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How do different navigation systems affect emergency response time? A prospective simulation study

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ABSTRACT

Objective There has not been a theoretical test run in Germany that compares different navigation systems with an industry solution (MapTrip112). The aim of this study was to compare navigation systems to elucidate whether the emergency response time (ERT) was reduced and, consequently, whether the adherence to the travel time improved.

Design Prospective, simulation study, cross-sectional study.

Setting Offices of the Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Goethe University Frankfurt (60 590 Frankfurt am Main, Germany). The situation-adaptable industry navigation solution MapTrip112 was tested in its 'Lights and Siren(s) (L&S)' mode in comparison to the TomTom and Google Maps navigation systems. MapTrip112 was set to calculate a route that takes special emergency rights of way into account.

Outcome measures All three navigation systems simultaneously calculated the distances and durations of fictitious routes. Three scenarios were tested: the University Hospital Frankfurt (60 596 Frankfurt am Main, Germany) and the Central Fire Station 1 (60435 Frankfurt am Main, Germany) served as the starting points for the urban routes, while the Odenwald Health Centre (64 711 Erbach, Germany) served as the starting point for rural routes. The routes' endpoints were arbitrarily chosen locations inside the customary operational radius. The routes were selected for short and long distances as well as for different periods, including weekdays, weekends and evening rush hour (4–7 pm), in the German cities of Frankfurt am Main and Odenwaldkreis (Southern Hesse).

Results The time and distance were calculated for a total of 4650 trips. When comparing travel times and distances between rural and urban areas as well as between weekdays and weekends, statistically significant results were obtained ($p<0.001$). With time advantages ranging from 23.5 s to 300.5 s (4.75% to 50% of the travel time) on weekdays and weekends, MapTrip112 consistently outperformed both TomTom and Google Maps. For city missions, MapTrip112 achieved time gains of up to 50% over its competitors, with significant advantages during the rush hours and around specific locations such as the University Hospital Frankfurt and Fire Station 1.

Conclusion MapTrip112 always achieved the fastest routes although these were not always accompanied by a shortened distance. These findings underscore MapTrip112's superiority in providing efficient routing solutions across various scenarios. For this reason, the use of this software should be considered in practice and investigated in real-world conditions in further studies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Large number of theoretical routes (different distances, 6 days/week, rush hours and off-peak hours, city and countryside rescue).
⇒ Evidence for significant time differences in the theoretical application of MapTrip112.
⇒ Theoretical routes, not under real-world conditions.
⇒ Data not yet transferable to other emergency organisations.

INTRODUCTION

When an emergency call is made, the so-called emergency response time (ERT) begins; this being the time span from receiving an emergency report until the arrival of a suitable rescue team at the emergency scene, that is, paramedic crews or firefighters (figure 1).[1–6] According to German law on the emergency services and the minimisation of response times, the maximum ERT is stated as being 10 min (§15) for the State of Hesse (Germany).[2] However, the ERT varies in Germany depending on the federal state.

In this context, on the one hand, little scientific data are available on the feasibility of this legal requirement or the dependence of the ERT on the location or time of day or week, while, on the other hand, the implementation of technical solutions in a rescue system is cost-intensive, must be functional and stable so as not to compromise the quality of the rescue operations (Code of Social Law, Book V, §12–1, §§ 133, 135–139).[7]

Bürger *et al*[8] showed a decrease in survival rates with increasing response times for cardiac patients and, thus, postulated a significant effect of the ERT on patient survival. Furthermore, international studies[9–13] have

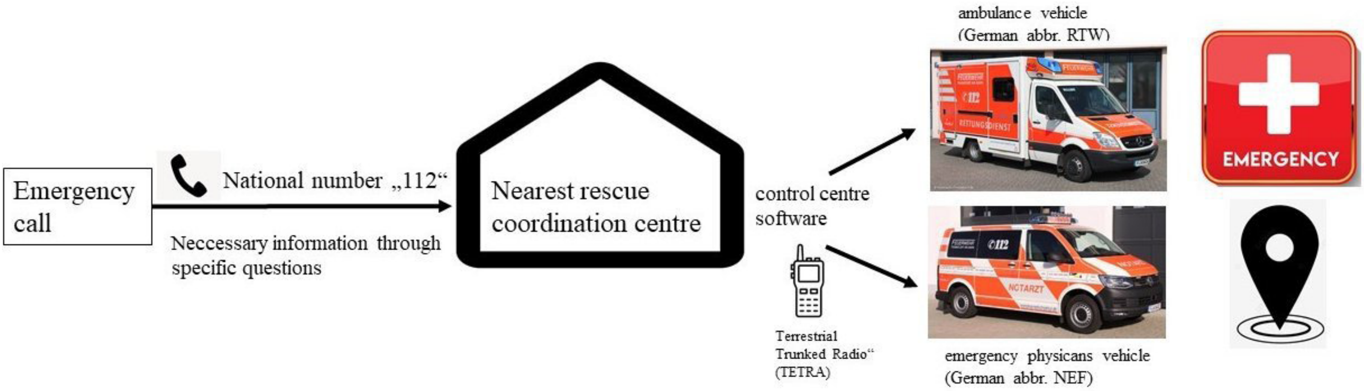

Figure 1 Emergency physician indication chart of the German Medical Association. RTW, Rettungswagen; TETRA, Terrestrial Trunked Radio; NEF, Notarzteinsatzfahrzeug.

investigated travel times when using 'Lights and Sirens (L&S)'. These authors focused on different factors such as whether the use of GPS (Global Positioning System)-based navigation generally reduces journey times,[9] or whether travel times could be significantly reduced by GPS-based navigation in comparison to a map.[10 11] Nehme *et al*[13] identified patient-level and system-level factors as predictors for the prompt arrival of ambulances, while other additional factors also influenced the (medical) emergency response, such as occupied or otherwise unavailable ambulances. In rural areas, ambulance use was found to be lower although the vehicles were unavailable more often.[14] A theoretical approach was proposed by Krampe *et al*[12] in the region of Styria (Austria) that uses an improved communication between the emergency coordination centre and the rescue vehicles with general traffic information systems (navigation solution: SDK MapTrip, company Infoware).

Despite the large body of evidence that GPS navigation can be useful for the ambulance service, it has not yet been investigated which navigation software solution provides the fastest arrival time for ambulances. Furthermore, it also has not been studied whether such a system is equally beneficial in a rural or an urban setting, or whether it brings particular advantages at certain times of the day or week. So far, there is no intelligent routing for vehicles using L&S signals.[15]

The topic of intelligent, specific software is of great practical relevance in Germany as there is a high turnover of ambulance crews, a shortage of personnel and a high mobility. As a result, ambulance crews rarely have detailed local knowledge (eg, about shortcuts and detours) and, therefore, are dependent on the help of routing systems that are, consequently, used regularly. This is particularly the case for larger cities such as Frankfurt am Main. Due to this lack of local knowledge, the routes suggested by conventional navigation systems can only rarely be checked against the driver's own local knowledge in order to arrive at their destination more quickly. This makes the use of an intelligent routing system, which has more specific route planning solutions, all the more important.

Alongside Garmin, TomTom is the most widely used navigation system in Germany. Both systems are used or integrated into proprietary systems in the automotive industry, among others. Google Maps is very frequently used as a mobile system due to the existing smartphone integration.

Therefore, the aim of this study was to investigate whether a software programme (such as MapTrip112) that can react dynamically to special traffic situations, such as road works, bollard systems, 'illegal' motorway entrances and exits, one-way streets, prohibited changes of direction such as U-turns, as well as the current traffic situation, would have a significant influence on the response time (time gains or delays). We also examined whether an intelligent routing system, which was developed especially for the ambulance service, can further reduce the arrival time as part of the time-to-patient (ERT) travel time. In this study, two widely used standard solutions for normal civilian use (TomTom and Google Maps) were compared with a software solution (MapTrip112) that contains a correspondingly improved routing through an optimised navigation system and map material.

MATERIAL AND METHODS

Navigation systems

According to the available research, three navigation software programmes (all versions from 2022 releases) were compared in this study:

Google Maps: this was used as a browser version in Google Chrome (V.90.0.4430.93 64-bit) on a desktop PC (processor I7-6700, 16 GB Ram, graphics card NVIDIA GeForce GTX 970, Microsoft Windows V.10 Home version V.10.0.19041 Build 19041) and was representative of an integrated system. After entering the desired address, a route was calculated based on the current traffic situation (fastest route). For the travel time calculation, Google Maps rounded the time up or down to the nearest 30 s.

TomTom: TomTom Navigation was used on Windows V.10 (Home V.10.0.19041 Build 19041) as a browser version in Google Chrome (V.90.0.4430.93 64-bit) on a desktop PC (processor I7-6700, 16 GB Ram, graphics card NVIDIA GeForce GTX 970) and represented an independent system. After entering the desired address, a route (fastest route) was calculated based on the current traffic situation. TomTom rounded the travel time up or down to the nearest 10 s.

MapTrip112: The software "MapTrip112" (INFOWARE GmbH, Bonn/Germany) was designed for authorities and organisations with security tasks (eg, for the fire brigade, ambulance service and police) and is now considered as an industry solution. In the study, it was used as a mobile app version (4.8.1) on a Huawei P20 Android handset, in the same way as the other two programmes. The suggested route was calculated with L&S and rights of way. If desired, the programme switched on the "blue light mode" for a radius of 2 km around the destination, thus optimising the route for an emergency situation and so could consequently change routes. For example, it was possible to use service junctions reserved for maintenance purposes or emergency cases. The system also recognised that one-way streets could be travelled in reverse for short distances before the destination. Furthermore, the programme could ignore areas with restricted driving rights, for example, through a pedestrian zone. In the associated management programme (DeTour Editor 8.2 TT201809), routing could also be optimised and passages could be added with an editor. For example, such a passage was entered in the routing from Fire Station 1 in Frankfurt am Main (Germany) for the study (figure 1). In this way, the crossing built especially for the fire brigade, being a no-passing zone for regular traffic, could be used. No other changes were made to the routes. Travel time estimation in Map-Trip112 was accurate to the second.

As this is a simulation study and not a field study, we used a stable WIFI internet connection for the navigation calculations. The measurements were always taken in the same office: affiliations and settings were identical. TomTom and Google Maps were used via the provider's website on the PC, however, MapTrip 112 could not be opened via the website, but only via an app on Android smartphones. The tests were started simultaneously on both websites and the MapTrip112 app. A stable WLAN connection was used specifically to exclude the influence of fluctuating mobile data in the field test as a confounder. At least 100 tests were calculated in 'real time' for every day of the week (Monday to Sunday).

Route calculations

All measurements were made as distances to randomly selected points on the map and were based on the theoretical assumption of the fastest route, that is, the trips were not made in real life but only simulated in the navigation systems. The targets were selected with the help of the 'leitstellenspiel.de' app, a training software for emergency service personnel in Germany. The times and distances determined were compared theoretically. Thus, high and low traffic volumes could also be included in the measurement procedure. These measurements were carried out in 'real time', simultaneously for the three systems at the respective locations.

For the comparison of the three existing measurement systems, different locations around the area of operation within the city or district boundaries ('city' and 'countryside rescue') were selected randomly. The travel distances were defined in consensus with the included rescue stations and their real-world operational experiences in the investigated regions and the corresponding population densities.

For the 'countryside rescue' scenario, the emergency physician vehicle (German abbreviation: NEF) at the Odenwald Health Centre at the local district hospital (64 711 Erbach, Germany) was used as the starting point. The population density of about 155 inhabitants per square kilometre could lead to longer travel distances.[16] Routes were classified as either short distance (less than 15 km) or long distance (more than 15 km) to approximate more accurately the countryside situation.

The 'city rescue' scenario included two starting points, that is, the emergency department at the University Hospital Frankfurt (Theodor-Stern-Kai 7, 60 596 Frankfurt am Main, Germany) and the Central Fire Station 1 (Feuerwehrstraße 1, 60 435 Frankfurt am Main, Germany). These two locations were selected to reflect urban rescue scenarios with the temporally changing city traffic (rush hour traffic) and the presence of many special routings and motorway junctions.

At least 50 measurements per weekday were carried out at both locations. Since a passage was added to the navigation system at Fire Station 1 in Frankfurt, we also compared whether the manual addition of the fire department exit showed a difference compared with the unchanged route calculation at the University Hospital Frankfurt.

All routes were separated into short distance (up to 3 km), medium distance 1 (3 to 6 km), medium distance 2 (7 to 10 km) and long distance (>10 km).

For the differentiation between the rush hours and off-peak hours, the traffic time between 16:00 and 19:00 on weekdays was selected for rush hour traffic.

Study execution

At each point in time, three measurements were carried out simultaneously. The travel times and route lengths were recorded for all three systems. All tests took place simultaneously with the routing by smartphone (MapTrip112) started at the same time as the two browser systems (TomTom, Google Maps) to prevent errors due to different measurement times. The time of the fastest route was recorded in seconds (s) and the length in kilometres (km).

The destinations were randomly selected, fictitious areas of operation.

Confounders, such as the weather, holidays, traffic jams, accidents and road closures, were not listed separately under the assumption that these factors were identical for each programme and, thus, had no relevance. It was also taken into account that MapTrip112 indicates the journey times to the second, while TomTom rounds up or down to the nearest 10 s and Google Maps rounds up or down to the nearest 30 s. Therefore, the values of TomTom and Google Maps had to be considered as being changeable.

Patient and public involvement statement

Patient and Public Involvement was not conducted in the present study due to it being a simulation study. No personal data were included in the study.

Statistical analysis

The statistical analysis was carried out with the BIAS programme (V.11.12, Epsilon Verlag: Darmstadt). Statistical comparisons were made for the differences in the individual results with regard to the different distances and the differences between weekdays and weekend days. For urban traffic, the weekdays were also compared with each other as well as the effect of the rush hour (16:00–19:00).

The theoretical journey times determined were compared with each other and related to the legal maximum 10 min response time as mandated by the Hessian Rescue Service Act.[6] In this context, the possible reduction of the driving time (the response time) with the respective software compared with the others was of particular interest. The aim was to show which of the programmes had the most favourable effect in terms of the response time, that is, which was most likely to meet the response time. This measured time from departure to arrival at the patient's location was referred to as 'ERT' in the context of this study. To compare the ERTs measured with the three navigation systems, the difference between the comparisons was then determined as a percentage value and this then formed the starting point for the subsequent discussion. In this context, it had to be taken into account that the journey time determined whether or not the assistance deadline could be met through the use of the navigation system.

First, the data were checked for normal distribution. Since the data were not normally distributed, the non-parametric Friedman test was employed followed by multiple pair comparison (Conover-Iman test), with subsequent Bonferroni-Holm correction of the p values. All significance levels were set at 5%.

RESULTS

A total of 9300 measurements were made at 1550 different time points for 4650 routes of rural and urban rescue simulations. This was due to the fact that at each time point, six measurements were started simultaneously by mouse clicks, that is, the travel time to the emergency scene and the distance travelled were recorded in each of the three software systems. The percentage of the statutory ERT of Hesse was always given in brackets next to the time saved (s).

Countryside and urban scenarios on weekends and weekdays

Travel times and distances were different for all scenarios of the rural and urban routes, at weekends and on weekdays (Friedman tests, $p\leq0.001$) (online supplemental table 1). After Bonferroni-Holm correction, all pairwise comparisons remained significantly different with $p\leq0.001$.

For the countryside scenarios on weekends, MapTrip112 had shorter travel times by 80.5–90.5 s (median 85.5 s; 14.25% of ERT) compared with TomTom, and by 115.5 s–175.5 s (median 145.5 s; 24.25% of ERT) when compared with Google Maps.

On weekdays, MapTrip112 had a time advantage of 23.5 s–33.5 s (median 28.5 s;

4.75% of ERT) over TomTom, and 118.5 s–178.5 s (median 148.5 s; 24.75% of ERT) over Google Maps.

The city scenarios for weekends showed that MapTrip112 routing was faster than TomTom by 133 s–143 s (median 138 s (23% of ERT) and faster than Google Maps by 198 s–258 s (median 228 s; 38% of ERT).

In the city measurements on weekdays, MapTrip112 was, on average, 192 s (32% of ERT) faster than TomTom and 252 s (42% of ERT) faster than Google Maps.

Navigation comparison on each working day in the city

All time and distance scenarios were significantly different (Friedman test $p\leq0.001$) during Monday-Friday (online supplemental table 2). All Bonferroni-Holm corrected pairwise comparisons remained significantly different ($p\leq0.001$ and 0.01, respectively), except for the distance between TomTom and Google Maps on Tuesdays.

On Mondays, MapTrip112 was 179.5.5 s–189.5 s faster than TomTom (median 184.5 s; 30.66% of ERT) and 214.5 s–274.5 s (median 244.5 s; 40.66% of ERT) faster than Google Maps. On Tuesdays, MapTrip112 achieved a time 64.5 s–74.5 s (median 69.5 s; 11.6% of ERT) faster over TomTom and 99.5 s–159.5 s (median 129.5 s; 22.58% of ERT) over Google Maps. On Wednesdays, MapTrip112 had a 105 s–115 s time advantage (median 110 s; 18.33% of ERT) over TomTom and 200 s–260 s (median 230 s; 38.33% of ERT) over Google Maps.

On Thursdays, MapTrip112 was 185 s–195 s (median 190 s; 31.67% of ERT) faster than TomTom and 220 s–280 s (median 250 s; 41.67% of ERT) faster than Google Maps. On Fridays, MapTrip112 had a time advantage of 235.5 s–245.5 (median 240.5 s; 40% of ERT) over TomTom and 270.5 s–330.5 s (median 300.5 s; 50% of ERT) over Google Maps.

This difference was greatest on Fridays with a time gain of 40% of ERT (240.5 s) over TomTom and 50% of ERT (300.5 s) over Google Maps.

Distance comparisons in the countryside and in the city

Countryside scenario

MapTrip112 routes were 40 s–50 s (median 45 s; 7.5% of ERT) faster for short distance scenarios up to 15 km than TomTom and 75 s–135 s (median 105 s; 17.5% of ERT) faster than Google Maps. Long distance scenarios over

15 km showed that MapTrip112 had a time advantage of 67 s–77 s (median: 72 s; 12% of ERT) compared with TomTom and 102 s–162 s (median: 132 s; 22% of ERT) compared with Google Maps (online supplemental table 3).

City scenarios

On the short distances (up to 3 km), MapTrip112 had shown a time advantage over TomTom of 105 s–115 s (median: 110 s; 18.3% of ERT) and over Google Maps of 60 s–120 s (median: 90 s; 15% of ERT). For the medium distance 1 (up to 6 km), MapTrip112 was 132.5 s–142.5 s (median 137.5 s; 22.9% of ERT) faster over TomTom and 227.5 s–287.5 s (median 257.5 s; 42.9% of ERT) over Google Maps. For the medium distance 2 (up to 10 km), MapTrip112 had a time advantage of 64 s–74 s (median: 69 s; 11.5% of ERT) over TomTom and 39 s–99 s (median: 69 s; 11.5% of ERT) over Google Maps. For the long distances (over 10 km), MapTrip112 showed a time advantage of 16 s–26 s (median: 21 s; 3.5% of ERT) over TomTom and a time advantage of 51 s–111 s (median: 81 s; 13.5% of ERT) over Google Maps (online supplemental table 3).

It was shown that there was no linear relationship between the distance travelled and the shortening of the response time.

Comparison of two city locations at rush hour

Considering the time comparisons at the evening rush hour and at the two city locations, MapTrip112 had a time advantage of 180.5 s–190.5 s (median: 185.5 s; 30.92% of ERT) over TomTom and of 215.5 s–275.5 s (median: 245.5 s; 40.92% of ERT) over Google Maps for the rush hour. Thus, MapTrip112 had a time gain of 30.92% (185.5 s) compared with TomTom and 40.92% (445.5 s) compared with Google Maps (online supplemental table 4).

At the University Hospital location, MapTrip112 showed a time advantage of 168.5 s–178.5 s (median: 173.5 s; 28.92% of ERT) compared with TomTom and of 263.5 s–323.5 s (median: 293.5 s; 48.92% of ERT) compared with Google Maps. For Fire Station 1, MapTrip112 showed a time advantage over TomTom of 157.5 s–167.5 s (median: 162.5 s; 27.08% of ERT) and, over Google Maps, a time advantage of 12.5 s–72.5 s (median: 42.5 s; 7.08% of ERT).

DISCUSSION

The aim of this study was to compare three different navigation systems and their use for emergency rescue services with regard to the calculated ERT and, thus, their possible positive effect on the adherence to the required ERT by German law in Hesse in a theoretical simulation. The results showed that the use of MapTrip 112 (industry solution) significantly reduced the response times, meaning that ERTs could be reduced by using this solution in a simulation setting. In summary, all measurements showed that both in the city and in the countryside, the sector-specific programme MapTrip112 calculated a shorter ERT response time by up to 50 per cent, that is, a time saving of 5 min, in relation to the ERT of 10 min, that is legally applied in Hesse (Germany).[6] Although the distances usually differed from each other, a calculated shorter travel time did not automatically result in a shorter calculated travel distance. This was due, among other things, to the fact that there were detours faster than the direct route, therefore, the distance to be travelled was not necessarily the decisive factor influencing the ERT. Bürger *et al*[8] retrospectively demonstrated that a longer response time can significantly shorten patient survival: 7.7 stroke patients per 100 000 inhabitants survived with good neurological recovery, when the ERT was less than 8 min, whereas when the ERT was longer, only 5.6 patients per 100 000 inhabitants achieved a good neurological recovery. They, therefore, postulated that the ERT has a significant impact on patient survival.

In line with the present results, a highly effective routing system should become part of the operator's planning requirement as a service provider in the emergency service, assuming that the service provider is able to build new rescue stations, purchase vehicles and build up additional personnel structures if the ratios are too poor to meet the response time. The results presented here showed that the possibility of improving the adherence to legal requirements can readily be achieved with a technical routing solution and, thus, with significantly less financial and structural effort. However, it must be kept in mind that all calculated measurements were based on the theoretical fastest route and were conducted simultaneously by the three navigation systems in the same office, while testing under real-world conditions had not yet taken place in order to evaluate the transferability of the simulations.

Moreover, there was no major risk in practical implementation when using such non-official forbidden routes by emergency vehicles. GPS devices have been used regularly during rescue operations for years. Every ambulance crew has to weigh up the risk for a non-routine route against potential hazards every time, regardless of the software used. Every ambulance in Germany is equipped with navigation software such as TomTom which is used regularly. Nevertheless, the routes suggested by the navigation systems are always supplemented by individual local knowledge, if available. If a vehicle with the right of way, as indicated by its emergency signal, is travelling in Germany, then it must be granted the right of way under traffic law, that is, normal traffic must give way to this vehicle and allow it to pass.

In prehospital rescue services, it is ultimately a matter of speed of the emergency vehicles that determine the response time. The minimisation of the ERT is, therefore, the subject of practical training, guidelines, professional discussions and coordination[17] and also forms the topic of this and other studies.[8–13]

Fleischman *et al*[9] concluded from their retrospective study that the use of the GPS-based navigation system

Google Maps, with the use of L&S, could improve resource allocation, although they only used a single, theoretical navigation. They also found a reduction of the transport time of up to 47% when using L&S, especially in rush hours. This effect could also be shown in the present work by using an industry solution with a reduction of the response time (ERT) of up to 40.92%.

The Google Maps web application discussed here was taken into account in this study because of its wide distribution, and the comparison showed that it is not sensible to use a single web application, but to compare several systems. In 2009, Gonzalez *et al*[10] compared the GPS system 'Garmin Streetpilot' with, or without, the use of GPS in 791 emergency calls in a rural area in Alabama, USA. Travel times to the emergency scene could be significantly reduced by using the GPS-based navigation in a year-long study (7.6 min with GPS vs 8.5 min without GPS). With 26 trips identical in distance to the previous year, the difference was 18.6 min without GPS compared with 15.4 min with GPS. The advantage was particularly obvious for journeys identical in distance. This study also suggested that the use of GPS-supported systems in rural areas resulted in a reduction in travel time depending on the system. On the basis of 29 real trips, Ota *et al*[11] were able to show that the use of GPS-supported systems, as compared with conventional map use, resulted in a shorter travel time, especially in urban areas, and that the use of different systems had a different impact on the calculated time savings. The team with GPS arrived at the location faster in 72% of the cases (GPS: median 13.5±6.1 min; road map: median 14.6±6.4 min). However, their study did not provide a more precise definition of the region studied; only the indication of 'in the city' or 'urban area' was mentioned. Furthermore, Nehme *et al*[13] concluded that a number of patient factors and systemic factors were useful predictors for the fast arrival of ambulances although they did not focus on the travel times for the ambulance vehicles, themselves. In contrast to the aforementioned studies, the present study has also shown that considerable differences were associated with the GPS systems that are presently available on the market and used for emergency travel as these systems calculated different times; the industry solution (MapTrip112) in the L&S mode navigated with the shortest median time and was faster than the TomTom and Google Maps systems. Consequently, it should be considered that different systems could be more or less suited for emergency travel planning. Analogous to the results of Nehme *et al*,[13] this analysis also showed that the distance to the location and the time of day also produced different results, for example, for different weekdays. All studies cited confirmed our results in some specific aspect.

This study did not investigate other measures to improve the response time. In our study, the data showed that the selection of a well-suited navigation system could significantly reduce the patient arrival time (the ERT in the present study). However, the time advantages, obviously, did not increase linearly with the distances covered; this could be due to the fact that the time advantage had a greater effect in the vicinity of the place of operation rather than on the distant route locations (at a greater distance from the starting point) because the route differences only became relevant for longer trips when within the 'last mile' of the journey (eg, for the last 2 km). This could be due to the fact that the route guidance in MapTrip112 changed more frequently in the proximity of the final destination, which, according to the manufacturer, would be caused by the programme making final changes according to the available options, for example, the reverse use of single-carriageway roads.

These L&S route changes were not possible with TomTom or Google Maps as these systems obey all traffic rules.

When analysing the results, however, the fact had to be taken into account that in contrast to MapTrip112, which enables measurements to the second in its present version, TomTom's software rounded the journey times to the nearest 10 s while Google Maps even rounds to the nearest minute. The methods of time approximation could not be clarified, even by contacting the companies directly, therefore, for TomTom, a systematic fluctuation of±10 s and for Google Maps of±30 s were derived. Nevertheless, MapTrip112 still offered a time advantage in all cases, even after this consideration.

As a result of the present analysis, software suitable for rescue services should include the 'drive with special signal' option for the route calculations. In addition to the other peculiarities of traffic law, emergency vehicles are allowed to use higher driving speeds, drive through traffic jams on emergency lanes, individually adjust their average speeds, possibly ignore roadworks restrictions or similar or other functions to improve the route selection. Thus, with a simulation study without the involvement of different crews and drivers, we avoided a bias due to individual differences and were able to make generally valid, simultaneous measurements.

The use of integrated systems with their response time indication would be a sensible addition for the navigation devices when driving with L&S, as the accuracy of the GPS reception can be altered by the deflection of the beams (eg, due to curvatures in the terrain), especially in cities.[18] Whether the use of the European navigation system 'Galileo' instead of GPS systems would further improve emergency vehicle routing should be clarified in further analyses.

This study also had some limitations. It should be noted here that these routes were theoretical routes that had been simulated and not been driven under real-world conditions. In addition, it should be noted that, in this study, the locations of emergency vehicles were used as examples. Nevertheless, these results should be transferred to other emergency organisations and regions since the use of a navigation system with L&S should be the norm as comparable in any emergency situation. The time of measurement or the location did not affect the results; MapTrip112 always calculated the faster route.

Ultimately, verification of our results in practice is needed to validate this assumption. It can, therefore, be assumed that in addition to the ambulance service, other rescue services such as the police, fire brigade or the Federal Agency for Technical Relief would also benefit from this system.

Conclusion

In summary, MapTrip112 always achieved the fastest routes but not always the shortest distance. The time advantage of the MapTrip112 system was more pronounced in the city than in the countryside. The advantage was also greater with higher traffic volumes, such as during rush hour or on Fridays. On Fridays, the use of this industry solution was able to calculate faster routes than a conventional navigation system by up to 50% of the response time (5 min). On other days of the week, the benefits were smaller, although they were still significant. Since the emergency service laws of the German states prescribe the response time, it is evident that the time advantages in this study were highly relevant for the ambulance service (as mandated by the Hessian Emergency Service Act HRDG[6]). Since a rescue service operator has to fulfil this requirement, even with the continuously increasing frequency of operations, improving the routing for a shorter travel time (and thus ERT) will help to facilitate compliance with the legally required period. For this reason, the use of this software should be considered in practice and investigated under real-world life conditions in further studies.

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Contributors AvM conducted the measurements, analysed and interpreted the data, conducted the statistical analysis and wrote the main manuscript text, study guarantor. TH conducted the measurements, analysed and interpreted the patient data, conducted the statistical analysis and was a major contributor in writing the manuscript. FH conducted the statistical analysis and reviewed the manuscript. DAG revised the manuscript critically for important intellectual content. DO analysed the data, interpreted the data and revised the manuscript critically for important intellectual content, study guarantor.

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Patient consent for publication Not applicable.

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