

10. Kapski, D. V. Nekotorye aspekty primeneniya sredstv personal'noj (individual'noj) mobil'nosti: in 2 vol. / D. V. Kapski, E. N. Kot // Avto-traktorostroenie i avtomobil'nyj transport : Sbornik nauchnyh trudov Mezhdunarodnoj nauchno-prakticheskoj konferencii. In 2 vol., Minsk, 25–28 maja 2021 goda. – Minsk : BNTU, 2021. Vol. 2. – P. 160–165.

11. Narbut, A. Transport zdorov'ja // Modelist-konstruktor / A. Narbut . – 1984. – № 11. – P. 3–4.

12. Organizacija velosipednogo dvizhenija v gorodah / I. N. Pugachev [et al.] ; pod obshej redakciej D. V. Kapskogo. – Habarovsk : Tihookeanskij gosudarstvennyj universitet, 2020. – 227 p.

UDK 656

KHODOSKIN Dmitriy P., Ph. D. in Eng.,  
Ass. Prof.,  
E-mail: dlya\_moih\_studentov@mail.ru

ATAMANENKO Anton S.,  
Undergraduate Student,  
E-mail: dlya\_moih\_studentov@mail.ru

Belarusian State University of Transport, Gomel, Republic of Belarus

*Received 10 October 2024*

## **ANALYSIS OF FOREIGN EXPERIENCE IN REDUCING THE NUMBER OF ACCIDENTS AT REGULATED INTERSECTIONS WITH VULNERABLE ROAD USERS**

*Pedestrians and cyclists are the most vulnerable road users, especially in urban areas – this is largely due to their high traffic intensity during morning and evening rush hours, as well as significant differences between these users and vehicles. These differences are related to both the degree of protection and speed characteristics. Comparison of these factors largely explains the increased number of injured and killed in accidents involving vulnerable road users. Therefore, the movement of these users should be “separated” from the movement of vehicles both by separating them in space and in time. Separation in space is based on the use of appropriate technical means that respectively separate the “zones” of their movement (barriers of various designs, etc.), and separation in time is based on the use of traffic light regulation, namely, for example, the organization of a separate pedestrian phase in the structure of the regulation cycle. This article is devoted to the consideration of the application of such approaches abroad (with the identification of the specific share of the reduction in the number of road accidents when they are applied).*

**Keywords:** road accident, vulnerable participants, pedestrians, pedestrian crossings, safety islands, road markings.

### **Introduction**

Every year, more than 270 000 pedestrians are killed on the world's roads. Worldwide, pedestrians account for approximately 22 % of all road traffic fatalities, and in some countries, up to two-thirds of these deaths. In addition, millions of pedestrians are injured and disabled in road traffic accidents. These situations cause great suffering and grief, and even result in both

economic hardship for families and heavy losses of all kinds for nations [1]. Although many countries have made significant improvements in road safety in recent decades, further improvements in safety are becoming increasingly difficult. Overall, the ability to improve pedestrian safety is a key component of efforts to prevent road traffic injuries. Pedestrian collisions, like other types of road traffic accidents, should not be con-

sidered a necessary evil. Because the collisions are, in fact, predictable and preventable. The main risks to pedestrians are well known and include many factors. Driver behavior is primarily associated with speeding and drunk driving. The level of development of pedestrian infrastructure, taking into account the absence of sidewalks, intersections and overhead boundaries, and the design of the vehicle – the presence of a rigid front part that does not cushion the force of the impact when hitting a pedestrian [2].

Reducing or eliminating risk factors affecting pedestrians is an important and achievable goal of any policy, including ours. Pedestrian safety measures improve pedestrian spaces and contribute to the regeneration of the urban environment, the development of local economies, social cohesion, improved air quality and the reduction of negative impacts of road noise. The implementation of measures to improve pedestrian safety requires increased attention and informed decision-making by governments, industry, non-governmental organizations and international organizations.

### Main part

Improving the conditions of motor transport in modern cities requires the use of a whole range of architectural, planning and technical measures. While the implementation of road, architectural and planning measures requires, in addition to significant capital investments, a fairly long period of time, measures to organize road traffic can provide a quick effect, and in some cases act as the only means of solving transport problems. Below, we will consider some of the indicated measures in more detail using examples.

*Reducing accidents at pedestrian crossings using artificial structures. Safety islands.* Safety islands (fig. 1) are small buffer zones for pedestrians in the middle of the roadway, marked out with markings and built in the form of a platform. Such structures are good for many reasons. Firstly, they allow people to cross the road in stages: cross one side, stop in a special place, make sure it is safe to cross, and then calmly continue crossing. Secondly, such islands attract the attention of drivers and narrow the roadway, forcing motorists to reduce speed to avoid hitting the curb.

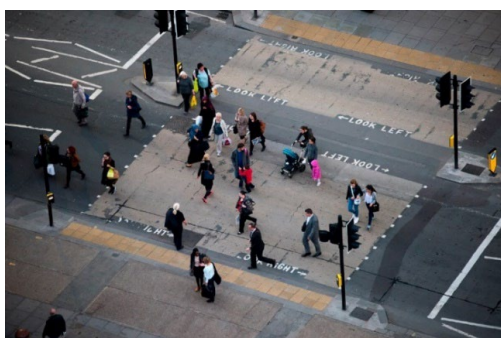


Figure 1 – Pedestrian crossing with a safety island in London [2]

Obviously, such islands are especially needed to “divide” wide streets, but, oddly enough, in some cities they are even installed on two-lane streets (fig. 2). If you think about it, there is logic here too. For example, a pedestrian often decides to cross the road when there is a traffic jam on the first lane. At the same time, the parked cars block the person’s view of the oncoming lane, which may not be congested. As a result, a person risks simply not noticing a car moving in the oncoming lane.

The safety island also reduces the turning radius of cars – which forces drivers to slow down (fig. 3).

Some widening of the sidewalk in the area of the pedestrian crossing also has a positive effect on safety: the zebra crossing itself becomes narrower (i. e. people have to cover a shorter distance), and conditions are created for drivers that force them to be more attentive and reduce their speed (fig. 4).



Figure 2 – Pedestrian crossing with a safety island in the UK [2]

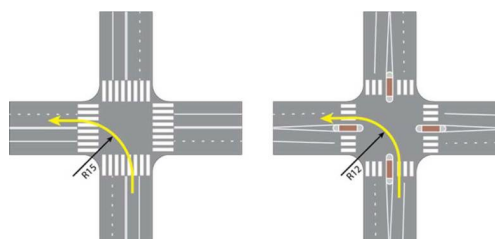


Figure 3 – Pedestrian crossing with a safety island [3]

*Pedestrian barriers.* Statistics show that on streets with modern barriers, the number of accidents with pedestrian injuries is 24 % lower. Pedestrian barriers should be installed in places with active traffic of vehicles and pedestrians, in places where cars are parked near supermarkets, factories, warehouses, etc. [4]. Correct installation of pedestrian barriers separates the movement of pedestrians (including cyclists) from the movement of various types of vehicles (fig. 5). Installed barriers direct pedestrian traffic to nearby intersections with excellent visibility of the road and the absence of potential obstacles on it. In addition, pedestrian barriers eliminate the possibility of parking cars on sidewalks (fig. 6).



Figure 4 – Intersection with widened sidewalks and safety islands in London [3]

*Reducing accidents at pedestrian crossings using various types of road markings.* Luminescent road markings (fig. 7). Luminescent markings in Nantes (France) help drivers to recognize them better at night (including at a greater distance) [5].

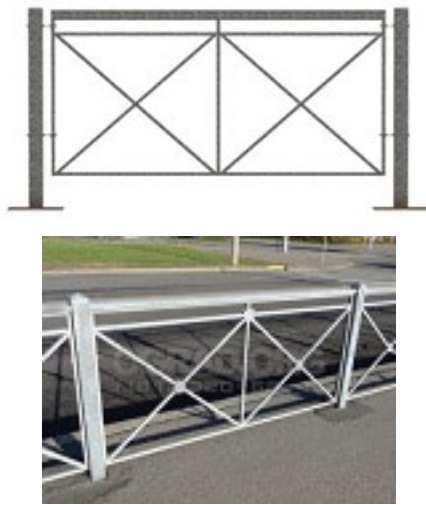


Figure 5 – Pedestrian barriers [4]



Figure 6 – Pedestrian barriers in London [4]

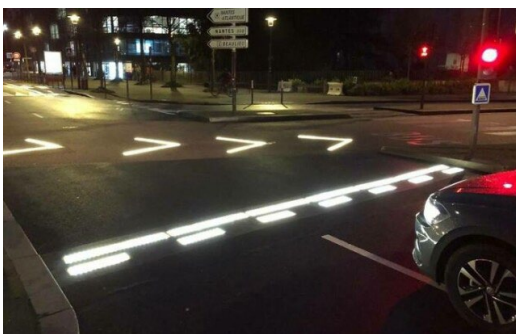


Figure 7 – Luminous road markings in France [5]

*Longitudinal and transverse noise markings* (fig. 8). In many European countries, longitudinal noise (vibrating) markings are widely used, which warn the driver of the approach or crossing of a dangerous section. They are used on motorways (or before the first intersections in cities) to notify drivers of an unintentional departure of a car from the lane. They help drivers to keep to the lane and reduce the risk of conflict situations.

This method of organizing traffic serves to attract additional attention of drivers in places on roads (streets) near pedestrian crossings, forcing them to slow down when approaching a crossing with the corresponding road markings.



Figure 8 – Installation of noise strips before a pedestrian crossing [6]

Noise strips are often placed not only before pedestrian crossings, their application is also effective in places before dangerous, accident zones. The main task of the noise strip is to wake up sleepy drivers or attract the attention of distracted ones [7].

*Projection road markings on pedestrian crossings.* Projection road markings have begun to appear on pedestrian crossings in Moscow and other cities, which illuminate a section of the road at night. LED projectors with color filters create a bright light corridor on the road, thanks to which drivers can see pedestrians on a poorly lit roadway at a sufficient distance to take the necessary actions. To do this, stands with LED projectors are installed above the roadway near the pedestrian crossing. A lighted crossing is created that “duplicates” the zebra crossing and illuminates the person, making him more visible. Thus, the driver sees the pedestrian and the markings at a distance of 100–150 m, even if there are puddles or snow on the road. Such markings can be useful at pedestrian crossings where there is an increased number of accidents. Or in places where additional caution is required – on the streets, for example, near schools (fig. 9).



Figure 9 – Projection road markings on pedestrian crossings [8]

*Reducing accidents at pedestrian crossings by separating traffic and pedestrian flows in time.* Often, at regulated pedestrian crossings, pedestrians cross the road simultaneously with moving (turning) vehicles. In this case, conditionally acceptable conflicts arise between turning vehicles and pedestrians. That is, there is a risk of an accident involving turning vehicles and pedestrians. In this case, organizing a separate pedestrian phase reduces the number of such conflict situations, and as a consequence – accidents. In addition, it becomes possible to organize a diagonal pedestrian crossing, where pedestrians have an additional opportunity to cross the intersection diagonally. However, this increases the duration of the pedestrian phase due to the increase in the length of the pedestrian crossing, but at the same time this solution increases the convenience for pedestrians crossing diagonally. In Germany, diagonal pedestrian crossings are equipped with additional pedestrian traffic lights and diagonal road markings (fig. 10).



Figure 10 – Intersection with a separate pedestrian phase in Germany [9]

The three-phase traffic light mode for providing a separate pedestrian phase increases the waiting time for a green light for both vehicles and pedestrians. Traffic safety in this case also depends on pedestrians observing the prohibiting traffic light signal, i. e. with a long wait for a green light, there is a high risk of an accident when a pedestrian crosses the roadway on a red light. However, as practice shows, this measure is very effective, especially at intersections with high pedestrian traffic intensity. A separate pedestrian phase in most cases allows for a higher level of road safety for pedestrians compared to the standard regulation scheme. According to observations, after the introduction of a separate pedestrian phase, several months are required for pedestrians to adapt to the new conditions.

In case of high traffic intensity at the intersection, separate pedestrian phases may be arranged only as a last resort to reduce accidents with vulnerable road users (after using all other measures in the standard traffic light scheme). When choosing a traffic light regulation program, in addition to other implemented measures, statistics on accidents involving pedestrians and turning vehicles for at least the last 3 years must be taken into account.

Thus, in order to reduce the number of conflicts, and accordingly, accidents, involving pedestrians and turning vehicles, separate pedestrian phases can be a very effective measure. However, it is necessary to carefully adhere to the conditions (during design and installation), under which pedestrians will not enter the roadway at a red light.

### Conclusion

Thus, the most effective measures aimed at improving the traffic safety of vulnerable participants, with a brief description, are given in table 1.

Table 1 – Measures aimed at improving the traffic safety of vulnerable road users

| № | Name                              | Description   | Country             | Efficiency                                      |
|---|-----------------------------------|---|---------------------|---|
| 1 | Safety islands                    | Allow pedestrians to cross the roadway in stages: cross one side, stop in a special place, make sure it is safe to cross, and then calmly finish crossing, also attract the attention of drivers and narrow the roadway, forcing motorists to slow down | UK, Germany, Poland | Reduction in pedestrian accidents by 45 %       |
| 2 | Pedestrian barriers               | Separate pedestrians and cyclists, including from large vehicles, direct pedestrians to nearby intersections with excellent visibility and without potential obstructions   | United Kingdom      | Reduction in pedestrian accidents by 24 %       |
| 3 | Isolation of the pedestrian phase | Allows complete elimination of conflict between vehicles and pedestrians, thereby minimizing the likelihood of accidents  | Germany, France     | Reduction of accidents with pedestrians by 87 % |

The above-mentioned measures, the implementation of which yields positive results in increasing the level of safety for pedestrians, are no less useful for other road users (except for vulnerable ones) [2]:

– the installation of median strips at different levels with the roadway on streets with multi-lane traffic reduces the number of accidents not only involving pedestrians, but also head-on collisions of vehicles (when driving into the oncoming traffic lane);

– the installation of acceleration and deceleration lanes reduces the number of accidents involving pedestrians moving along the shoulder, as well as the number of accidents involving vehicles whose drivers lost control or collided with stationary objects;

– the use of a separate phase for vehicles turning left at regulated intersections, which reduces the number of accidents – both involving pedestrians and involving vehicles moving in the transit direction, etc.

## References

1. Pedestrian Safety : [website]. – URL: [https://apps.who.int/iris/bitstream/handle/10665/79753/9789244505359\\_rus.pdf?sequence=10](https://apps.who.int/iris/bitstream/handle/10665/79753/9789244505359_rus.pdf?sequence=10) (access date: 22.04.2024).

2. Pedestrian crossings for people (and how they are made in other countries) : [website]. – URL: <https://dzen.ru/a/YRU3X5Rdqa8aOvb> (access date: 22.04.2024).

3. How to make city roads safe for pedestrians? European experience : [website]. – URL: <https://euro-pulse.ru/eurotrend/kak-sdelat-gorodskie-dorogi-bezopasnyimi-dlya-peshehoda-opyit-evropyi/> (access date: 22.04.2024).

4. Pedestrian crossings arrangement : [website]. URL: <https://www.kb-spectech.ru/projects8.html>. – (access date: 22.04.2024).

5. Berlin pillow :[website]. – URL: <https://zen.ati.su/news/2020/12/24/berlinskie-ati.su/news/2020/12/24/berlinskie-podushki-lezhachie-politsejskie-kotoryenestrashny-dalnobojshikam-805237/> (access date: 22.04.2024).

6. Kapski, D. V. Implementation of the methodology for improving road safety in urban accident hotspots / D. V. Kapski, A. I. Ryabchinskiy. – Minsk : BNTU, 2013. – 8 p.

7. Ideas that make traffic on roads safe and convenient, which have been implemented in different countries : [website]. – URL: <https://bugaga.ru/interesting/1146785920-krutye-idei-delajuschie-dvizhenie-na-dorogah-be-zopasnym-i-udobnym.html> (access date: 22.04.2024).

8. Methods for reducing collisions with pedestrians in the urban environment : [website]. – URL: [metody\\_snizheniya\\_naezdov\\_peshehodov\\_gorodskoy\\_](https://metody_snizheniya_naezdov_peshehodov_gorodskoy/) (access date: 22.04.2024).

9. Advanced stop line : [website]. – URL: <https://alex-maisky.livejournal.com/10221.html> (access date: 25.04.2024).

10. Kapski, D. V. Prediction of Accident Rate in Road Traffic: monograph / D. V. Kapski // Minsk : BNTU, 2008. – 243 p. + incl.

11. Kapski, D. V. The method of the conflict zones forecasting road traffic accident rate by potential danger: a monograph / D. V. Kapski // Moscow: New Knowledge, 2015. – 372 p.

12. Kapski, D. V. Methodology of improving the quality of road traffic traffic / D. V. Kapski // Minsk : BNTU, 2018. – 372 p.

ХОДОСКИН Д. П., канд. техн. наук,  
доцент,  
E-mail: dlya\_moih\_studentov@mail.ru

АТАМАНЕНКО А. С.,  
магистрант  
E-mail: dlya\_moih\_studentov@mail.ru

## **АНАЛИЗ ЗАРУБЕЖНОГО ОПЫТА ПО СНИЖЕНИЮ ЧИСЛА ДТП НА РЕГУЛИРУЕМЫХ ПЕРЕКРЕСТКАХ С УЯЗВИМЫМИ УЧАСТНИКАМИ ДОРОЖНОГО ДВИЖЕНИЯ**

Белорусский государственный университет транспорта, Гомель, Республика Беларусь

Поступила в редакцию 20.09.2024

*Пешеходы и велосипедисты являются наиболее уязвимыми участниками дорожного движения, особенно при движении в условиях города – это в большей степени связано с их высокой интенсивностью движения в утренний и вечерний часы-пик, а также с существенными различиями между этими участниками и транспортными средствами. Эти различия связаны как со степенью защищенности, так и со скоростными характеристиками. Сравнение указанных факторов в большей степени и объясняет повышенное число раненых и погибших в ДТП с участием уязвимых участников движения. Поэтому движение этих участников должно быть «отделено» от движения транспортных средств как с помощью разделения их в пространстве, так и во времени. Разделение в пространстве основывается на применении соответствующих технических средств, соответственно разделяющих «зоны» их движения (ограждений различной конструкции и т. п.), а разделение во времени – на применении светофорного регулирования, а именно, к примеру, организации отдельной пешеходной фазы в структуре цикла регулирования. Данная статья посвящена рассмотрению применения таких подходов за рубежом (с выявлением конкретной доли снижения числа ДТП при их применении).*

**Ключевые слова:** дорожно-транспортное происшествие, уязвимые участники, пешеходы, пешеходные переходы, островки безопасности, дорожная разметка.

### **Литература**

1. Безопасность пешеходов : [сайт]. – URL: [https://apps.who.int/iris/bitstream/handle/10665/79753/9789244505359\\_rus.pdf?sequence=10](https://apps.who.int/iris/bitstream/handle/10665/79753/9789244505359_rus.pdf?sequence=10). – (дата обращения: 22.04.2024).

2. Пешеходные переходы для людей (и как их делают в других странах) : [сайт]. – URL: <https://dzen.ru/a/YRU3X5Rdqa8aOvb>. (дата обращения: 22.04.2024).

3. Как сделать городские дороги безопасными для пешехода? Опыт Европы : [сайт]. – URL: <https://euro-pulse.ru/eurotrend/kak-sdelat-gorodskie-dorogi-bezopasny-imi-dlya-peshehoda-opyit-evropyi/> (дата обращения: 22.04.2024).

4. Обустройство пешеходных переходов : [сайт]. – URL: <https://www.kb-spectech.ru/projects8.html> (дата обращения: 22.04.2024).

5. Берлинская подушка : [сайт]. – URL: <https://zen.ati.su/news/2020/12/24/berlinskie-podushki-lezhachie-politsej-skiekotoryenestrashny-dalnobojschikam-805237> ( дата обращения: 22.04.2024).

6. Капский, Д. В. Внедрение методологии повышения безопасности дорожного движения в городских очагах аварийности / Д. В. Капский, А. И. Рябчинский. – Минск: БНТУ, 2013. – 8 с.

7. Идеи, делающие движение на дорогах безопасным и удобным, которые реализованы в разных странах : [сайт]. – URL: <https://bugaga.ru/interesting/1146785920-krutye-idei-delajuschie-dvizhenie-na-dorogah-bezopasnym-i-udobnym.html> (дата обращения: 22.04.2024).

8. Методы снижения наездов на пешеходов в городской среде : [сайт]. – URL: metody\_snizheniya\_paezdov\_peshehodov\_gorodskoy\_ (дата обращения: 22.04.2024).

9. Advanced stop line : [сайт]. – URL: <https://alex-maisky.livejournal.com/10221.html> (дата доступа: 25.04.2024).

10. Капский, Д. В. Прогнозирование аварийности в дорожном движении : монография / Д. В. Капский // Минск : БНТУ, 2008. – 243 с.

11. Капский, Д. В. Метод конфликтных зон прогнозирование дорожно-транспортной аварийности по потенциальной опасности: монография / Д. В. Капский // М. : Новое знание, 2015. – 372 с.

12. Капский, Д. В. Методология повышения качества дорожного движения/ Д. В. Капский // Минск : БНТУ, 2018. – 372 с.

УДК 625.76.08

БЕЛЕНИНИК А. И.,  
аспирант,  
E-mail: [gra\\_atf@bntu.by](mailto:gra_atf@bntu.by)

КЛОКОВ Д. В. канд. техн. наук, доц.,  
доц. каф. «Гидропневмоавтоматика и гидропневмопривод»  
E-mail: [klokkoff\\_dm@mail.ru](mailto:klokkoff_dm@mail.ru)

ЗАХАРОВ А. В., канд. техн. наук, доц.,  
зав. каф. «Гидропневмоавтоматика и гидропневмопривод»  
E-mail: [gra\\_atf@bntu.by](mailto:gra_atf@bntu.by)

ЕРМИЛОВ С. В.,  
ст. преп. каф. «Гидропневмоавтоматика и гидропневмопривод»  
E-mail: [ermilov.tut@gmail.com](mailto:ermilov.tut@gmail.com)

Белорусский национальный технический университет, г. Минск, Республика Беларусь

Поступила в редакцию 20.09.2024

## **МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ГИДРООБЪЕМНОГО РУЛЕВОГО УПРАВЛЕНИЯ УНИВЕРСАЛЬНОЙ МОБИЛЬНОЙ МАШИНЫ**

*В статье рассматривается подход к математическому моделированию гидрообъемного рулевого управления (ГОРУ) универсальной мобильной машины. Анализируются принципы работы ГОРУ, с акцентом на его два основных компонента: механическую и гидравлическую части. В работе приводится математическое описание, охватывающее управление колесами машины и их углы поворота, которые определяют устойчивость и маневренность. Разработанная математическая модель позволяет рассчитывать зависимости между углами поворота правого и левого колеса. Выведенные дифференциальные уравнения, описывают динамику и взаимодействие основных компонентов. Уравнения учитывают влияние различных факторов, включая вязкость рабочей жидкости, сопротивление трубопроводов и эластичность шин, что позволяет точно спрогнозировать поведение машины. Важной особенностью является интеграция об-*