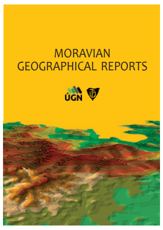

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Modelling the road network riskiness for motorcycle transport: The use of accident probability and accessibility to emergency medical service

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Abstract

Motorcycle users are generally perceived as one of the most vulnerable road user groups. It is therefore evident that, in addition to a range of prevention and awareness-raising activities, it is also necessary to identify specific locations where motorcycle users are at risk. We use a synthetic approach to identify the road network sections dangerous for motorcycle traffic. We perceive the risk level of individual sections as a complex combination of the causes (accident probability) and consequences (accessibility of medical services) of motorcycle accidents. The combination of both factors is then used to define the Road Network Hazard Index (RNHI) as a newly introduced indicator synthetically assessing the risk levels of individual road network sections for motorcycle traffic. The motorcycle accident probability on the Czech road network is extremely differentiated. The time accessibility of accident locations from EMS dispatch stations shows a clear correlation with the severity of motorcycle accidents. The model for the accident locations' accessibility indicates that the sparsely populated peripheral regions of the Czech Republic in particular show not only a higher motorcycle accident probability but also higher time accessibility values for emergency vehicles. The new RNHI provides a comprehensive view of the risk levels for motorcycle traffic in different Czech road network sections.

Keywords: *Motorcycle transport; road hazards; accessibility; traffic safety; Czech Republic*

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1. Introduction

Road safety has become an important transport priority worldwide. Many countries are therefore investing heavily in transport infrastructure and vehicles, as well as in transport education. The common goal of these efforts is to improve road safety for road users. The WHO estimates that transport accidents kill about 1.3 million people worldwide each year, and another 20–50 million people face the consequences of transport accidents www.who.int. There are also many other direct and indirect negative economic, social and psychological consequences (Bastida et al., 2004). The issue of transport accidents and their prevention has therefore long attracted the attention of researchers from various scientific disciplines. Recent academic debates, however have shifted from isolated accident research to looking at the more complex risks associated with road transport in general.

Today, a lot of attention is paid to the safety of motorcycle transport (Rodrigues et al., 2009; Jung et al., 2013 and Salum et al., 2019). Motorcyclist safety is also relevant due to the motorcycles' growing popularity worldwide. One of the reasons for the recent increase in its popularity is the global Covid-19 pandemic. Many people see motorcycle transport as a good way to eliminate interpersonal contact in public transport, while still meeting their mobility needs (see also Zhang et al., 2021). Although there is an overall downward trend in motorcycle accidents and their consequences, this decline is slower than in other means of transport. Motorcycle users are generally perceived as one of the most vulnerable road user groups and motorcycle accidents are often fatal (Di Stasi et al., 2011; Shinar, 2012; Rowden et al., 2016). The risks connected to motorcycle accidents are usually serious and the susceptibility to injury is high, especially in collisions with an obstacle or another road user. An important factor to ensure the fastest possible medical assistance in the event of a motorcycle accident is a reliable emergency medical service (EMS). EMS is a comprehensive system composed of personnel, facilities, and equipment to ensure efficient, coordinated, and timely delivery of health and safety services to victims of sudden illness or injury (Al-Shaqsi, 2010). Effective territorial coverage by the EMS system and their dispatch bases is thus a key factor for the entire healthcare system.

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Research on traffic accidents in connection with EMS and their medical response times is almost exclusively associated with car accidents, although motorcycle accidents account for roughly one-third of total traffic fatalities when compared to other transport modes (WHO, 2018) and time accessibility of EMS to a motorcycle accident is a key factor given the higher risk of severe consequences. Despite modern motorcycle safety features, such as ABS, and motorcycle equipment technologies including airbag vests (Serre et al., 2019; Thollon et al., 2010), riding a motorcycle is riskier than travelling by car due to the rider's vulnerability. Compared to car accidents, the risk of serious injury is higher due to the absence of a physical barrier or crumple zone.

The last decade has also marked the promotion of geographical approaches to the study of traffic accidents (see e.g. Kingham et al., 2011; Andersson & Chapman, 2011, or Bíl et al., 2013). This is because traffic accidents always have a spatial aspect. They always take place in specific temporal and spatial conditions. It was not until modern spatial analysis methods were developed, however, that spatial data was made more readily available, and geographic information systems (GIS) were introduced, that the importance of geographic approaches in traffic accident analysis grew. Thus, current geographic approaches often integrate spatial and traffic data. In addition, many countries now record accidents' precise locations as well as other characteristics, which allows for an adequate combination of spatial-statistical methods (Shafabakhsh et al., 2017; Shahzad, 2020). Although the factors influencing motorcycle accidents are relatively well researched (see e.g. a comprehensive study by Vlahogianni et al., 2012), a research gap still prevails. This is particularly evident considering the specific spatial patterns of motorcycle accidents and the associated coverage of the area by the health care system. A comprehensive approach to these risks is currently lacking. Therefore, spatial approaches are important to the study of motorcycle accidents and so is the related provision of post-accident health care (see also Sánchez-Mangas et al., 2010, or Bíl et al., 2019).

This paper aims to define complex road network hazards through spatial-statistical methods. The road network hazard index (RNHI) defined in this paper represents a new synthetic indicator to assess the risk levels of individual road network sections for motorcycle traffic. The RNHI design is based on a series of sub-steps specified below. In general, the RNHI uses the precise location of motorcycle accidents on the road network. This is then used to define the motorcycle accident probability in individual sections. It also utilises the time accessibility of accident locations from the nearest EMS dispatch station. The RNHI is then defined based on the interaction between accident probability and the EMS stations' time accessibility. This issue is of high social relevance as such approaches are currently lacking. The results of the study contribute to the current state of knowledge in the field of motorcycle accidents and their spatial aspects. They can also be applied when planning a territorial EMS coverage system or coordinating motorcycle traffic safety.

2. Theoretical background

Emergency response time (ERT) is a key factor in accident mortality and the chance of survival, and most deaths associated with traffic accidents occur before the subject reaches the hospital (Clark et al., 2012; Travis et al., 2012). The time elapsing between the accident and the emergency services arriving is therefore of the utmost value in terms of rescuing the persons involved in the accident (Clark et al., 2013). The available literature on accident rates and ERT mostly focuses on the relationship between the accident's consequences and the provision of health care. In general, improving medical care and technological developments contribute to reducing the health consequences of road accidents (Noland & Quddus, 2004). Developments in communication and GPS technologies also play a significant role in reducing EMS response time. Timely and accurate accident notification, including details such as type of accident, number of persons, severity, etc., are also among early rescue factors and contribute greatly to reducing post-accident mortality (Clark & Cushing, 2002; Lahausse et al., 2008; Wu et al., 2013; Plevin et al., 2017).

A key factor for the EMS' timely arrival to a traffic accident, however, is the distance between the accident scene and the medical centre. This depends on the different geographical conditions of accident blackspots and causes the difference in traffic mortality rates due to different ERTs (Li et al., 2008; Clark et al., 2013; Wilde, 2013; Byrne et al., 2019). Several studies (McCoy et al., 2013; Swaroop et al., 2013; Harmsen et al., 2015) have indicated a threshold interval of 15–20 minutes as the key EMS unit response time, after which a significant increase in patient deaths due to various types of trauma has been observed. In the Czech Republic, the EMS deployment system is regulated by legislation. According to the Emergency Medical Services Act (374/2011 Coll.):

> "the plan for the coverage of the territory with EMS stations determines the number and location of EMS stations depending on the demographic, topographic and risk parameters of the territory of individual municipalities so that the location of an incident in the territory of individual municipalities can be reached from the nearest EMS station within a response time of up to 20 minutes" (§5).

Thus, the time elapsed between the incident notification and the arrival of EMS units at the accident scene has a significant impact on increasing the survival rate. This factor has subsequently become an international standard for EMS station localisation, especially in urban environments. The situation is different in rural areas, however, which are often less accessible. There are usually issues with lower quality road infrastructure and longer commuting distances. Consequently, "blind spots" in the territory arise, most often in rural and sparsely populated regions with lower EMS density (He et al., 2018; He et al., 2019; Xiong et al., 2022).

Accident localisation is a key factor related to the quick EMS arrival. Research in how accident location is related to EMS response time has shown a significant difference between accidents in rural and urban areas (Kmet & Macarthur, 2006; Alanazy et al., 2019). The difference between urban and rural EMS performance in achieving better patient rescue outcomes has been demonstrated by several studies conducted exclusively in developed countries. American research on EMS arrivals to accident scenes revealed a significant difference in medical response time; the model for urban environments showed significantly shorter arrival times to accidents than the model for rural areas (Gonzalez et al., 2009; Newgard et al., 2017). Similar findings were reported by the Polish researchers (Aftyka et al., 2014), who found that EMS in a rural area has a significantly longer response time than in an urban location. The increased accessibility and performance of EMS in an urban environment is in turn related to road infrastructure density and its quality relative to the location of EMS stations. On a trans-regional scale (e.g. the Czech Republic), however, EMS travel times are determined by spatial complexity and geographical characteristics such as the terrain or road network sinuosity. Studies such as Liu et al. (2014) and Amorim et al. (2017) explain the higher accident rate as a result of densely populated urban environments with developed infrastructure.

Detailed accident information from Automatic Crash Notification systems (ACN), which currently offer the possibility to locate the accident immediately and determine its crash characteristics by analysing the data transmitted from the vehicle, can also influence medical response time. This data is evaluated in real-time by EMS units. The emergency service must identify accidents with serious injuries and deploy appropriate rescue and treatment capacities according to the type and severity of the accident. These systems' contribution to reducing the mortality rate in traffic accidents has been demonstrated by studies such as Clark and Cushing (2002) and Bahouth et al. (2014).

3. Data and methods

We use the traffic accident database in the Czech Republic provided by the Police of the Czech Republic. The database contains all transport accidents reported to the Police from January 1, 2016 to December 31, 2020. All accidents involving motorcycle drivers have been selected from this database. The database contains 10,460 motorcycle accidents happening during the entire period. Each accident recorded in the database contains its detailed characteristics, i.e. time, date, exact coordinates of the accident (latitude, longitude), and a lot of other information.

Our methodological approach is based on an attempt to synthesise the risk levels of individual road network sections for motorcyclists. The risk levels of individual road network sections are defined as a combination of the probability of a motorcycle accident occurring on a given section and the nearest EMS station's time accessibility, which plays a key role in saving human health and life in the event of an accident (see Azimian et al., 2021). This process consists of the following steps.

In the first phase, we study the motorcycle accident probability in all sections of the Czech road network in detail. To determine the probability, we first observe the spatial concentration of motorcycle accidents in each section of the road network. The road network sections were taken from the road network database managed by the Road and Motorway Directorate of the Czech Republic and the Technical Road Administration of Prague. Sections are generally defined as parts of the road network between two junctions. The advantage of choosing sections using this method is that each section contains information about the average daily motorcycle traffic intensity. A total of 9,334 sections covering almost 33,800 km (more than 61% of the Czech road network) are recorded in this database. It therefore contains a substantial part of the busiest roads in the Czech Republic.

The concentration of traffic accidents is expressed as the number of motorcycle accidents in individual sections in the given period divided by the length of the relevant road network section. This process identifies specific concentrations of motorcycle accidents in individual road sections. We then divide the specific concentrations of the road network's risk sections by the motorcycle traffic volume in the section. The data on motorcycle traffic volume in each section are taken from the national traffic census results from 2020. Thus, we know the average daily motorcycle traffic volume (number of motorcycles passing in 24 hours) for each section. This figure is then multiplied by the number of days in the whole reference period using the formula

$$P(x) = \frac{N(s)/l}{T(x) \times (5 \times 365)}$$

where $P(x)$ is the accident probability in x coordinates per 1 km of road length, N is the number of accidents in the segment, s is the segment containing x, l is the length of the segment, and T is the average motorcycle traffic volume in 24 hours according to the results of the national traffic census.

Based on the proportion of the values in the spatial concentration of motorcycle accidents and the total intensity of motorcycle traffic, each section of the Czech road network is defined in terms of the motorcycle accident probability.

Based on previous findings (see e.g. Kraft et al., 2022), it has been confirmed that motorcycle accident blackspots exhibit specific spatial patterns. It is generally true that motorcycle accidents occur away from major thoroughfares, on lower road classes, and further from population centres. This harms the time accessibility of accident locations from EMS stations, which are usually located in urbanised areas (see Xia et al., 2019). Therefore, in the second phase, we monitored the time accessibility of each road section from the nearest EMS station. We measure it as the amount of time needed to reach a particular road network section from the nearest EMS dispatch base. The exact EMS station locations were taken from the individual regions of the Czech Republic's coverage plan. In total, we work with 327 EMS dispatch stations. We determine the time accessibility through the Network Analyst extension in ArcGIS Pro. The individual sections connecting the starting point (the EMS dispatch base) and the destination (the centre of the surveyed road section) are assigned average speeds (according to ČSN 73 6100-2). The time required to reach the destination is then calculated for each section. Based on this sub-procedure, we define the accessibility of individual accident locations, which significantly influences the chances of rescuing injured persons.

We calculated the dependence of traffic accident severity on EMS time accessibility using the local contingency table introduced in Dvořák and Mrkvička (2021). We divided the accessibility into 4 categories: up to 10, 20 and 30 minutes and longer. Each accident's severity was rated according to the average insurance company's claim for injuries to reach the overall RNHI. Thus, we created a model of the injury severity from the insurance company's perspective. A subjective model from the injured person's perspective could also be made, but for the sake of objectivity, we chose to create the model from the insurance company's perspective. The average insurance claim values were obtained from Česká pojišťovna, a.s. data (Tab. 1).

	Severity = Average claims in CZK
Death	420,000
Serious injury	34,521
Minor injury	13,741
No injury	0

Tab. 1: Average claim values based on the accident's severity
Source: authors' calculations based on discussion with expert (see above)

The resulting road network hazard index (RNHI) is a combination of the above sub-processes. The RNHI is calculated for each section of the road network. Its value is determined as the product of the accident probability in a given section and the mean accident severity value identified by the frequency of individual accident categories occurring (death, serious injury, minor injury, no injury). Thus, the overall formula for calculating the RNHI value is:

$$\text{RNHI (of segment s)} = P(x) * E(\text{accident severity} \mid \text{accessibility} = D)$$

$$E(\text{accident severity}|\text{accessibility } D) =$$
$$= \sum_{i \in \{Death, serious\ injury, minor\ injury,\ no\ injury\}} severity * P(i|D),$$

where $P(i\,|\,D)$ is the probability of phenomenon i, subject to the availability of D, which is determined by the contingency table (see Section 4.2)

4. Results

4.1 Motorcycle accident probability

In the first phase, we assess motorcycle accident probability in individual sections of the Czech road network. This characteristic is based on the number of accidents, the length of individual sections and the intensity of motorcycle traffic. This indicator has a significant predictive value in terms of motorcycle safety.

It defines the relative risk sections of the road network for motorcycle traffic. The motorcycle accident probability is shown in Figure 1.

The probability of a motorcycle accident is spatially differentiated in individual sections. An increased motorcycle accident probability can be observed, especially on sections of lower-class roads (2nd and 3rd class roads). At the same time, there is an increased concentration of such sections in less urbanised parts of the Czech Republic (e.g. Nunn & Newby, 2015). This makes some sense as population centres become important sources and destinations for individual motorcycle rides (see e.g. Iamtrakul et al., 2003). Nevertheless, the accident rate is particularly high in their surroundings, where the likelihood of motorcycle accidents increases due to the popularity of more remote roads with less traffic among motorcycle riders (Cater, 2017). This confirms previous findings that specific concentrations of motorcycle accidents occur on less busy roads further away from population centres (e.g. Kraft et al., 2022).

Most motorcycle accidents occur on sections of 2nd class roads with generally low traffic volumes. The section between Chudenice and Švihov in the south-western part of the Czech Republic has been identified as the riskiest in terms of motorcycle accident probability. The sections in rural regions located further away from urban areas predominate among the twenty sections with the highest motorcycle accident probability. Another key observation is that these are, with few exceptions, long sections (the average length of the section is 6.8 km) with no junctions. The road sections where a greater number of risk factors intersect (unclear horizon, multiple sharp curves, poor visibility conditions, etc.) have been identified as sections with a high motorcycle accident probability. These sections in particular should draw more attention from the authorities responsible for road safety (see also Bíl et al., 2019). Identifying sections with high motorcycle accident probability is undoubtedly the key to further improving motorcycle traffic safety and implementing effective measures to eliminate them (Kashani et al., 2014). The accumulation of risk sections on lower-class roads can also be illustrated by data on the road network structure showing the probability of motorcycle accidents (Tab. 2).

4.2 Time accessibility of accident localities from the nearest EMS

As discussed above, the time accessibility of health services is one of the key post-accident aspects in saving human life and health. Given the specific motorcycle accident concentration spatial patterns noted above, this availability is often hampered by the fact that motorcycle accidents tend to occur in remote locations with lower traffic volumes, higher elevation, more curves, etc. (Jiang et al., 2020). Accidents involving quad bikes and enduro motorcycles in very inaccessible forest or mountain locations are no exception, however, which makes transporting injured people to medical facilities much more difficult. This is evidenced, among other things, by Figure 2 showing the locations of motorcycle accidents

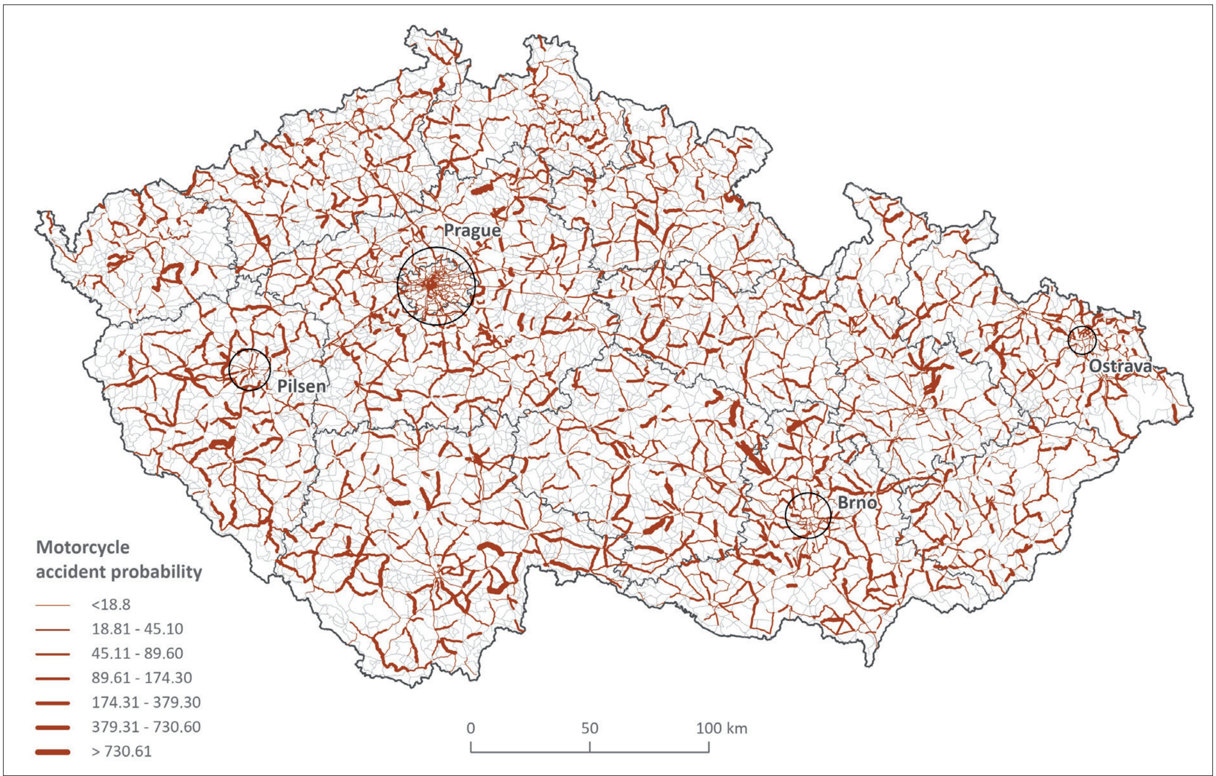

Fig. 1: Motorcycle accident probability on road segments in the Czech Republic
Source: authors' elaboration based on data from www.policie.cz and www.rsd.cz

Road class	Number of motorcycle accidents	Average daily motorcycle traffic volume	Average accident probability
Freeways	314	105	23.26
1st class roads	3,034	75	23.49
2nd class roads	4,535	39	53.99
3rd class roads	1,277	30	70.88
Urban roads	2,432	161	19.87
Local and other roads	800	80	25.30

Tab. 2: Road network structure according to number of accidents, average daily motorcycle traffic volume and motorcycle accident probability
Source: authors' calculations based on data from www.policie.cz and www.rsd.cz

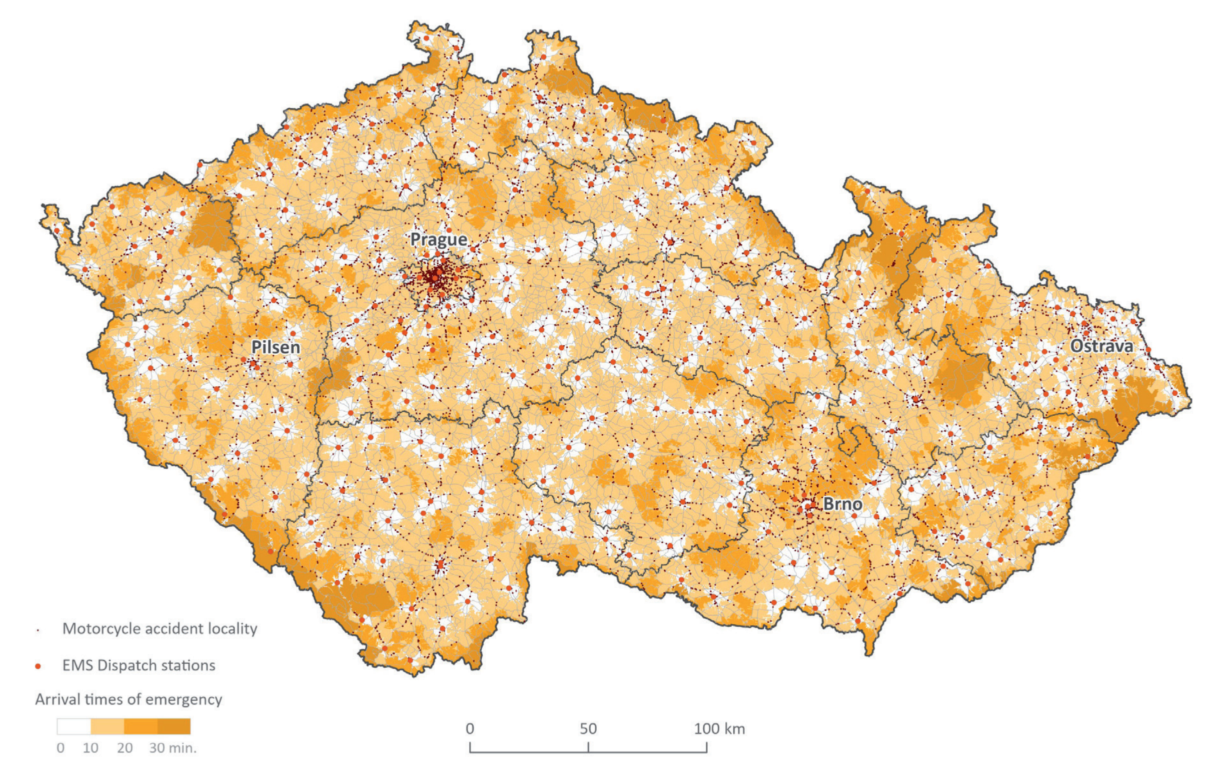

Fig. 2: Time accessibility zones from the nearest EMS to accident locations
Source: authors' elaboration based on data from www.policie.cz and Emergency Medical Services Act (374/2011 Coll.)

in relation to the nearest EMS station's temporal availability. Although the Czech Republic's EMS system coverage is relatively good (see e.g. Dolejš et al., 2020), one can also find locations where the nearest EMS station is very inaccessible.

It is evident that the statutory 20-minute accessibility (see above) cannot be adhered to in some accident locations. However, the overall coverage of the EMS dispatch stations according to motorcycle accident locations is relatively good. Nearly half of the accidents happened in locations accessible within 10 minutes from the nearest EMS (see Fig. 3). The lowest time accessibility values are usually found in urbanised regions where the population is more concentrated, the road network is denser and therefore there are more EMS dispatch stations. Especially considering the specifics of the motorcycle accidents' spatial distribution, however, the accidents often occur in very remote locations, i.e. with worse accessibility values. Such locations can be found especially in less accessible areas further away from cities, in rural regions and mountainous areas. Such sections are concentrated especially in the mountainous border regions of the Czech Republic. Although the road network is much thinner here, motorcycle accidents occur quite often (see e.g. Rezapour et al., 2020). In addition, intervention by air ambulance is more complicated in these regions.

We calculated the traffic accident severity as dependence on EMS availability using a local contingency table. The reported local results are bound by the global p-value of the test = 0.001 based on 1,000 permutations. The local results are presented in Table 3.

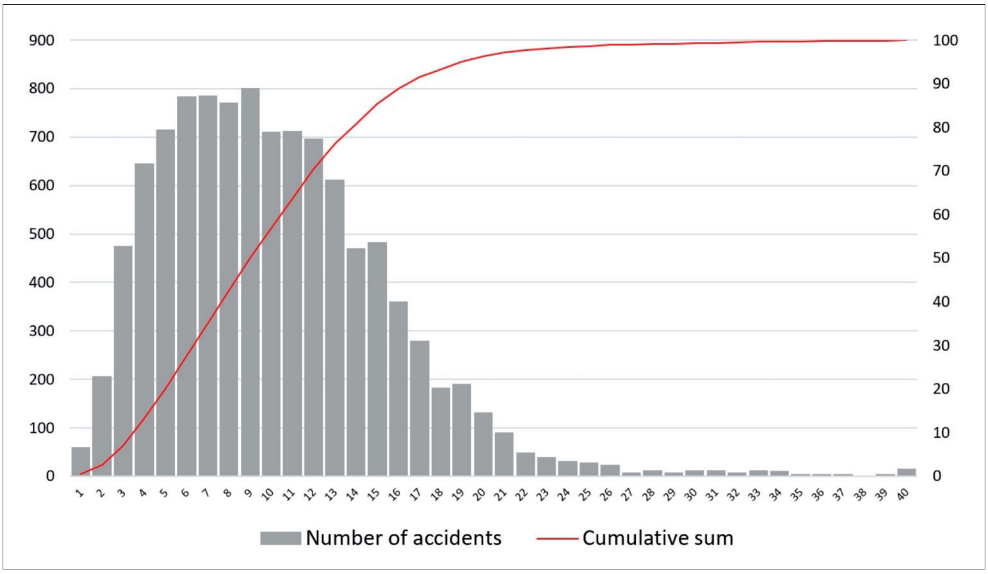

Fig. 3: Number of accidents according to the accessibility from nearest EMS
Source: authors' calculations based on data from www.policie.cz and Emergency Medical Services Act (374/2011 Coll.)

Severity/Minutes	0–10 minutes	11–20 minutes	21–30 minutes	More than 30 minutes
Death	119	102	10	4
Serious injury	579	518	48	12
Minor injury	4,054	2,759	216	53
No injury	1,205	742	31	8

Tab. 3: Statistical dependence of motorcycle accident severity on EMS accessibility
Note: The combinations marked in green show that there are fewer cases than there should be under independence. On the other hand, combinations marked in red show that there are more cases than there should be under independence.
Source: authors' calculations based on data from www.policie.cz and www.rsd.cz

This test shows that more serious injuries occur in cases with EMS availability of 11–20 minutes, while more cases with no injuries occur in cases when EMS availability is under 10 minutes. Furthermore, there are fewer cases of serious injuries with availability under 10 minutes and fewer cases of no injuries for 21–30 minutes. The mosaic exploratory plot further suggests that this trend already appears in the case of 10-minute availability but is more apparent for the 20-minute availability. Since the data for 20 and 30-minute availability are sparse, the difference is not proven, even though it is larger.

4.3 Road network hazard index

The synthetic Road network hazard index (RNHI) is a combination of these two approaches. Thus, on the one hand, it uses the identified probability of a motorcycle accident occurring in specific sections of the monitored network, but on the other hand, it operates with information on the time accessibility of the nearest EMS dispatch station for individual sections. This approach can therefore be seen as a synthetic approach to motorcycle accident risks and their spatial aspects. Based on the methodological approach described above, each road network section is assigned an RNHI value as a product of the motorcycle accident probability and the nearest EMS station's time accessibility expressed in terms of the financial insurance claim's mean value by accident type. The combination of both factors shows the actual risk for motorcycle users (see also Gutierrez-Osorio & Pedraza, 2020).

The results indicate that individual road network sections in the Czech Republic show significantly differentiated RNHI values. The sections with the highest RNHI values are those with a high motorcycle accident probability, which are also relatively far from EMS dispatch stations. This is further confirmed in Figure 4. The combination of the two chosen factors (accident rate and remoteness) is evident in the sections with the highest RNHI values. Again, these are generally road sections on lower-class roads (2nd and 3rd class roads) in rural areas, where the risk of an accident with a high temporal availability value from the nearest EMS station is evident.

The sections defined in this way reflect the risks of individual road sections for motorcycle traffic comprehensively. In general, the lowest RNHI values tend to be in urban areas, which are relatively safe in terms of possible motorcycle accidents. EMS vehicles' accessibility also tends to be very good there, which significantly increases the chance of patient survival in post-accident care (Hashtarkhani et al., 2020; Xiong et al., 2022).

Moreover, these characteristics are relatively evenly distributed across urban areas, as there are no significant differences between urban regions. The situation is very different in rural and remote areas of the Czech Republic (see Travis et al., 2012). Here, the RNHI values differ significantly. Especially in the eastern part of the Czech Republic, the RNHI values are relatively low. The rural areas in this region tend to be characterised by larger

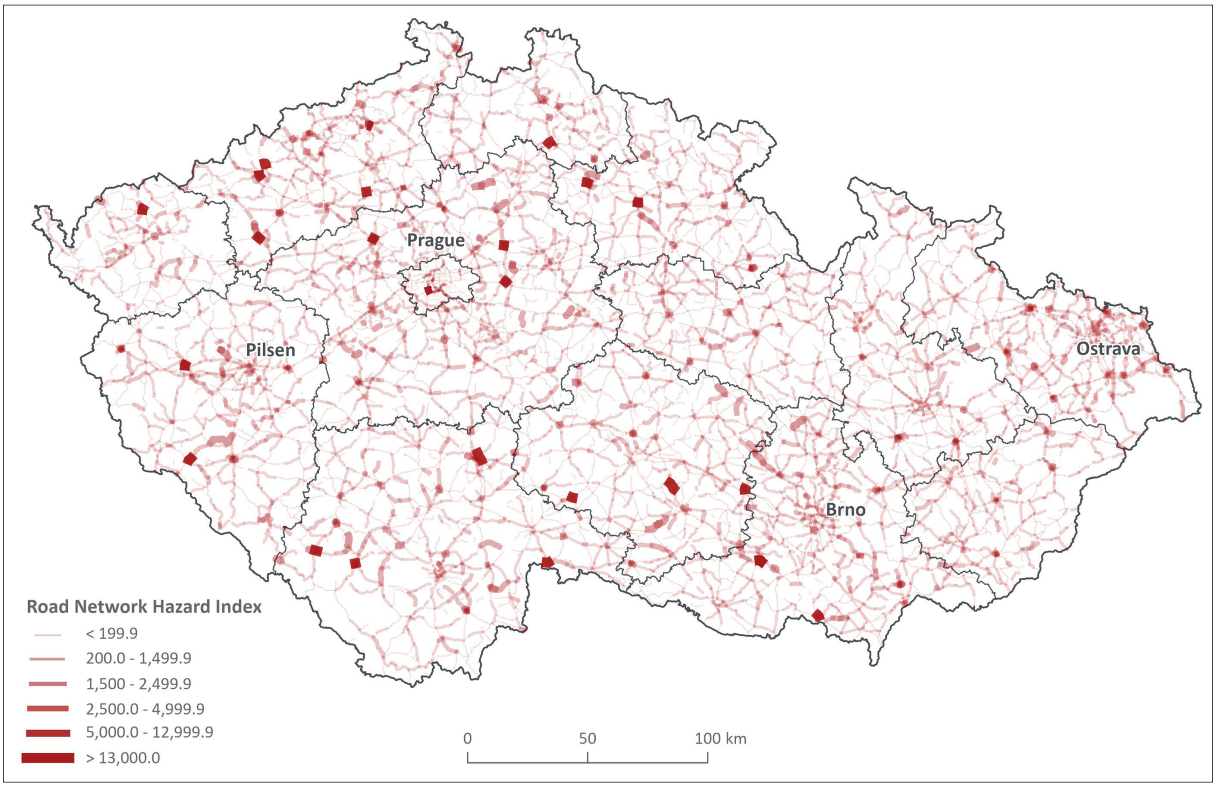

Fig. 4: Road network hazard index (RNHI) for individual road sections in the Czech Republic
Source: authors' elaboration based on data from www.policie.cz, www.rsd.cz and Emergency Medical Services Act (374/2011 Coll.)

rural settlements with very good service provision (including health services). On the other hand, the highest RNHI values are found in rural areas in the central and western half of the Czech Republic. These regions are characterised by lower population density, lower road density and dispersed settlements. The higher RNHI values is typical for so-called "inner peripheral areas" of the Czech Republic. These areas are located on the borders of autonomous administrative units (regions of the Czech Republic) with many negative socio-economic phenomena (see also Pileček et al., 2013 and Klapka et al., 2020). These negative socio-economic characteristics (low population density, low service provision, lower road network density, etc.) further negatively affect the risk level of road sections for motorcycle traffic.

5. Discussion and conclusions

Motorcycle safety is among the main priorities and challenges of many countries' transport policies. It is therefore evident that, in addition to a range of prevention and awareness-raising activities, it is also necessary to identify specific locations where motorcycle users are at risk. In this paper, we have used a synthetic approach to identify the road network sections dangerous for motorcycle traffic. We see the risk level of individual sections as a complex combination of the causes and consequences of motorcycle accidents (see also Xie et al., 2019). We have described the causes of accidents as an accumulation of various risk factors directly affecting motorcycle accident rates. Thus, we define the probability of a motorcycle accident based on accident accumulation in each section of the road network. The consequences of motorcycle accidents are monitored through accident severity and the accident locality accessibility for health service vehicles. The combination of both factors is then used to define the RNHI as a newly introduced indicator synthetically assessing the risk levels of individual road network sections for motorcycle traffic.

The results of our study have shown that the risk levels of individual road network sections for motorcycle traffic vary considerably. The most important results can therefore be summarised as follows:

- The motorcycle accident probability on the Czech road network is extremely differentiated. Its levels are influenced mainly by the road class along with other factors (unclear horizon, multiple sharp curves, poor visibility conditions, etc.). These sections are concentrated in less urbanised regions, especially in the south-western part of the Czech Republic;
- The time accessibility of accident locations from EMS dispatch stations shows a clear correlation with the severity of motorcycle crashes. An interval under 20 minutes shows significantly more favourable values for less severe injuries than intervals above 20 minutes, where the categories of severe injuries and fatalities caused by the accident are significantly more pronounced. Moreover, the model for the accident locations' accessibility indicates that the sparsely populated peripheral regions of the Czech Republic in particular show not only a higher motorcycle accident probability but also higher time accessibility values for emergency vehicles; and
- The newly introduced RNHI provides a comprehensive view of the risk levels for motorcycle traffic in different Czech road network sections. It confirms, among other things, that the highest risk level is characteristic for lower-class roads in areas further away from large population centres. In these regions, the negative factors caused by higher motorcycle accident probability and higher time accessibility values for emergency service vehicles from EMS dispatch stations, accumulate. Thus, in the case of sections with the highest RNHI values, there are multiple risks caused by the combination of both factors which influence motorcycle traffic safety negatively.

The results of the study are partly influenced by the fact that a model condition is used to determine the accessibility of the EMS dispatch stations. This condition occurs when there are no other incidents reported in the vicinity of the EMS station and the emergency vehicle crew is ready to depart immediately. It is often the case, however, that the crew is not at the station, for example, due to responding to another reported incident (see Enayati et al., 2018). In such a case, the second closest crew is called (often from another dispatch station), which increases the time required for transport to the accident locality and back. This information could become more accurate by gathering actual data on the medical service vehicles' movement (GPS records), but these are currently unavailable for the Czech Republic in general.

The main results of this study could become a useful resource to implement effective measures within the Czech Republic's transport policy. In this context, we would like to point out that motorcycle transport is, with few exceptions, not included in transport policies and does not receive as much attention as other transport modes (Pinch & Reimer, 2012). The results of this study could therefore have obvious practical applications, such as introducing specialised navigation applications designed for motorcyclists or installing traffic signs notifying motorcyclists of the risk levels on certain road network sections.

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Availability of data and material

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