processing of the data into situation information including the realized traffic management measures enables a new quality in the interaction of vehicle navigation and traffic control. Although the route recommendations and the corresponding mobile traffic information are an elementary component of a traffic management strategy with the associated traffic control measures, they have so far often escaped the influence of the road authority.

2.2. System Architecture

The necessary input data for the RTTI is collected from different data sources including induction loops and other traffic count systems as well as centralized traffic planning information (e.g., location and duration of construction sites). The data is then aggregated into a real-time traffic situation, which is the RTTI in this system. The situation data is then uploaded to the MDM in a Datex-II-format. The FaMoS app accesses the MDM via an API and downloads the RTTI. In the route calculation process, the RTTI is used for putting additional costs/ travel time on the links. This is used in cases where the RTTI indicates a high occupation, construction site or road closure. The FaMoS app itself is based on the HERE Maps developer platform and runs on Android smartphones. In the case that no RTTI is available, the routing algorithm is the same as in the standard HERE Maps navigation app. The system can be classified primarily as an en-route ATIS according to a systematic proposed by Ackaah et al. (2016), although it also has some potential for pre-trip ATIS.

3. Research Design

To test the developed navigation application, a test with friendly users (students and employees of the department) was conducted in June 2020 in Erfurt, Germany. The FaMoS app was tested against the HERE Maps navigation app as a baseline, as the routing algorithm of the FaMoS app is based on the HERE Maps app.

3.1. General

The basic idea of the experiment design was to let several vehicles drive in parallel on the same Origin-Destination-pairs (OD-pairs) with the FaMoS app as well as with a comparable, commercially available navigation application and to record the trip data. For the test, GNSS position, time and current speed of the cell phones in the vehicles were recorded every full second via the FaMoS-app.

An optimal experiment design would have two identical vehicles, each with one of the applications to be compared and the same drivers, starting at the same location with the same destination at the same time. The problem is that even when driving directly behind each other, the test vehicles no longer encounter the same traffic situation (e.g., due to changes in the traffic signal, different time gaps when entering an intersection, etc.) and the results can therefore not be compared exactly, since at least the second vehicle is always adversely affected. This error can be reduced by the behaviour of the test drivers, but it still can lead to driving behaviour that does not conform to the German Road Traffic Regulations (StVO) or is distorted.

3.2. Reduction of systematic measurement errors

To unify the driving behaviour, thus improving data quality and objective comparability, the most practical solution was to send several vehicles to the same OD-relation at approximately two-minute intervals. The FaMoS-app was installed on eight similar Samsung A20e smartphones running Android 11, hence a comparability in the tracking is given. The order of the drivers and the applications used was rotated every two trips, with the intention that differences due to individual driving behaviour, the car used or the position in the line of drivers would cancel each other out. In addition, all drivers underwent theoretical training to improve their driving style in terms of

- the minimum distance to be maintained,
- the exact maximum permitted speed to be maintained,
- the behaviour in the event of a change in the traffic signal,
- the general acceleration and braking behaviour and
- the handling of non-StVO-compliant navigation prompts.
- to homogenize driving as much as possible. Despite all the measures taken, a small possibility for error due to differences in driving behaviour or simple chance persists, but this would affect both apps and also exist in a trial with real users.

3.3. Selectıon of routes

For a pre-test in early 2020, different origin and destination locations were selected, each with a high density of traffic position sensors and road works on the route that the "fastest connection" routing mode shows. This way the data density of RTTI provided by the city is as high as possible and traffic-related route adjustments by FaMoS are likely (Figure 1):

A. P+R Ringelberg – P+R Messe (red)
B. P+R Messe – P+R Grubenstraße (yellow)
C. P+R Grubenstraße – P+R Thüringenhalle (green)
D. P+R Thüringenhalle – Globus Linderbach (blue).

Each of these routes incorporates streets that are part of the coordination and traffic management strategy of the City of Erfurt.

As a result of the pre-test, three OD-pair (A, C & D), each with outbound (a) and return (b), turned out to be especially suitable for the main test. These covered a wide range from minor (OD-pair A) to large-scale deviation (OD-pair D), so the results have a greater insight potential. OD-pair B was not selected because its characteristics were already included in OD-pairs C & D and its omission created more trip capacity for the other three OD-pairs.

3.4. Implementation

In the week of 08.06.–12.06.2020, 360 test runs were carried out during rush hour from 6–10 a.m., as well as from 2–6 p.m. with 2–6 vehicles each. The main test ran mostly without major problems, the only discrepancy was due to an inaccuracy in the construction site database on the OD-pair Aa. Here, an unrealizable routing decision was issued (Fig. 2), which meant that OD-pair Aa and Ab could only be tested on Friday, 12.06.2020, after the problem had been corrected.

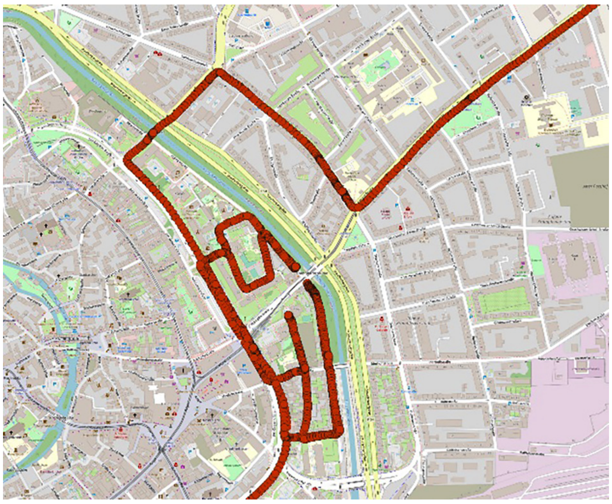

Figure 2. Detours in routing due to street closure not known to the app (Background map: OpenStreetMap, n.d.)

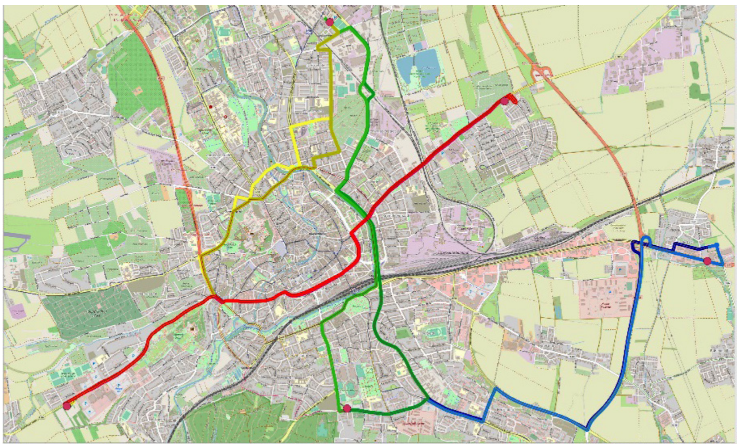

Figure 1. OD-pairs and sample routes for the experiment (Background map: OpenStreetMap, n.d.)

3.5. Analysis

During the main test phase, approx. 140 hours of position data were generated, which then was entered into a database and, with the aid of a GIS, start and end points for the calculation were defined uniformly for all trips. These were set at locations that were close to the start and end of the trip so that parking and parking search processes did not distort the measurement. The scattering of the selected start and end points is exemplarily shown for the P + R Messe in Figure 3. The differences mainly result from different driving lines & GNSS inaccuracies. The minimum spread is about 8 m, and the maximum is about 33 m.

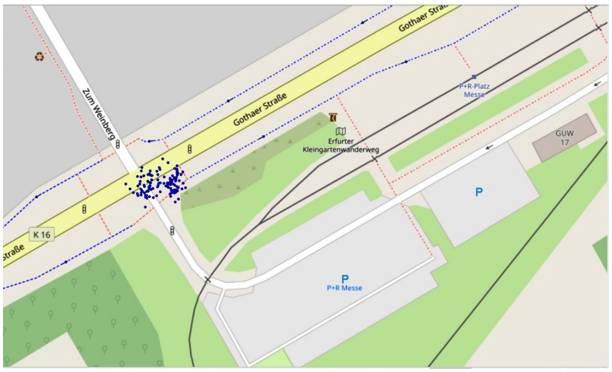

Figure 3. Example for the scattering of GPS data (Background map: OpenStreetMap, n.d.)

During data validation, unsuitable trips were sorted out, such as when:

- legitimate routing recommendations were not followed;
- the tracking was incomplete;
- the trip was aborted;
- unusual detours (Figure 2), or
- other than the standardized entries and exits at the start or destination were used.

A total of 326 trips remained for the comparison of both applications on the three OD-pairs A, C & D. These were combined in various aggregations by OD-pair, direction, and application used so that comparisons could be made. Due to the data adjustment in advance, these are hardly influenced by outliers, which is also confirmed by the medians.

4. Results

Tables 1 and 2 show the average trip times and average trip distances for both apps on the selected OD-pairs. Drivers using the FaMoS app had on select OD-relations (Ab and Ca) an average trip time that was up to 12.6% smaller than with the standard app. On the other OD-relations, the differences in average trip time were between –0.5% to 2.4%. Regarding the average trip distances, the FaMoS app routed the driver mostly on longer routes. Only for OD-relations Ab and Db, the distances were 2.7% and 0.2% smaller.

For the two OD-relations which showed a notable reduction in travel time (Ab and Ca), a correlation analysis was conducted (see Tables 1 and 2) using JASP (JASP Team, 2022). Significant correlations were found between

Table 1. Comparison of the Average Trip Time of the two Apps compared

OD-pair	Starting point	Standard App		FaMoS		FaMoS is faster by
		Samples	Average Trip Time	Samples	Average Trip Time	
Aa	Ringelberg	32	00:20:16	28	00:20:05	0.9%
Ab	Messe	25	00:25:23	28	00:22:11	12.6%
Ca	Grubenstraße	30	00:18:27	25	00:16:27	10.8%
Cb	Thüringenhalle	34	00:13:59	24	00:14:03	-0.5%
Da	Thüringenhalle	20	00.13:59	26	00:14:01	-0.3%
Db	Globus	27	00:13:12	27	00:12:52	2.4%

Table 2. Comparison of the Average Trip Distance of the two Apps compared

OD-pair	Starting point	Standard App		FaMoS		FaMoS drives less by
		Samples	Average Distance [m]	Samples	Average Distance [m]	
Aa	Ringelberg	32	8624.0	28	8831.2	-2.4%
Ab	Messe	25	9218.5	28	8973.1	2.7%
Ca	Grubenstraße	30	7282.4	25	7302.6	-0.3%
Cb	Thüringenhalle	34	7188.5	24	7185.5	0.0%
Da	Thüringenhalle	20	7456.8	26	7608.3	-2.0%
Db	Globus	27	7494.6	27	7479.2	0.2%

the app used and the trip time as well as trip distance for OD-relation Ab and between the app used and the trip time for OD-relation Ca (see Tables 3 and 4).

Table 3. Correlation analysis for OD-pair Ab

		App used		Trip Time		Trip Distance
App used	Pearson's r	—				
	p-value	—				
Trip Time	Pearson's r	−0.319	*	—		
	p-value	0.018		—		
Trip distance	Pearson's r	−0.425	**	0.425	**	—
	p-value	0.001		0.001		—

Notes: * p < .05, ** p < .01, *** p < .001.

Table 4. Correlation analysis for OD-pair Ca

		App used		Trip Time	Trip Distance
App used	Pearson's r	—			
	p-value	—			
Trip Time	Pearson's r	−0.288	*	—	
	p-value	0.030		—	
Trip distance	Pearson's r	0.093		0.232	—
	p-value	0.491		0.082	—

Notes: * p < .05, ** p < .01, *** p < .001.

5. Discussion

The results of the app test show that the RTTI-enriched FaMoS app can lead to faster travel on some routes. While the FaMoS app has in each case produced travel times that are similar to the non-RTTI-enriched competitor, on select routes the advantage in travel time can be up to 12.6%, while the distance mostly does not show big differences. It is suspected that this phenomenon is due to the different characteristics of the routes and that the sub-routes Ab and Ca share some features where the RTTI can give clear advantages (e.g., road closures, traffic jams). The fact that the travel times with the FaMoS app are, at maximum, 0.5% longer in comparison to the baseline of the competitor app, shows that there are no relevant disadvantages of using the RTTI-enriched app.

It has to be noted, that the tests were conducted all in one week and therefore do not reflect changes in road closures and construction sites. It is possible that in different weeks, different routes show the advantages of using the RTTI-enriched navigation. Therefore, more tests with the application are needed. The additional tests also should include other routes and other times of the day, as the tests were only conducted during or close to peak-hour. For a further stage of app testing, a test with real-world testers, which use the FaMoS app on their daily trips within Erfurt would be needed in contrast to the test by friendly users driving predefined routes, which was conducted for this study. A further possible limitation lies in the fact, that the tests were performed in June 2020 amid the Covid-19-pandemic, which led to shrinking traffic amounts throughout the country, although traffic volumes at the time of the tests had reached almost pre-pandemic levels again.

Conclusions and Outlook

The test of the FaMoS app has shown that RTTI-enriched navigation can give drivers an advantage. The results are limited to one week, but they provide a starting ground for further research and tests of the concept of RTTI-enriched navigation apps. While the FaMoS app currently only works for the city of Erfurt, future apps should include data access for more cities in Germany and Europe. The MDM and its successor *Mobilithek* and the Datex-II-standard provide a basis for this. Stieler et al. (2015) pointed out that the provision of RTTI as open data by the municipalities is necessary for ITS systems to work. For a greater market penetration, which would be in the interest of the road authorities, the provision of the data in an open format would be ideal so it could be included in different apps as well as in OEM navigation systems in cars.

The general concept of improving, combining and enriching traffic data by the road authorities and making it available for use, as demonstrated in the FaMoS project, is a base for the ongoing Bauhaus.MobilityLab research and transfer project in Erfurt.

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Contribution

JU was responsible for the development of the app and the coordination of the test. He also was the lead person to write the paper. HJR was involved in the preparation and implementation of the application test and was responsible for the statistical analyses. PV worked on the overall project implementation and helped with the composition of texts for this paper. UPW was the project leader and contributed texts and ideas for this manuscript.

Disclosure statement

The authors declare no competing interests.

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