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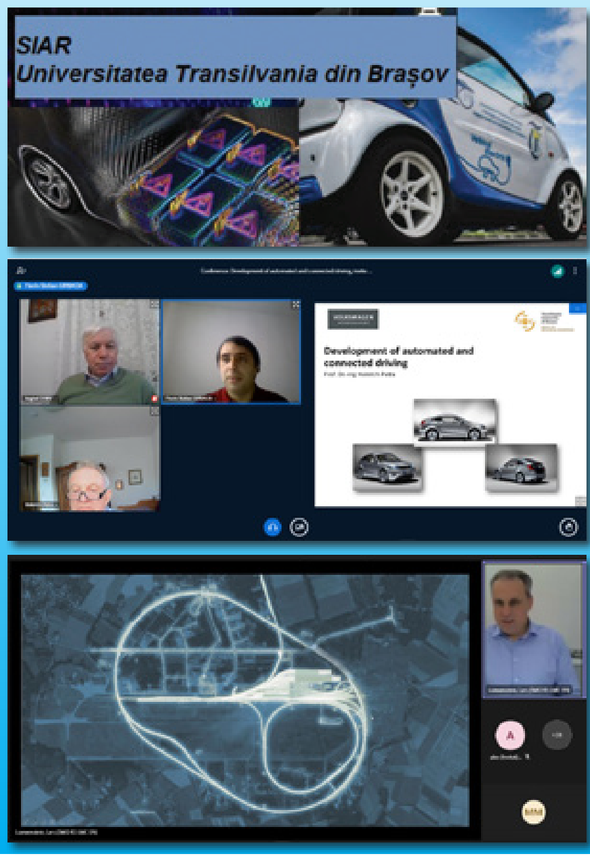



- Riscuri de vătămare a ocupanților în trei scenarii de coliziune dintre două autovehicule
- Utilizarea scanării 3D în inspecția pieselor de caroserie a autovehiculelor
- Vizibilitatea pe timp de noapte a pietonilor
- Republica Moldova: analiza accidentelor rutiere pe durata a două decenii

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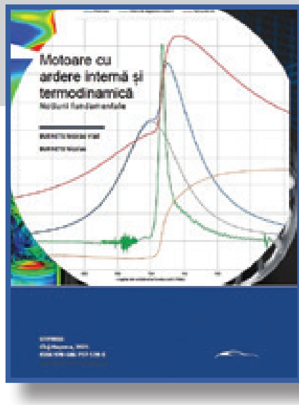
APARE TRIMESTRIAL
QUARTERLY

## MOTOARE CU ARDERE INTERNĂ ȘI TERMODINAMICĂ. NOȚIUNI FUNDAMENTALE

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În această lucrare autorii prezintă într-o manieră detaliată și atrăgătoare noțiunile teoretice fundamentale specifice domeniului motoarelor cu ardere internă și termodinamicii. Lucrarea este destinată studenților programelor de studii de licență „Autovehicule rutiere” și „Ingineria transporturilor și a traficului”, „Mașini și instalații pentru agricultură și industria alimentară” „Sisteme și echipamente termice”, precum și master („Automobilul și mediul”, „Sisteme de management și control ale autovehiculelor”, „Tehnici avansate în ingineria autovehiculelor”), fiind de fapt utilă tuturor studenților din universitățile tehnice care studiază cursul de „Motoare cu ardere internă”, cât și specialiștilor care lucrează în cercetare.
Lucrarea cuprinde un capitol de notații și abrevieri, un dicționar, două anexe, o listă bibliografică și este organizată pe următoarele capitole:

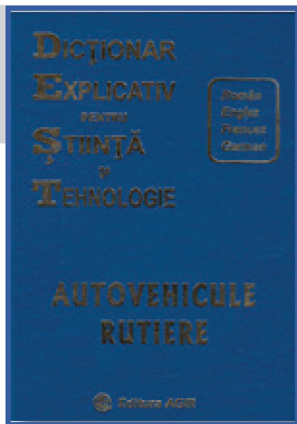
***1. Noțiuni introductive. Parametrii constructivi ai MAI***
*Cinematica mecanismului motor; Noțiuni privind formarea amestecului aer-combustibil; Parametrii funcționali ai MAI; Randamentul MAI; Consumul specific de combustibil; Regimurile de funcționare a motorului; Sarcina motorului; Indicii de competitivitate ai MAI*

***2. Noțiuni de termodinamica MAI***
*Noțiuni de bază de termodinamică (Sistem, mărimi de stare și mărimi de proces; Forme de energie și schimb de energie; Agenți de lucru; Transformările de stare ale agenților de lucru; Entalpia și ecuațiile calorice de stare; Legea (principiul) conservării masei pentru sistemele deschise; Forme ale bilanțului masic; Legile (principiile) termodinamicii; Entropia; Randamentul termodinamic); Aplicarea legilor (principiilor) termodinamicii la MAI; Fenomene de curgere (Curgere cu aport de energie; Ecuația de curgere); Ciclurile teoretice ale motoarelor cu ardere internă (Ciclul Otto (ardere la volum constant); Ciclul Diesel (ardere la presiune constantă); Ciclul Seiliger (cu ardere mixtă/cu presiune limitată); Ciclul Atkinson (comprimare parțială și destindere prelungită); Ciclul Miller (comprimare parțială și destindere prelungită); Schimbul de gaze; Performanțele ciclurilor teoretice; Comparația ciclurilor teoretice); Procesele motorului ideal;*

***3. Procesul de ardere al MAI***
*Calculul procesului de ardere (Puterea calorică; Formarea amestecului; Temperatura flăcării adiabatice); Termodinamică de echilibru (Starea de echilibru; Entalpia (energia) liberă Gibbs; Potențialul chimic); Noțiuni de cinetică chimică (Reacții globale și reacții elementare; Viteze elementare de reacție; Vitezele de reacție ale mecanismelor în mai multe trepte; Viteza de reacție și starea de echilibru; Mecanisme de reacție); Elemente de ardere a combustibililor în MAI (Limitele de aprindere; Compoziția gazelor de ardere (ardere ideală sau teoretică); Variația molară; Disocierea; Aprinderea polistadială a hidrocarburilor; Aprinderea polistadială a hidrocarburilor)*

***4. Simularea zero-dimensională a motorului cu ardere internă***
*Modele de simulare; Modele unizonale (Modelarea energiei interne; Modelarea procesului de ardere; Utilizarea modelelor de ardere; Căldura netă; Modelarea pierderilor de căldură prin pereți; Modelarea lucrului mecanic de dilatare; Modelarea fluxurilor de entalpie); Modele cu două zone; Modele multizonă; Metoda umplerii și golirii; Modelarea frecărilor; Analiza curbei de presiune și calculul ciclului motor.*

## DICŢIONAR EXPLICATIV PENTRU ŞTIINŢĂ ŞI TEHNOLOGIE. AUTOVEHICULE RUTIERE




Autori (*Authors*): **Gheorghe FRĂŢILĂ, Cristian ANDREESCU, Cornel VLADU, Raluca MOISESCU, Cornelia STAN, Marius TOMA, Gabriel CRISTEA**
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Dicţionarul de faţă reuneşte şi completează termenii publicaţi în volumele I şi II ale Dicţionarului Explicativ pentru TRANSPORTURI – Autovehicule Rutiere, apărute în anii 2006 şi respectiv 2009, în seria DICŢIONARE EXPLICATIVE pentru ŞTIINŢĂ şi TEHNOLOGIE, coordonată de regretatul acad. Gleb Drăgan. El se referă la terminologia domeniului AUTOVEHICULELOR RUTIERE şi este realizat pe baza fondului terminologic standardizat pe plan mondial.
Având la obârşie construcţia simplă a unei trăsături cu motor, automobilul a evoluat spectaculos pe parcursul unui secol, devenind un sistem complex la realizarea căruia contribuie specialist din multe domenii: mecanică, electronica, hidraulică, ştiinţa materialelor, optică, automatizări şi prelucrarea informaţiei, design şi altele. Acestora li se adaugă un mare număr de oameni implicaţi în activităţi conexe realizării automobilului propriu-zis, activităţi care au căpătat dimensiunile unor adevărate „industrii”: comercializare, mentenanţă, asigurări, organizarea traficului şi transportului rutier, definirea regulamentelor tehnice privind automobilul şi urmărirea respectării lor etc. În aceste condiţii, fondul de termini cuprinşi într-un dicţionar explicativ referitor la domeniul autovehiculelor rutiere ar trebui să ajungă la dimensiuni apreciabile –după unii specialişti, până la 15.000-16.000. Întrucât, aşa cum s-a arătat mai sus, prezenta lucrare se încadrează într-o serie de dicţionare elaborate pe diferite domenii, s-a considerat că pentru evitarea unor suprapuneri, să fie prezentaţi termenii specifici autovehiculelor rutiere, iar dintre cei aparţinând ştiinţelor fundamentale (matematică, fizică, chimie ş.a.) sau celor tehnice generale (rezistenţa materialelor, organe de maşini, electrotehnică, electronică, termotehnică, informatică ş.a.) să fie abordaţi doar cei mai importanţi şi intim legaţi de ingineria autovehiculelor.
Forma în limba română, termeni şi definiţii, au rezultat în urma consultării unui număr larg de factori tehnico-economici, de cultură şi educaţie apropiaţi domeniului, prin anchetă publică.
Autorii au dedicat realizarea lor promotorului învăţământului superior de autovehicule rutiere din ţara noastră, profesorul universitar inginer Constantin Ghiulai şi memoriei academicianului Gleb Drăgan, iniţiatorul secţiei DICŢIONARE EXPLICATIVE pentru ŞTIINŢĂ si TEHNOLOGIE.

*Lucrările prezentate fac parte din fondul bibliografic al Centrului de documentare al SIAR.*

# A FI SAU NU, DE NOTA 5!

# TO BE OR NOT TO BE... AN UNDERTRAINED PROFESSIONAL!

Nu rareori am impresia că, cel puţin la nivelul societăţii noastre, trăim sub imperiul *legii* „Las' că merge şi-aşa!" sau, pe jumătate apoteotic, „Românul este genial, se descurcă oricând! Găseşte el o soluţie mulţumitoare indiferent de situaţia în care ar fi"!

Cu toate acestea, pretutindeni auzim nemulţumirea exprimată deseori exotic, majoritatea celor „intervievaţi" în „sondaje imparţiale-neutre" sperând la o îmbunătăţire spectaculoasă, dacă este posibil „instantanee", a veniturilor, a nivelului de dezvoltare, a nivelului de trai etc.

Privim în jurul nostru şi ne întrebăm de ce lucrurile nu merg aşa cum am dori! Sau, cam aşa ne exprimăm! Ne întrebăm, nemulţumiţi, nedumeriţi, dezamăgiţi... de ce autorităţile şi concetăţenii nu acţionează spre binele comun, „fericirea deplină"... considerând inacceptabilă acţiunea/atitudinea lor în cele mai multe cazuri!

Dacă ar fi să ne întrebăm un prieten, coleg, vecin... dacă împărtăşeşte o asemenea impresie, vom primi aproape sigur un răspuns afirmativ (de cele mai multe ori argumentat diferit). Argumentarea diferită poate să conducă rapid chiar şi la disoluţia unor amiabile conexiuni.

Aşadar, s-ar putea observa o stare acută de aşteptare a intervenţiei „providenţiale" (indiferent de camuflajul adoptat „primărie, minister, guvern, stat ...") pentru rezolvarea nevoilor legate de viaţa de zi cu zi, a escapadelor de sfârşit de săptămână, a concediilor etc.

Astfel, în opinia mea, se scapă din vedere rolul individului în mecanismului social.

Rolul unei furnici „neînsemnate" în muşuroi.

Sunt aproape sigur că tinerii mei colegi nu au discutat/dezbătut (într-un cadru adecvat) teme de genul „rolul personalităţii în istorie"! Poate că astfel ar fi fost puse în discuţie/dezbatere moştenirea culturală/istorică a unor diverse personaje istorice: Cezar (dreptul roman), Napoleon (codul civil)...

Dacă ar exista dezbateri de această natură, am putea observa (poate) că fiecare dintre noi are viaţa lui, rostul lui, aportul lui la mersul (înainte) al societăţii noastre!

Fie că suntem sau nu Cezar sau Napoleon sau...

Fie că suntem sau nu conştienţi de asta!

Dar...

Zi de zi, asemenea tuturor, putem observa în jurul nostru distorsiuni... grave...

Exemple (trăite personal):

1. Vancouver, intersecţia dintre North Road şi Cameron Street; o echipă de muncitori restricţionează circulaţia – aspect semnalizat în stradă prin panouri perfect vizibile cu o săptămână în urmă – apoi, în interval de 3 ore, instalează sub asfalt senzori de prezenţă a autovehiculelor în scopul optimizării funcţionării semafoarelor – cu refacerea stării normale a căii de rulare;

2. Bucureşti, Calea Griviţei (sub aşa-zis-ul Pod al Constanţei), pe o stradă cu o linie de tramvai şi o cale de rulare nemarcată pe care încap – zi de zi – cu chiu cu vai – două autoturisme – găsim câteva panouri limitatoare care zac în stradă cu rolul de a limita mai mult decât o cale de rulare de trei săptămâni! Stau mai mult de trei săptămâni! Vă puteţi imagina, sub un pod, ca într-un tunel, într-un spaţiu limitat, un obstacol aşezat pe o cale de rulare, cu rolul de a permite refacerea modului de fixare a unui capac de canal din sistemul de canalizare al municipiului Bucureşti! Trei săptămâni! Nici după trei săptămâni lucrarea nu a fost finalizată şi panourile îndepărtate! Nu-i aşa? Merge şi aşa! Cui îi pasă? Primarului? Directorului care răspunde de administrarea căilor de rulare în Bucureşti? Şefului de serviciu? Şefului de birou? Şefului de „bulevard"? „Inginerului" (specialist – sic!) care a scris hârtiile? NIMĂNUI NU ÎI PASĂ! NIMĂNUI NU ÎI PASĂ! MERGE ŞI AŞA! Incompetenţa e la ea acasă! Şi nimeni nu pune întrebări! Şi nimeni nu răspunde pentru asta! Şi aşa, în toată România!

Evident, majoritatea participanţilor la trafic sunt nemulţumiţi, unii chiar înjură... Cu atât rămân!

Şi atunci te întrebi! Cum este posibil! Cum se poate întâmpla aşa ceva? Da!

Se poate pune o asemenea întrebare dacă eşti afectat direct! Dacă nu te afectează, este ok! Dar, „vrei o ţară, ca afară!" De cele mai multe ori! Deşi, în opinia mea, nu se înţelege mare lucru din asta! Amintiţi-vă ce a spus un Preşedinte al SUA! „Nu te întreba ce face America pentru tine, întreabă-te ce faci TU pentru America!"

Aşadar, „specialişti" (probabil ingineri din domeniul traficului rutier, transporturilor etc.) au formulat în cadrul Primăriei Bucureşti astfel de cerinţe de executare a contractelor de „modernizare", „viabilizare", „reabilitare" etc... a unei importante magistrale din Bucureşti! Te întrebi ce a fost în mintea lor!

Şi atunci, vrând-nevrând, îmi vin în minte (excepţional) gânduri care m-au frământat (recunosc) ani la rând!

Cum ne găsim locul în ierarhia profesiei noastre? Cine suntem, unde suntem!

Din punctul meu de vedere, inginerul din Vancouver merita nota 10, în vreme ce inginerul din Bucureşti „merită" nota 4! De fapt, în opinia mea nu este inginer! Doar un impostor! Chiar iresponsabil! Precum toţi cei de pe lângă el, implicaţi în... cum să îi zic?

Şi atunci, ne putem pune o întrebare! Ce este nota 5? Nota 5 atribuită într-un examen! Într-un examen profesional! Un profesor şi studentul său!

*Continuare la pagina 18*

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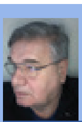
# EVALUAREA POTENȚIALULUI DE VĂTĂMARE A OCUPANȚILOR ÎN CAZURILE A TREI SCENARII DIFERITE DE COLIZIUNE DINTRE UN AUTOTURISM ȘI UN AUTOCAMION

# ASSESSING POTENTIAL CARS OCCUPANT'S INJURIES IN THREE DIFFERENT COLLISION SCENARIOS BETWEEN A CAR AND A TRUCK

**REZUMAT:** *Coliziunile dintre autoturisme și vehicule comerciale (camioane) sunt frecvente. Atunci când astfel de coliziuni au loc la viteze relativ medii spre mari, acestea au un efect semnificativ asupra potențialelor leziuni ale ocupanților. Având în vedere diferențele de masă (și cel mai adesea și viteză) dintre vehiculele implicate în astfel de coliziuni, magnitudinea leziunilor este semnificativ mai mare în ocupanții mașinii. Diferențe semnificative în ceea ce privește amploarea vătămărilor apar, de asemenea, din cauza rigidităților complet diferite ale zonelor afectate în cazul coliziunilor dintre autoturisme și camioane. Această lucrare își propune să evalueze gravitatea potențialelor vătămări ale ocupanților autovehiculelor prin determinarea experimentală a parametrilor specifici de coliziune, luând în considerare trei scenarii de impact diferite între un autoturism și un autocamion.*

***Key-words:*** *traffic, accidents, fatalities, experimental results*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## 1. INTRODUCTION

Traffic accidents remain or the significant cause of mortality in Romania despite preventive measures to increase road safety [1]. An important class of collisions, with a high potential for serious injuries to occupants, is that of two vehicles with large differences in mechanical momentum (large differences in mass and / or speed). Collisions of the truck type (commercial vehicle of class N2) car falls very well in this category.

The comparison between the number of fatal accidents registered in 2019 compared to 2010, in Europe (figure 1) [1], although it indicates a decrease, still keeps Romania on the first place of this gloomy European ranking.

Fatalities in road traffic accidents are associated with very high values that act on the occupants of vehicles involved in collisions, as are those of the car-truck type produced at medium and high speeds [2]. This type of collision studied in three distinct scenarios in this scientific paper is important because it highlights the consequence of acceleration pulse on potential serious injuries to potential occupants [3].

The paper's experimental results were obtained by support of DSD, Dr. Steffan Datentechnik GmbH - Linz, Austria in "Easter 2018 PC-Crash Seminar", using the same instrumentation as that described in [4]. The experimental research described below was organized according to three distinct scenarios, detailed in three experimental tests, which resulted in a large volume of experimental data. The severity of the injuries and the possibilities of avoiding the collision relative to each scenario can be better estimated considering the collision in each scenario as occurring in a cross – intersection [5].

## 2. EXPERIMENTAL RESULTS AND DISCUSSIONS

The numerical results obtained in three distinct collision scenarios were measured and taken over:

Collision between the moving truck, with a speed of 60 km/h, with the stationary car. Collision in the front axle area, on the right side, of the car (figure 2);

Front-rear collision with the stationary truck and the moving car with a speed of 70.8 km/h (figure 3);

Collision between the moving car with a speed of 90.6 km / h and the

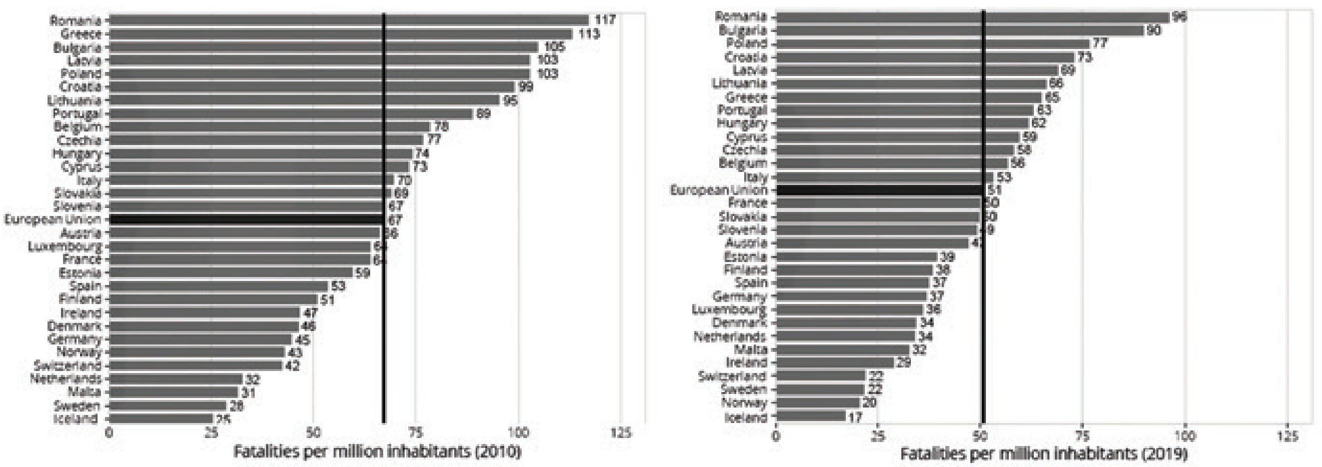
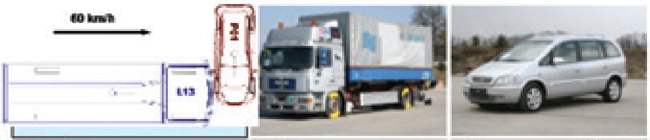



Fig. 1. Fatalities per million inhabitants in the EU, 2019 compared to 2010

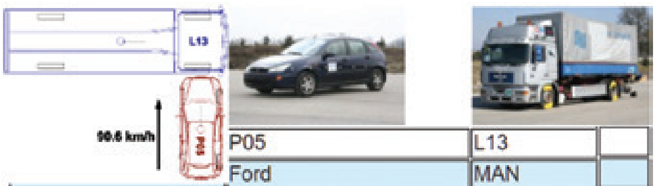



| | | | |
|---|---|---|---|
| Label | L13 | P01 | |
| Make | MAN | Opel | |
| Model | 19.403 FLLC | Zafira-A | |
| Year | 1997 | 1999 | |
| Velocity | 60.0 | 0 | km/h |
| Weight | 10754 | 1333 | kg |
| Length | 9.6 | 4.32 | m |
| Width | 2.5 | 1.74 | m |
| Height | 3.6 | 1.68 | m |
| Wheelbase | 5.5 | 2.69 | m |
| Trackwidth | 2.04 | 1.48 | m |
| Axle load front | 5400 | 771 | kg |
| Axle load rear | 5354 | 562 | kg |
| Dist. COG to front axle | 2.74 | 1.14 | m |

Fig. 2. First collision scenario with truck in movement


| | | | |
|---|---|---|---|
| Label | P02 | L13 | |
| Make | Opel | MAN | |
| Model | Zafira-A | 19.403 FLLC | |
| Year | 2000 | 1997 | |
| Velocity | 70.8 | 0 | km/h |
| Weight | 1395 | 10754 | kg |
| Length | 4.32 | 9.6 | m |
| Width | 1.74 | 2.5 | m |
| Height | 1.68 | 3.6 | m |
| Wheelbase | 2.69 | 5.5 | m |
| Trackwidth | 1.48 | 2.04 | m |
| Axle load front | 811 | 5400 | kg |
| Axle load rear | 584 | 5354 | kg |
| Dist. COG to front axle | 1.13 | 2.74 | m |

Fig. 3. Second collision scenario




| | | | |
|---|---|---|---|
| | P05 | L13 | |
| | Ford | MAN | |
| Model | Focus Ambiente 1.8 TDDI | 19.403 FLLC | |
| Year | 2000 | 1997 | |
| Velocity | 90.6 | 0 | km/h |
| Weight | 1214 | 10754 | kg |
| Length | 4.15 | 9.6 | m |
| Width | 1.70 | 2.5 | m |
| Height | 1.44 | 3.6 | m |
| Wheelbase | 2.62 | 5.5 | m |
| Trackwidth | 1.50 | 2.04 | m |
| Axle load front | 775 | 5400 | kg |
| Axle load rear | 439 | 5354 | kg |
| Dist. COG to front axle | 0.95 | 2.74 | m |

Fig. 4. Third collision scenario

stationary truck, at the front axle of the truck and in its right-side area (figure 4).

To measure the physical parameters of the collisions in the three scenarios we used the coordinate system in figure 5.

In figures 2, 3 and 4, for each collision scenario, the main characteristics of the vehicles involved were presented (besides the impact sketch - in the upper left corner).

For the first and third impact scenario, the angular velocities of the car involved were also represented, considering that the characteristic variation of the angular velocity can determine risk values of the angular acceleration pulse with the potential to influence the occupants' injuries [6]. The accelerations and angular velocities of the vehicles represented in Figures 6 -13 were determined in the centers of gravity of the respective vehicles. In order to be able to evaluate the risks of injury of the occupants, the hypothesis was used that the same variations of the accelerations and

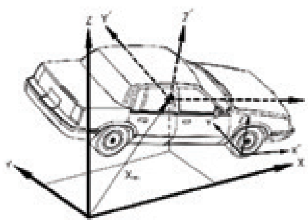


Fig. 5. The coordinate system for the car (truck) used to measure the physical parameters in the three scenarios

angular velocities would have been registered in the centers of gravity of the respective potential occupants.

## 3. CONCLUSION

Road accidents still remain major causes of mortality in Romania in terms of the increase of the national car park and their relative renewal.

Truck-car accidents are possible generators of serious injuries to occupants, especially due to the large differences in the mechanical impulse that occur in such collisions. The results obtained by the experimental research, in three distinct scenarios, of the car-truck collision are presented in this scientific paper.

The three distinct collision scenarios from which numerical data, images, movies, high speed movies were purchased were: Collision between the moving truck, with a speed of 60 km/h, with the stationary car. Collision in the front axle area, on the right side, of the car; Front-rear collision with the stationary truck and the moving car with a speed of 70.8 km/h; Collision between the moving car with a speed of 90.6 km / h and the stationary truck, at the front axle of the truck and in its right-side area.

In order to highlight favorable factors but also the possibilities of avoiding the situations described in the three collision scenarios, we considered the first and third scenario possible to happen in cross-intersection, after entering the intersection, and the situation in the second scenario. as being similar to the moments from entering a cross-intersection [5].

Modern technologies for point cloud generation for vehicles both before and after the collision were used in the measurements and processing carried out in the three collision scenarios. These numerical visual representations allow the exact numerical determination of the dimensions of the deformations of the vehicles involved in the impact and the degree to

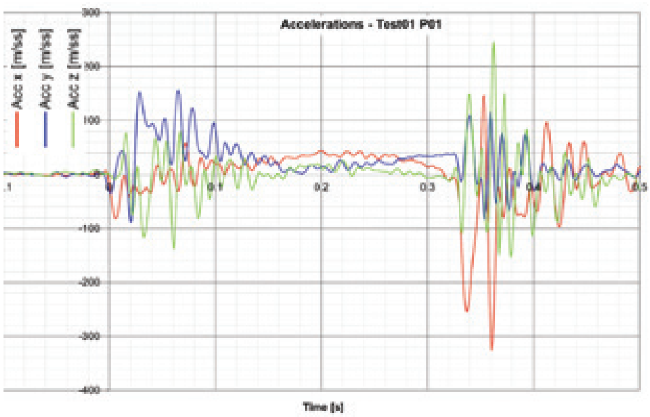



Fig. 6. Car acceleration in the first test scenario

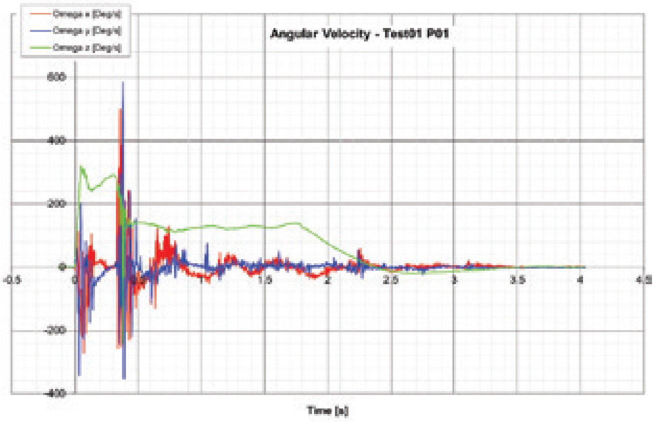



Fig. 7. Car angular velocity in the first test scenario

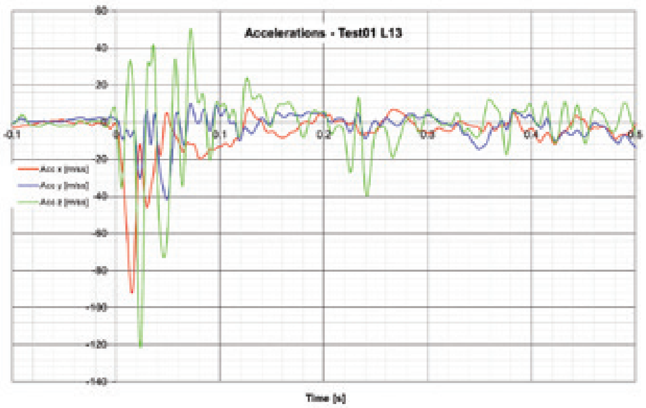



Fig. 8. Truck acceleration in the first test scenario

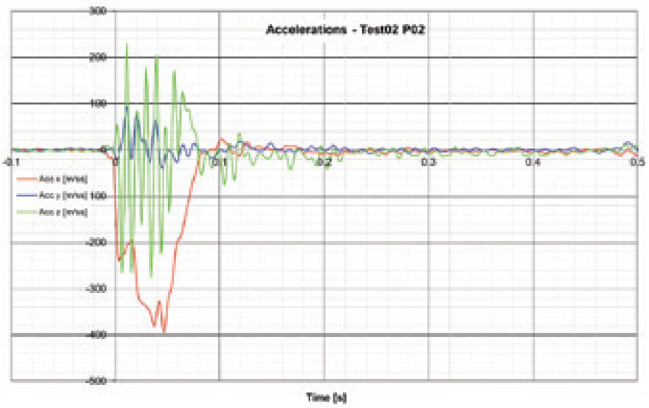



Fig. 9. Car acceleration in the second test scenario

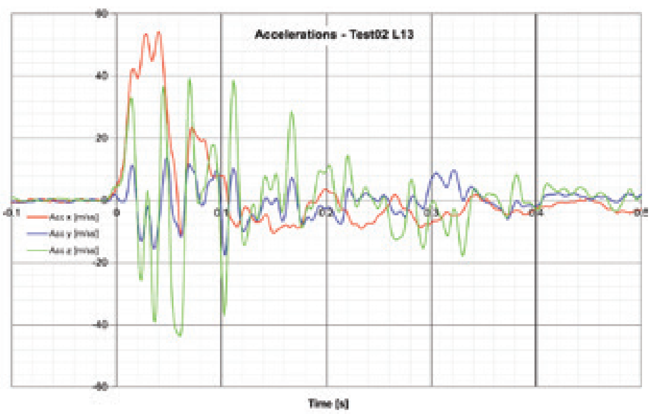



Fig. 10. Truck acceleration in the second test scenario

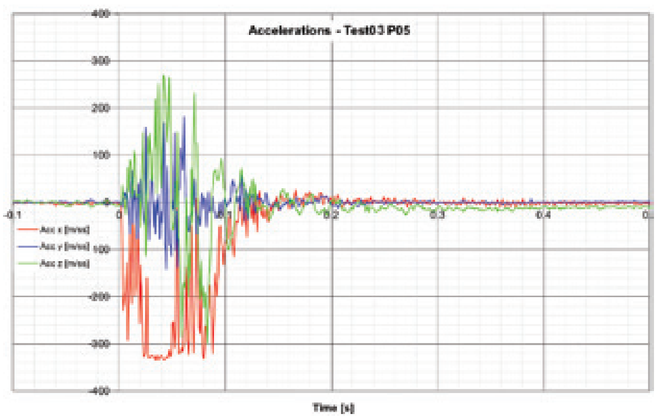



Fig. 11. Car acceleration in the third test scenario

which the bodies of the potential occupants can come into contact with the deformed areas of the vehicles. Figures 14 and 15 show examples of point cloud for car involved in the first collision scenario and truck involved in the third collision scenario.

Each point in the point cloud is associated with a set of three coordinates (x, y, x) that allow the exact

determination of the spatial position of each point of vehicles involves, the determination of distances and angles usable in road traffic accident analysis and reconstruction software (such as PC Crash, for example) [7]

Regarding the assessment of the potential for injuring the occupants, for each of the three collision scenario tests presented in the paper we formulated the following conclusions:

In the first collision scenario, the acceleration of the car on X direction reaching an absolute maximum value of 325 m/s$^2$ in the second part of the collision. The component in the Y direction of acceleration reaches a maximum value of 160 m/s$^2$ in the first part of the collision. The duration of the acceleration pulse in this direction is about 0.1 s, having a potentially dangerous severity of injury; For the component on the Z direction of the acceleration, an absolute maximum value of 250 m/s$^2$ was registered, but also a series of acceleration pulses stretched over 0.15 s with an increased risk of injury potential. Acceleration pulses in the X direction from the moment 0.35 s until the moment 0.5 s can be considered the

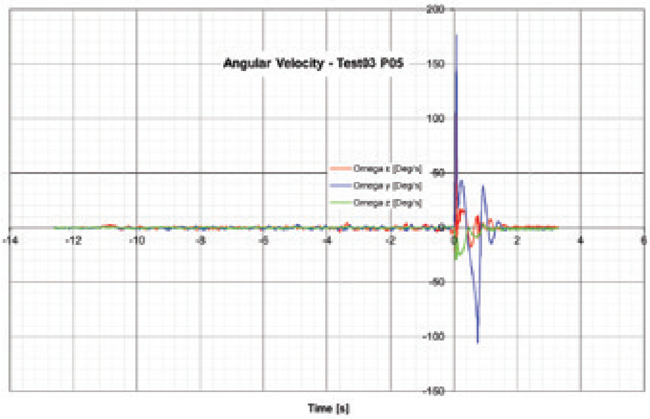



Fig. 12. Car angular velocity in the third test scenario

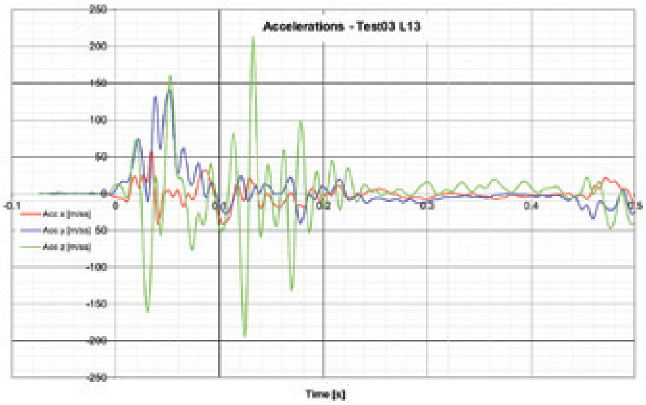



Fig. 13. Truck acceleration in the third test scenario

Fig. 14. Car point cloud after first scenario collision

Fig. 15. Truck point cloud after third scenario collision

most dangerous for the integrity of the car occupants;

In the first scenario test, the recorded angular velocities (especially the X-axis component) generate the largest / most dangerous angular accelerations of all three scenario tests. They are dangerous for the integrity of the occupant's brain [7];

Also in the first scenario test, the acceleration on the Z direction of the center of gravity of the truck reaches an absolute maximum value of 120 m/s$^2$ registering a succession of acceleration pulse for a duration of 0,2 s;

In the second test scenario, the highest absolute accelerations were registered at the level of the car's center of gravity: 400 m / s2 component in the X direction, 230 m / s2 in the Z direction and 100 m / s2 in the Y direction. Initial acceleration pulse it is dangerous for the occupants;

In the second scenario, at the level of the center of gravity of the truck, the following absolute maximum values for acceleration were registered: 56 m/s for component X, 12 m/s$^2$ for component Y and 44 m/s$^2$ for component Z;

In the third scenario test, the following absolute maximum values of the car's acceleration were recorded: 324 m/s$^2$ for component X, 267 m/s$^2$ for component Z and 180 m / s2 for component Y. The initial acceleration pulse with a duration of 0,2 s is very dangerous for occupant's integrity;

In the third scenario, the angular speed of the car reached the maximum value of 175 grd/s;

In the third scenario test, the values of the absolute maximum accelerations at the center of gravity of the truck were: 54 m/s$^2$ for component X, 143 m/s$^2$ for component Y and 221 m/s$^2$ for component Z. The initial acceleration pulse with duration of about 0.3 s is dangerous.

**Acknowledgment**

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# UTILIZAREA SCANĂRII 3D ÎN INSPECȚIA PIESELOR DE CAROSERIE A AUTOVEHICULELOR

# APPLICATION OF 3D SCANNING IN INSPECTION OF THE AUTOMOTIVE BODY PARTS

**REZUMAT:** *Scanarea 3D este o tehnologie emergentă pentru controlul calității dimensionale, datorită capacităților sale de a furniza informații geometrice ale pieselor complexe sau asamblate. Pentru industria auto, caracterizată prin astfel de tipuri de piese, această tehnologie oferă si posibilitatea de măsurare și inspecție, complet automatizate, a pieselor,. Această lucrare prezintă un ciclu de evaluare a acurateței dimensionale a unei piese de tablă obținută prin hidroformare, folosind procesele de digitizare prin scanare laser și fabricare. Dispozitivul folosit pentru digitizare este GOM Atos Core, utilizat în etapele de dezvoltare, control al calității și producție a pieselor de caroserie. Ciclul propus constă în scanarea suprafeței matriței după prelucrare și evaluarea preciziei acesteia, hidroformarea piesei, scanarea piesei hidroformate și evaluarea acurateței acesteia. Abaterile piesei hidroformate, care includ și abaterile matriței, vor fi utilizate pentru îmbunătățirea preciziei suprafeței matriței, impunând eventual o nouă prelucrare. Ciclul poate fi reluat până când precizia piesei va corespunde cerințelor de proiectare. Precizia piesei studiate în acest caz, după un ciclu, nu a depășit toleranțele pentru piesele din tablă utilizate în industria auto.*

**Key-words:** *3D scanning, automotive body parts, quality inspection*


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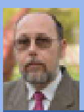
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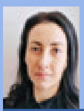
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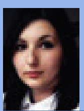
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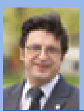
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## 1. INTRODUCTION

In the automobile industry, the control methods, and techniques, along with quality assurance, present particular interest by the economically outcomes particularly through lowering lead time, increasing profits, satisfying customers or lower-level challenges linked to the automotive production processes [1]. Two crucial aspects of quality assurance are output product quality and process performance [2]. Output product quality refers to the geometrical accuracy related to dimensions, shape, and material characteristics because of production process. Achieving the desired output product quality, ensuring geometrical accuracy for successive assembly operations, reducing material scrap, assures the aesthetic outlook of the product, while achieving product safety standards and meeting customer quality thus demands influencing the market presence [2].

Process performance relates to the ability of the production process to permanently produce products with the desired quality without obstructions due to process - disturbed or varying the product-process conditions. In mass production, ensuring efficient process performance is critical, due to the high tool costs and related resource investments (e.g. energy, material, labor, machinery and robots). So, the problem of intelligent measurement and integrated dimensional control is needed to ensure the quality of the product or of the industrial manufacturing process [3].

The products' quality mainly will be discussed in the following.

Traditionally, the products' quality control in automotive industry is performed using manual methods of inspection and various statistical sampling procedures, which are generally time consuming, and require a precise activity [3]. Instead of these, 3D scanning is used to create a digital information of the geometry of a physical object (solid), process called digitization. „3D digitization" uses a contact or non-contact digitizing feeler to capture the objects' form and recreate them in a virtual workspace in a very dense network of points (X-Y-Z), in the form of 3D graphical representation. 3D dimensional control with contact is made using coordinate-measuring machines (CMM). Contactless methods are divided into two categories: optical and non-optical. Laser sensors and video-lasers used in the dimensional control technologies have been developed as an alternative to replace the feelers with contact, where physical contact is not possible, generally in the case of fine or gently finished surfaces, super-finished or with large asperities, and for those with sharp edges [3]. In both cases, data is collected in the form of „point cloud" and is typically post-processed in a network of small polygons (simple mode), which are called 3D polygonal network [4][7][8].

Optical 3D coordinate measuring machines capture detailed and easily interpretable quality information in a short measuring time. They provide fully automated full-field deviations between the actual 3D coordinates and the CAD data. As this measuring data contains all the object information, in addition to the surface deviations from the CAD, the software also automatically derives detailed information, such as GD&T, trimming or hole positions. GOM's measuring systems ensure the dimensional quality, in particular of sheet metal, casting and plastic products in the automotive, aerospace or consumer goods industries. They form the basis for the optimization of production and machine parameters as part of a value-added measuring procedure [5][10][11]. Within this paper, a method for assessing the dimensional accuracy of a sheet metal part, using the processes of digitizing and manufacturing is developed. After the introduction, the second section presents the manufacturing process of the hydroforming part by plastic deformation. The next section shows the general principles of 3D scanning. The fourth and fifth sections present the cycle methodology for 3D scanning and inspection of the die and respectively the 3D scanning and inspection of the hydroforming part methodology. The last section presents the paper's conclusions, emphasizing the importance of 3D scanning for automotive industry.

Fig. 1.a Die used for forming

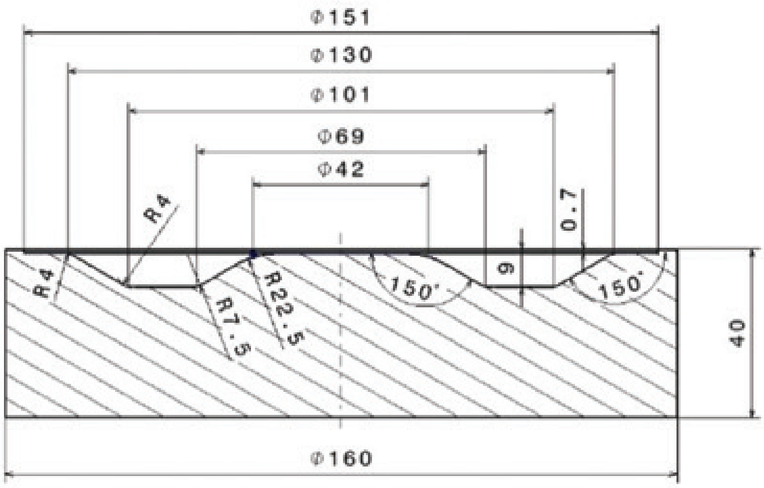


Fig. 1.b Dimensions of the die

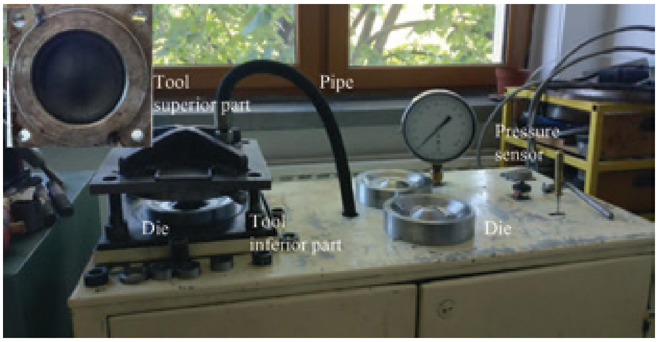


Fig. 2. Hydroforming press [9]

Fig. 3. Imagines of the hydroformed part

## 2. THE MANUFACTURING PROCESS OF THE HYDROFORMING PART

The manufacturing process used for obtaining the studied part is sheet hydroforming. Sheet hydroforming is a near net shape manufacturing process, which means that the parts it produces, using the fluid pressure, are close to the final specified geometry and require minimal rework. There are many sheet hydroforming components found in the automotive, including door panels, roofs and various structural frames. In our case, the manufacturing was performed on a die with the form and dimensions presented in figure 1.

The die is paced on the tool inferior part situated on a hydraulic press, figure 2, [9]. The fluid pressure is applied to the sheet with the help of an elastic rubber mounted on the tool superior part, as an uniformly distributed load, from top to bottom, on the outer surface of the blank. A pressure sensor indicates the value of the applied pressure.

The blank's material is aluminum alloy type 6061, with a diameter of 140 mm and a thickness of 1 mm. The applied pressure was 10 MPa. For determining the material properties, a traction test has to be done. The traction tests have been realized with Instron 352 testing machine. The test samples used had the calibrated dimensions of 120 x 20 x material thickness, in accordance with ISO 6892-1:2009. The average values of maximum tensile stress $R_m$ were 243 MPa for the considered thicknesses.

Figure 3 presents the images of the obtained hydroformed part. The forming part cavity consists of a succession of revolution surfaces; both stretching and compression are presented during the material deformation.

Table 1. The main characteristics of ATOS Core 3D Scanner [5]

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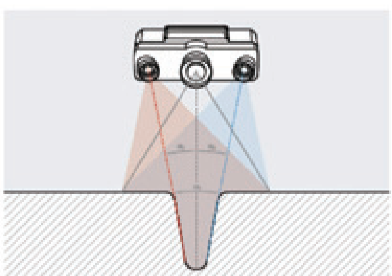
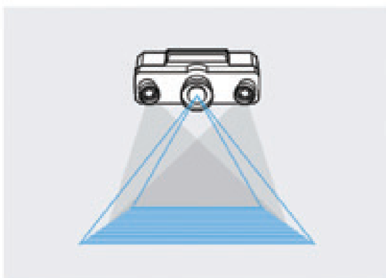
|---|---|---|
|  |  |  |
| Triple Scan Principle | Blue Light Technology | Self-Monitoring System |


Fig. 4. ATOS Core 3D Scanner Equipment [5]

## 3. 3D SCANNING PRINCIPLES

For the three-dimensional measurement of small components up to 200 mm in size, we used ATOS Core 3D Scanner, figure 4. It generates high-quality 3D data for applications such as reverse engineering and rapid prototyping in design, product development and enables efficient quality control in the production process [5].

The main characteristics of ATOS Core 3D Scanner are presented in table 1. According to the Triple Scan Principle, precise fringe patterns are projected onto the surface of the object and are recorded by two cameras and the projector unit. The positions of the 3D surface points from three different ray intersections can be calculated.

Blue Light Technology is based on a narrower wavelength which helps enable better filtering of interference from ambient light. As a result, short measuring times can be achieved, which offer better precision, accuracy, and higher quality outputs.

ATOS Core 3D Scanner has a Self-Monitoring System, which can recognize changing ambient conditions during operation and can compensate these changes, including part movements.

The measuring sequence is comprised of the following stages:

1. The sensor head is freely positioned in front of the object to be scanned.
2. The sensor projects fringes onto the measuring object.
3. The measuring process is captured by two cameras and will result in the 3D coordinates of the camera image pixels.
4. To capture the object entirely, more scanning from different positions of the object is necessary.
5. Polygonization: The conversion of a point cloud into a polygon mesh can be done by running software that connects all the points to form a mesh of triangles (polygons), namely a triangulated point cloud model. Then, the polygonization process merges/overlaps scanned images into a mesh.
6. All the captured images are correlated to obtain the complete numerical model of the part as a triangulated point cloud model. The model thus obtained is saved as a STL (Solid to Layer) file to allow accessing it with GOM Inspect.
7. GOM Inspect software allows the user to align the scanned data to the CAD data which means to bring the points into the same Cartesian coordinate system. Then the comparisons between the two are used to carry out the inspection, using points, lines and surfaces. All the captured data points with their nearest neighboring point in the CAD data are compared

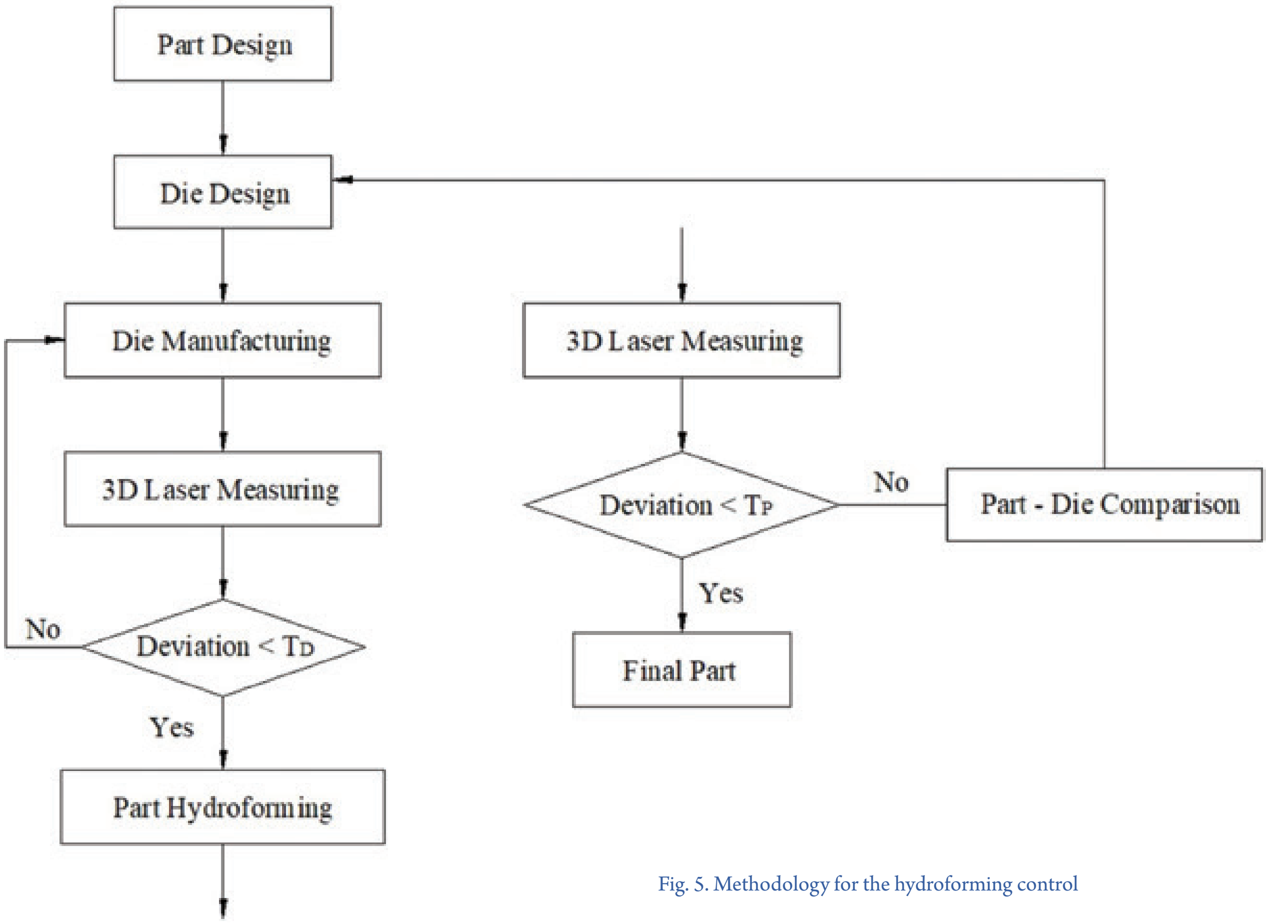



Fig. 5. Methodology for the hydroforming control

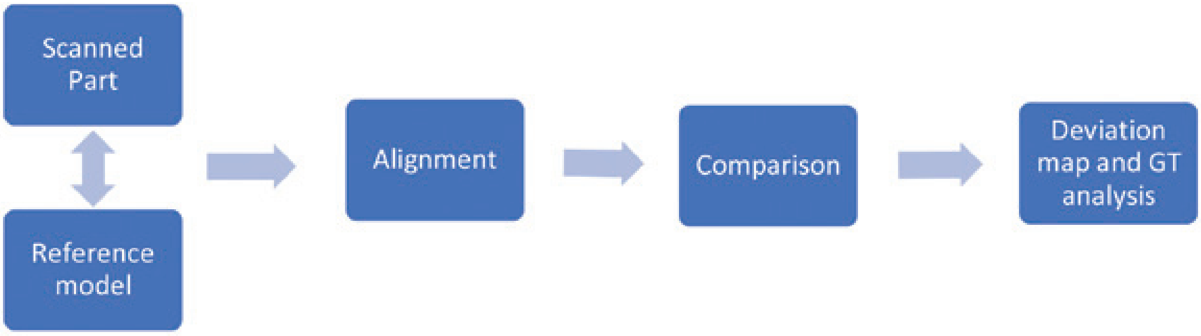



Fig. 6. Outline of the inspection process

and a displacement distance is calculated. This distance is then displayed in the form of a "color map", regions of varying color corresponding to different displacements, projected on the surface of the object [6]. In this way, the user can identify areas of the part that may need improvement [6].

## 4. 3D SCANNING AND INSPECTION OF THE FORMING DIE AND OF THE HYDROFORMED PART

In hydroforming, the accuracy of the die is very important. The blank comes into contact with the die surface, so each deviation of the die will lead to the deviation of the part.

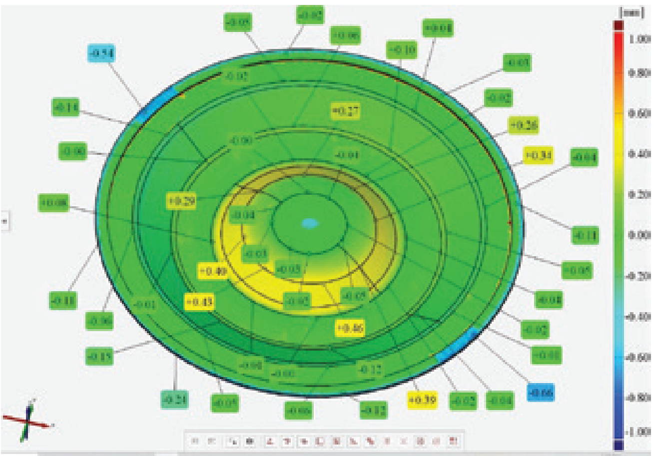


Fig. 7. Colourmap showing deviations of scanned die surface from CAD model

In the proposed methodology, figure 5, each step involved in the part manufacturing by hydroforming, is controlled using 3D laser measuring. After the die tolerances ($T_D$) will meet the requirements, the part will be deformed by hydroforming and, by 3D scanning, the part tolerances will be analysed. If these tolerances exceed the limits, then the comparison with the die tolerances is made. An automatic alignment assurance between the part and the die was made. The values which result from this comparison, depend only on the part springback, and will be used to modify the die design. The cycle is reloaded until the part tolerances are reached.

Practically, after die manufacturing, we will start with the 3D scanning of the die surface. For scanning, the die surface needs to be clean, then it was necessary to coat the surface with a powdered chalk in spray form. After that, reference points are put onto the part, for assembling the individual scans from various measuring positions. For this, after each scan, the rotation table, where the sample is placed, was rotated with an arbitrary angle, so that the camera's focus can obtain part views from different angles. We checked the mesh after each step, and we scanned additional steps, in order to obtain the complete part. The other steps to be carried out for 3D scanning follow the measuring sequences presented in chapter3.

The inspection process is outlined in figure 6. Before the comparative analysis, the compared objects have to be aligned one to another. After the alignment, the scan data and the reference model can be compared for deviations. The results of the comparative analysis are often displayed as colored 3D maps, green usually shows areas within tolerance, yellow indicates borderline areas and red depicts regions that are out of tolerance.

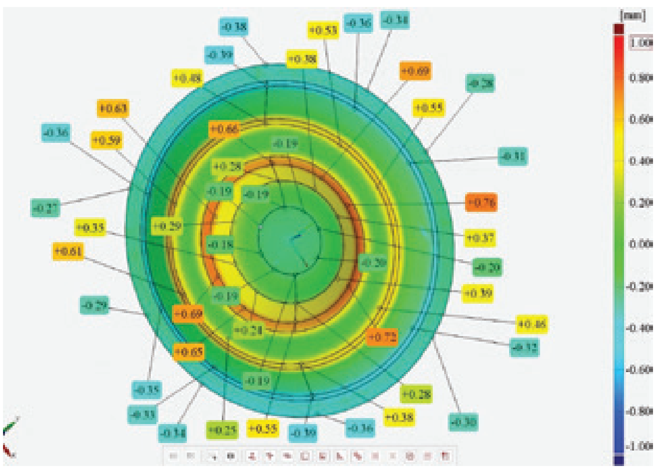


Fig. 8. Colourmap showing deviations of scanned hydroformed part surface from CAD model

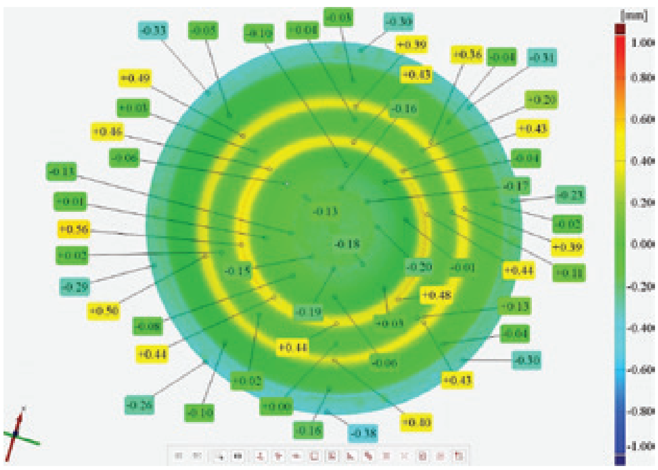


Fig. 9. Colourmap showing deviations between the scanned formed part surface and scanned die

At the end of the analysis, the inspection process provides automated reporting by graphical documents and tables.

The alignment operation aims at matching the two models, scanned part, and reference model. The alignment operation, also called registration, is of great importance in the contactless inspection process, because an inaccurate definition of the part reference frame can lead to incorrect evaluations of real part deviations. The alignment of a scanned 3D model to the reference one is carried out by computing the 3D rigid transformation to be applied to the first model to bring it into a common coordinate frame with the other [12].

A roto-translation matrix must be found and be applied to the first model to minimize its distance to the other. The selected point cloud is rotated and translated so that the mean square distance between its points and the ones of the reference point cloud is minimized or kept within a specified tolerance [12]. For the minimization different algorithms are used. The GOM software computes the transformation automatically without requiring any human interaction.

After registration, the two models can be compared for analysing the overall quality and deviations. The distance of individual homologous points is calculated and then displayed by 3D coloured deviation maps.

Figure 7 presents the result of the die inspection. Using a colormap, as seen in figure 7, it is easy to identify the deviations between the machined part and the CAD model. In figure 7, most of the surface aligns well with the CAD model. There does appear to be some deviations from the CAD model, the greater one belongs to the superior radius which correspond to the diameter of 42 mm. This is caused by the uncontrolled machining parameters. The die was obtained by turning on a conventional lathe. After machining, the surface was polished to obtain a surface quality of *Ra=0.8* μm. These deviations will affect the formed part quality in terms of accuracy.

In the second step of the proposed methodology, figure 5, the hydroformed part, obtained using the technology presented in chapter 2, was scanned following the same stages as above.

Figure 8 presents the result of the formed part inspection, in comparison with the CAD model. The results show that exists, also, deviations between the real object and the theoretical one. The bigger deviations appear in the areas of the radii at the base, *R*=4 mm and *R*= 7,5 mm where the part didn't make a full contact with the die, at the end of the deformation.

The forming part quality is affected by factors such as:

1. die accuracy – the smaller the accuracy, the higher the part errors. All the deviations of the die are included in the part accuracy.
2. material behaviour – the part accuracy is affected due to springback. The springback is the difference in shape between the actual contour of the die and the shape of the stamping produced in them. In comparison with the CAD model, the dimensions of the part are different.
3. process parameters – the rubber elastic properties of the pressure chamber are limited, so this limited, also, the material deformability, special in the areas of the radii at the base.

All these factors act together toward the formed part accuracy.

## 5. RESULTS AND CONCLUSIONS

The cycle of accuracy assessment consists of scanning the die to verify its compliance with the CAD model – hydroforming the part - scanning the hydroformed part and compare it with the CAD model - compare the surfaces of the hydroformed part and die for accuracy improvement. For this simple regular geometry of the part, only a cycle for the accuracy improvement was made.

The result of the final step, namely the comparison between the formed part and the die, as the third step in our proposed cycle, is presented by the colourmap in figure 9.

The accuracy of the formed part and the actual die is acceptable and corresponds to the values presented in [11, 13]. The deviations for the hydroformed part in comparison with CAD model, meet the limits provided by the Romanian standard [13], related to the precision of the profiled sheet metal parts, which belongs to the second class of precision. According to [13] for the thickness of 0.8 mm and the diameter of 140 mm, the limit deviations are ± 1.2 mm.

The quality of hydroformed part is affected due to the factors presented in chapter 4. As a result, it is complicated, without modern measurement techniques, to match the formed part with the die and with the CAD geometries. Using the proposed methodology, which combines manufacturing technologies and measurement techniques by laser scanning, this shortcoming is eliminated.

The case study was developed to exemplify the application of the 3D scanning in sheet metal forming. 3D scanning's ability to accurately monitor the die and the corresponding part it produces helps reduce design iterations, saving time and resulting in parts that more accurately match the CAD reference.

**Acknowledgement**

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# ASPECTE PRIVIND VIZIBILITATEA PE TIMP DE NOAPTE A PIETONILOR

# ASPECTS REGARDING THE NIGHT-TIME VISIBILITY OF PEDESTRIANS


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**REZUMAT:** *Această lucrare studiază diversele aspecte privind vizibilitatea pe timp de noapte a pietonilor. Obiectivul principal al acestui studiu este de a determina timpul total de reacție al conducătorului auto și al vehiculului. Au fost efectuate trei tipuri de teste, folosind ambele faruri și folosind un sistem de iluminat defect în ordine succesivă (far stânga și dreapta). Același subiect a fost folosit ca pieton, îmbrăcat în negru, respectiv în roșu.*

***Key-words:*** *night-time visibility, pedestrian accidents, experimental tests*

## 1. INTRODUCTION

The mortality rate for driving at night is four times higher than during the day. According to statistics, approximately 70% of pedestrian accidents occur at night, driving at night represents only 20% of total traffic [1]. The operating conditions of the vehicle's lighting system, as well as the environment lighting conditions can greatly influence the occurrence of accidents at night. It is also important that the headlamps are properly adjusted and that any surface between the road and the eyes is kept clean in order to maintain proper visibility. To travel safely at night, pedestrians must ensure that drivers can see them from an appropriate distance. The main objective of this study is to determine the total reaction time of the driver and the vehicle. Three types of tests were performed using both headlamps and using a faulty lighting system in successive order (left and right headlamp). The same subject was used as a pedestrian, dressed in black and red, respectively. All pictures presented in this paper are realized especially for this article.

## 2. METHODOLOGY

### *2.1. General aspects regarding the night-time visibility*

Visual observation ensures the perception of objects in the environment, which is reduced during the night. The field of vision is influenced by atmospheric conditions such as fog, rain or snow. In good visibility conditions, the identification time of objects is about 0.2 seconds. The time required to recognize a new object varies between 0.1 and 0.3 seconds [2]. The duration of the normal reaction time of the driver and the vehicle, when the intrusion of a pedestrian is detected, is 1.5 seconds. The perception of objects of different colours determines the levels of contrast between the object and the environment. Experimentally, it was found that the human eye perceives best the contrast difference between white and black, respectively yellow and red. When both eyes looking in the forward direction at a fixed object, the visibility cone of a driver forms an angle of 120 ° -160 °. Night-time visibility has a number of features in terms of road lighting level. On clear nights the illuminance has a value of $10^{-1}$lx. Therefore, visual acuity decreases resulting in a reduced perception of shapes and contrasts [3].

Table 1. Visual impairments of the drivers from the study

| Driver no. | Height [m] | Eyes colour | Visual impairment |
|---|---|---|---|
| 1 | 1.68 | brown | myopia |
| 2 | 1.71 | green | without visual impairment |
| 3 | 1.84 | brown | without visual impairment |
| 4 | 1.95 | brown | myopia |
| 5 | 1.80 | green | without visual impairment |
| 6 | 1.69 | brown | without visual impairment |
| 7 | 1.64 | brown | without visual impairment |
| 8 | 1.55 | brown | myopia |
| 9 | 1.91 | brown | without visual impairment |
| 10 | 1.90 | green | without visual impairment |
| 11 | 1.78 | brown | without visual impairment |

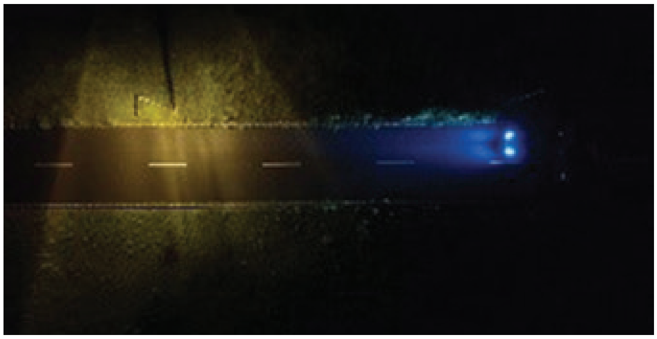

Fig. 1. Test track

### *2.2. Procedures and techniques for the organization of the experimental research*

*2.2.1. Testing procedure*

The experiment was performed during a single day in a night with a clear sky and the location was the Research and Development Institute of Transilvania University of Brasov.

During the experiment, tests were performed for different clothing colours in order to ensure the full visibility. The measurements were performed on the abdomen of the pedestrian, respectively on the shoulders. The same subject dressed in black and red respectively was used as a pedestrian so that the difference in height does not influence the test. In this research 11 drivers were involved additionally in order to get and compare different results and to determine how the visual impairments influence the visibility of pedestrian. The drivers have different sexes and heights with and without visual impairments presented in table 1. The first author of this study performed the experiment, the second author was responsible for the scientific

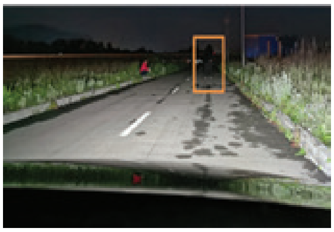

Fig. 2. Black clothing, both functional headlamps

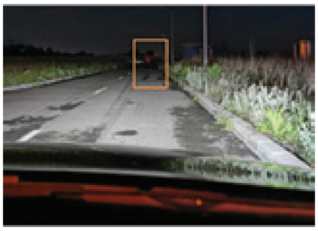

Fig. 3. Red clothing, both functional headlamps

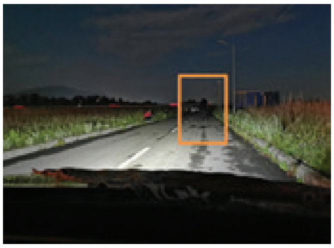

Fig. 4. Black clothing, left functional headlamps

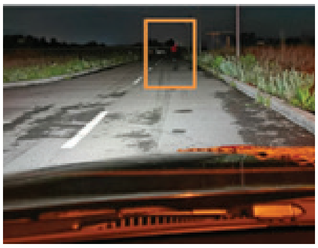

Fig. 5. Red clothing, left functional headlamps

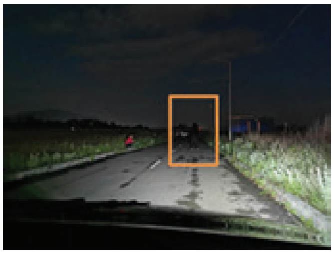

Fig. 6. Black clothing, right functional headlamps

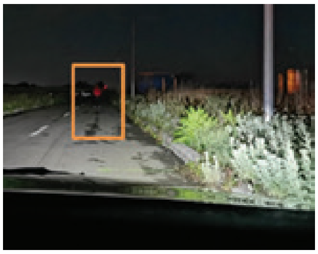

Fig. 7. Red clothing, right functional headlamps

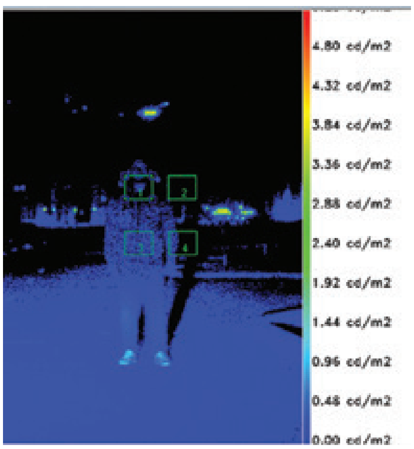


Fig. 9. Example of photo processing to determine the visibility of the pedestrian

accuracy and coordinating the research and the rest of authors were involved in performing the measurements and processing the data.

In the opposite direction to the pedestrian was a Volkswagen Golf V equipped with a lighting system with Xenon H7 headlight lamps for testing at a distance of 100m. A calibrated camera was introduced to capture the photos at night, without changing the focus in order to perform three types of tests using both functional headlamps, functional right headlamp and functional left headlamp. To perform this experiment, measurements were performed on the test track. Therefore, a road with a length of 100 m was chosen. On this test track, markings were performed at intervals of 10 meters, so that the test track was divided into 10 intervals. The experiment was conducted on a section of unlighted road as shown in Figure 1.

In the experimental test, the pedestrian was positioned in the middle of the distance between the right side of the road and the road axis. The vehicle was positioned at a distance of 100 m from the pedestrian. For the two colours of clothes, each driver started from the point of 100 meters and

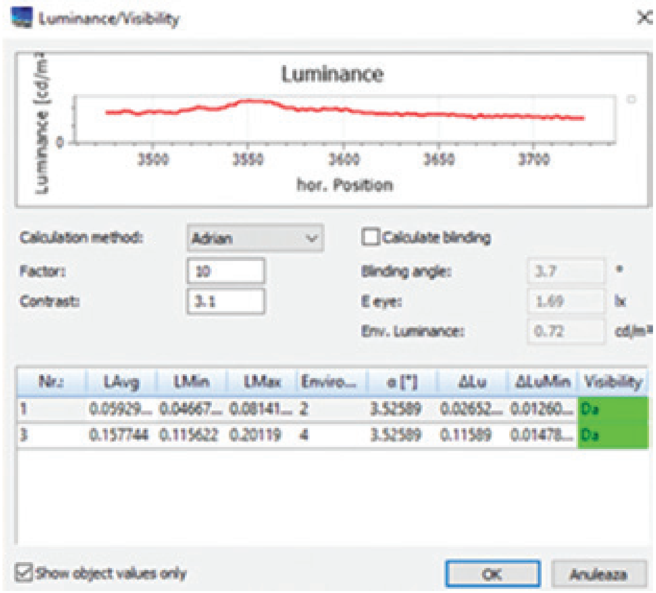


Fig. 8. Determining the visibility from PC Rect

approached the pedestrian, until he was visible as shown in figures 2-7.

*2.2.2. Equipment features and performance*

In order to perform the measurements, the following equipment was required: Geko G03351 telemeter, with a maximum measuring distance of 60 m for determining distances, Nikon camera for capturing photos, Gossen Mavo Spot 2 lux meter for determining the luminance between 0.01 and 99,900 , Phantom Pro drone for aerial photos;

*2.2.3. Data acquisition and processing.*

Because the constant velocity $v$ is the variation of space $\Delta S$ in the unit of time $\Delta t$, the relation can be written as follows:

$$v=\Delta S/\Delta t \quad [m/s] \tag{1}$$

And the time can be expressed:

$$t=\Delta S/v \quad [s] \tag{2}$$

The time period that defines the total reaction time can be considered to consist of the reaction time of the driver and the braking time of the system until the vehicle stops, as follows [4]:

$$t_r=t_d+t_b \quad [s] \tag{3}$$

The total distance until the vehicle stops is obtained by the sum of the distance travelled in the reaction time of the driver with constant velocity and the braking distance of the vehicle :

$$\Delta S=\Delta S_1+\Delta S_2 \quad [m] \tag{4}$$

Using the PC-Rect photogrammetry program, the brightness is determined on different areas of the image and the contrast between two analysed areas can be calculated, so the visibility of the pedestrian is given by the software by comparing two luminance values and determining the contrast as shown in figure 8. It is based on Adrian Werner's method, which is the method of stabilizing the visibility of the object in different light conditions.

Where: Lavg - average luminance; LMin, LMax - minimum and maximum luminance in the measured areas; α- the size of the object; Umfeld - chosen background area; ΔLu – the difference in luminance between Lavg of the chosen area and Lavg of the chosen background; ΔLight - the difference of the minimum luminance. An object is visible if ΔLu > ΔLight. In the test scenario the analysed area on the pedestrian was the thorax area. In figure 9 is an example of photo processing using PC-Rect. There are four frames that represent the analysed areas in order to obtain the luminance and to obtain the contrast. Two of them are placed in the

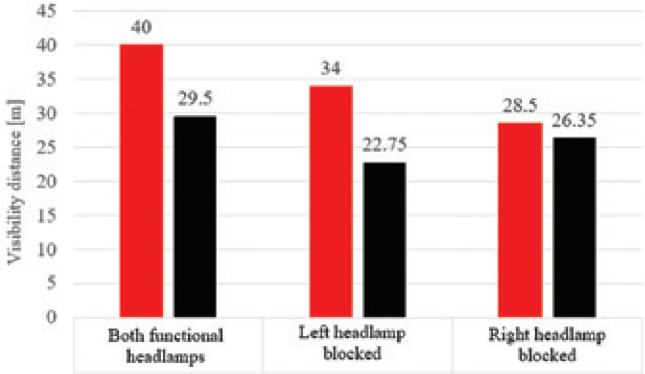


Fig. 10. Visibility diagram depending on the clothing colour for the driver 1.

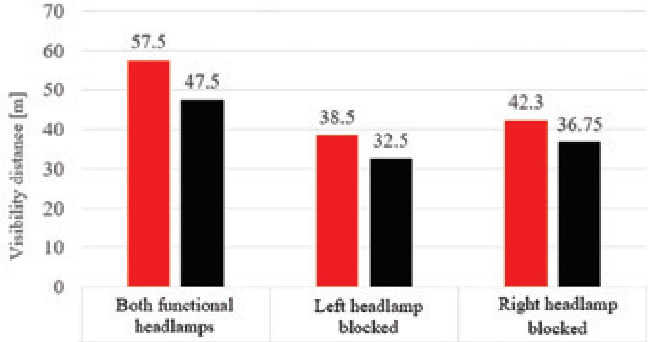


Fig. 11. Visibility diagram depending on the clothing colour for the driver 2.

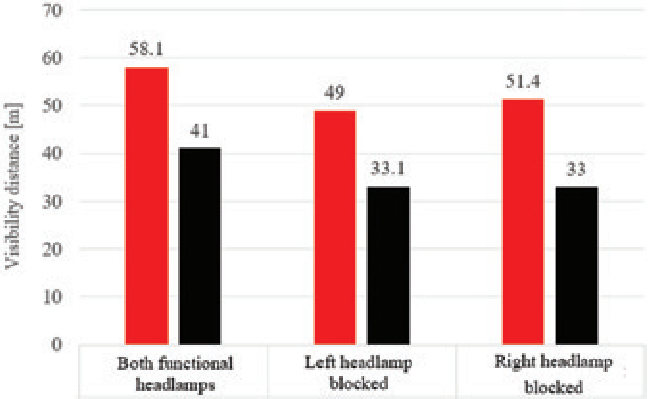


Fig. 12. Visibility diagram depending on the clothing colour for the driver 3.

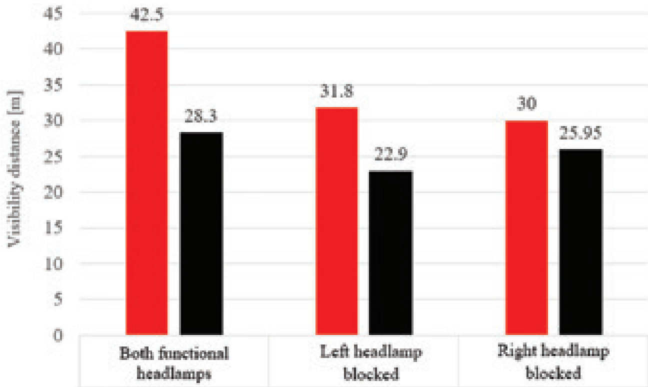


Fig. 13. Visibility diagram depending on the clothing colour for the driver 4.

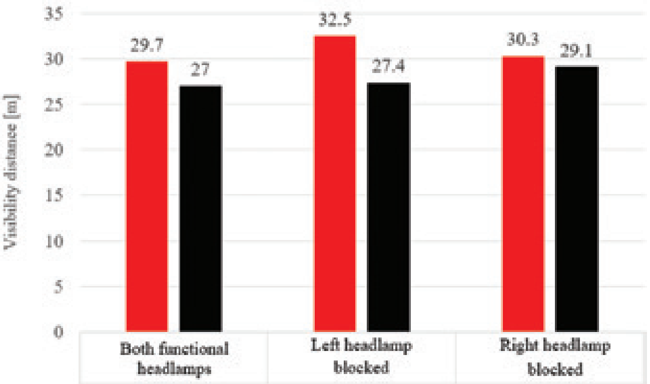


Fig. 14. Visibility diagram depending on the clothing colour for the driver 5.

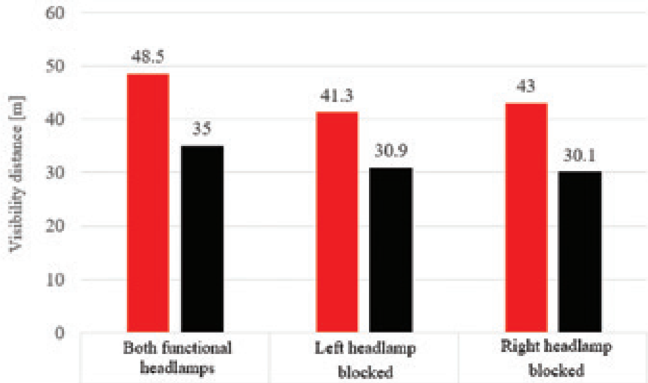


Fig. 15. Visibility diagram depending on the clothing colour for the driver 6.

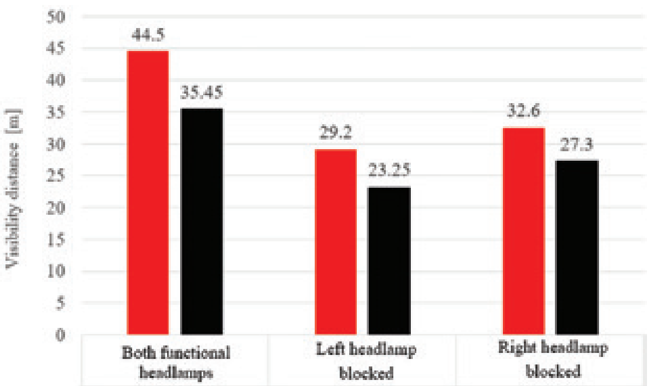


Fig. 16. Visibility diagram depending on the clothing colour for the driver 7.

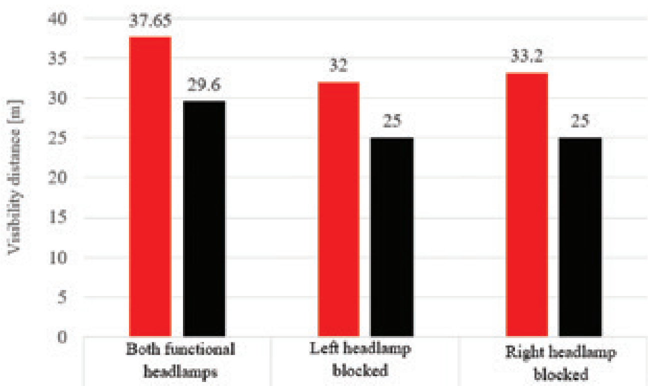


Fig. 17. Visibility diagram depending on the clothing colour for the driver 8.

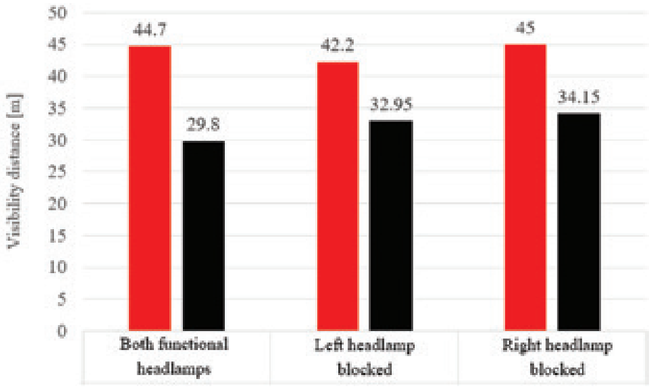


Fig. 18. Visibility diagram depending on the clothing colour for the driver 9.

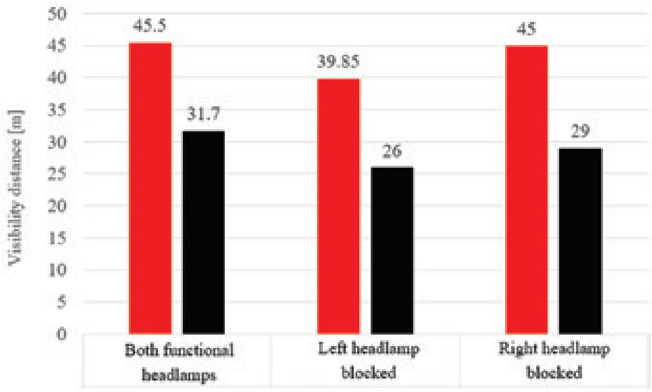


Fig. 19. Visibility diagram depending on the clothing colour for the driver 10.

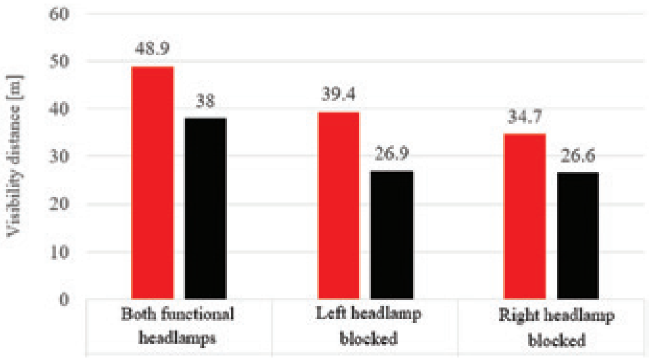


Fig. 20. Visibility diagram depending on the clothing colour for the driver 11.

shoulder area and the other two in the abdomen area. The software determines the luminance value of the object inside the first two frames and compares them in order to get the value of the contrast between the measured object and the environment. Based on the contrast, the program will display if the object is visible.

On the right side of the photo, there is the value of the luminance on a scale from 0 to  and also the colours assigned to each value.

## 3. RESULTS ANALYSIS

Representative visibility diagrams were obtained using the data resulted from the processing of photographs of the parameters ΔLu based on following parameters: distance - between the vehicle and the pedestrian [m], Black - the value of the parameter ΔLu de for this colour of clothing [], Red - the value of the parameter ΔLu obtained for the colour red [].

The visibility diagrams of the pedestrian depending on the colour of clothing, the distance between the vehicle and the pedestrian and the difference between the left headlamp and the right headlamp are presented in figures 10-20:

It is observed that the values of the minimum visibility distances of pedestrian were obtained in the case of the driver no 1 who has a visual impairment. In the case of the left headlamp blocked, where the pedestrian was dressed in black colour, the minimum visibility distance is 22.75 m. When the right headlamp is blocked and the pedestrian is dressed in red colour, for the same subject the minimum distance of 28.5 m was obtained. According to the ECE Regulation 48, the maximum intensity of the main-beam headlamps which can be operated simultaneously does not exceed 430.000 cd [5]. The intensity of the headlamps was mapped using the lux meter, measuring the luminance on each headlamp, on the right side of the road, on the road axis and on the left side of the road. The data were centralized in Microsoft Excel and the test was performed for the distance from 10 to 100 meters. In table 2 was measured the luminance which can be calculated depending on the luminous intensity and the visible surface:

The total reaction time of the drivers and the vehicle was calculated and presented in table 3. The data shown are calculated based on the average of results from all 11 drivers.

Based on experimental research, it was established that the total duration of the normal reaction time when the intrusion of a pedestrian is detected is 1.5 seconds. Therefore, if the velocity exceeds 30 km/h, in case of pe-

Table 2. The luminance measured from pedestrian to headlamps.

| | Right side of the road | | Road axis | | Left side of the road | |
|---|---|---|---|---|---|---|
| Distance [m] | Left headlamp | Right headlamp | Left headlamp | Right headlamp | Left headlamp | Right headlamp |
| **10** | 3301 | 1880 | 5106 | 344.7 | 4842 | 6004 |
| **20** | 1387 | 1121 | 1645 | 1528 | 1793 | 2230 |
| **30** | 713.1 | 655.7 | 789.8 | 803.2 | 839.5 | 1089 |
| **40** | 426.5 | 433.7 | 459.7 | 507.9 | 487.1 | 660.1 |
| **50** | 283 | 312.3 | 306 | 352.9 | 329.8 | 463 |
| **60** | 200 | 244.2 | 215 | 264.5 | 230.6 | 366.1 |
| **70** | 146.6 | 197.9 | 160.7 | 214.6 | 167.3 | 298.1 |
| **80** | 118.5 | 164 | 126.1 | 182 | 128.8 | 269.8 |
| **90** | 94.3 | 145.8 | 99.6 | 146.9 | 104.2 | 224.3 |
| **100** | 78.96 | 119 | 81.95 | 127.6 | 84.12 | 203.4 |

Table 3. Determination of the total reaction time

| Velocity [km/h] | Grip coefficient (dry asphalt) | Braking distance $\Delta S_2$ [m] | Distance travelled in the reaction time of the driver $\Delta S_1$ [m] | Total distance travelled $\Delta S$ [m] | Total reaction time $t_r$ (driver and vehicle) [s] |
|---|---|---|---|---|---|
| 0 | 0.65 | 0 | 0 | 0 | 0 |
| 10 | 0.65 | 0.60 | 2.5 | 3.10 | 1.116 |
| 20 | 0.65 | 2.41 | 5 | 7.41 | 1.334 |
| 30 | 0.65 | 5.43 | 7.5 | 12.93 | 1.552 |
| 40 | 0.65 | 9.65 | 10 | 19.65 | 1.769 |
| 50 | 0.65 | 15.08 | 12.5 | 27.58 | 1.986 |
| 60 | 0.65 | 21.71 | 15 | 36.71 | 2.203 |
| 70 | 0.65 | 29.56 | 17.5 | 47.06 | 2.420 |
| 80 | 0.65 | 38.60 | 20 | 58.60 | 2.637 |
| 90 | 0.65 | 48.86 | 22.5 | 71.36 | 2.854 |
| 100 | 0.65 | 60.32 | 25 | 85.32 | 3.072 |

destrian intrusion on the road, stopping in time and avoiding collision becomes difficult for the presented situation.

## 4. CONCLUSIONS

This study highlighted the importance of the colour of clothing used by pedestrians, and how these influence visibility distances. Based on the analysis of the experimental data, it is found that the visibility of pedestrians on the road is influenced by the colour of the equipment and the operating conditions of the lighting system. It is recommended that pedestrians to use light-coloured clothing, which can create a positive contrast with the environment in order to be easier for drivers to perceive it; Visually impaired drivers are more likely to observe pedestrians at shorter distances, which can make it difficult to avoid them. Predominantly in the case of black colour, visually impaired drivers recorded the lowest values. Based on the experimental research, if the velocity exceeds 30 km/h, when a pedestrian is detected by driver, stopping in time and avoiding collision becomes difficult due to increasing reaction time.

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*Continuare din pagina 3*

Într-o discuţie cu un coleg întrebam: „Ferească Dumnezeu, dacă ai fi nevoit să faci o operaţie pe cord, ai accepta să fii operat de un medic „de nota 5”? Sau, dacă ai ajunge în instanţă, ai accepta să fii apărat de un avocat „de nota 5”! Sau, dacă ar fi să îţi construieşti o casă, ai fi de acord ca proiectul şi execuţia lucrărilor să fie elaborate/coordonate de un „inginer constructor” de nota 5?

Răspunsul (evident, care ar putea fi generalizat) a fost: Nu! Nu aş dori aşa ceva!

Şi atunci, firesc, apare o întrebare (cred eu legitimă): de ce aş accepta ca repararea automobilului meu să fie făcută de un inginer de nota 5? De ce aş include în echipa de proiectare a sistemului de frânare a unui anumit autovehicul a unui inginer de nota 5? De ce aş accepta ca intersecţiile bulevardelor să fie proiectate de un inginer de transporturi de nota 5? Sau, mai grav, de ce aş avea nevoie de un inginer de nota 5, atâta vreme cât nu vreau un chirurg de nota 5, nu vreau un economist/contabil de nota 5, nu vreau un judecător de nota 5, nu vreau un primar de nota 5, nu vreau un ministru de nota 5... ş.a.m.d.?

De ce acceptăm „ingineri ”de nota 5?

DE CE „PRODUCEM” INGINERI DE NOTA 5?

La începutul carierei universitare am avut numeroase discuţii cu colegi – onorat fiind de situaţie – profesori ai mei în studenţie – cadre didactice universitare cu o colosală experienţă profesională (amintesc doar pe unii, dar au fost mult mai mulţi: Mircea IONESCU, Victor GHIZDAVU, Paul LIXANDRU, Sterie ŞTEFAN, Mircea NĂSTASE, Neculai RĂDUŢ, Ioan FILIP, Horia VERTAN, Constantin MANEA) privind menirea de a fi „profesor-mentor” şi de a îndruma în devenirea profesională tinerii discipoli.

De atunci mi-am format convingerea că un cadru didactic universitar este doar „cel care îndrumă / cel care asistă” demersul (dorinţa) conştient al unui tânăr discipol în drumul lui responsabil de devenire civică şi profesională.

A rămas din numeroasele discuţii ideea de bază: a acorda unui student nota 5 la examen este mai dificil decât a acorda nota 10!

Timpul aşează multe lucruri la locul lor!

A accepta mediocritatea constituie (în opinia mea) un atentat la realitatea şi viitorul acestei ţări, la aşteptările şi visele celor mulţi care îşi încredinţează zilele/vieţile/copiii pe mâinile acestor „ingineri”, „medici”, „jurişti”, „agronomi”, „economişti”... de nota 5!

Dar, întrebarea aplicabilă – având în vedere doar specificul SIAR: ingineria autovehiculelor, transporturilor şi securităţii rutiere – rămâne: de ce acceptăm să certificăm ingineri de nota 5?

Nu vrem (cred) chirurgi de nota 5, nu vrem judecători de nota 5, nu vrem... nu vrem primari de nota 5, nu vrem miniştri de nota 5...!

NU VREM O ŢARĂ DE NOTA 5...!

ATUNCI, NOI, SIAR, PRIN TOT CE REPREZENTĂM, DE CE ACCEPTĂM INGINERI DE NOTA 5?

DE CE?

**Prof. univ. dr. ing. Minu MITREA**
Secretar General SIAR,
Academia Tehnică Militară „Ferdinand I”

# TWO DECADES OF ACCIDENTAL SITUATION IN THE REPUBLIC OF MOLDOVA

# REPUBLICA MOLDOVA: ANALIZA ACCIDENTELOR RUTIERE PE DURATA A DOUĂ DECENII

**REZUMAT:** *Accidentele de circulație sunt cea mai periculoasă amenințare pentru sănătatea și viața oamenilor din întreaga lume. Daunele provocate de accidentele rutiere depășesc daunele provocate de toate celelalte accidente de transport (aeriene, navale, feroviare etc.) luate împreună. Problema se agravează prin faptul, că victimele accidentelor de circulație sunt, de regulă, persoanele tinere și sănătoase, apte de muncă. Accidentele rutiere cauzează daune sociale, materiale și demografice enorme economiei oricărei țări și societății în ansamblu. În Republica Moldova în perioada anilor 2000–2019, au murit în accidentele rutiere 7702 de oameni, iar 63560 de persoane au fost traumatizate. Articolul cuprinde o analiză succintă a statisticii accidentelor rutiere în ultimii 20 ani în Republica Moldova și în diferite zone geografice ale globului pământesc.*

**Key-words:** *road accidents, statistics, accidents severity*

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## 1. INTRODUCTION

It has been more than a century since the first car appeared on earth. Time passed, they multiplied. The number of vehicles is increasing day by day and it is difficult to estimate exactly how many cars are currently in the world. However, experts say that the number of cars exceeds 1,2 billion, and in 2035 will reach 2 billion. By 2050, the figure will reach 2,5 billion, and the world's population – 9,731 billion [1][2]. There will be almost one car for four people.

For the first time, the number of vehicles exceeded one billion in 2010. According to a study by Wards Auto [3], there were 1,015 billion cars on the planet at the time, and the engine level of the population was 1 to 6,75. For comparison: in 2009, the world car fleet was 980 million transport units, in 1986 – 500 million, and in 1970 – 250 million. Since 1950, the number of vehicles has begun to double approximately every ten years.

With the advent of cars, road accidents also appeared. The information about the first road accident is quite controversial [4][5]. While some claim that the first accident took place in 1869, others claim that the first was in 1834. Unofficial sources claim that the first traffic accident took place on July 29, 1834. A steam stagecoach, of the Edinburgh engineer, hit a stone intentionally placed on the road. The steam boiler exploded, killing 5 people. Other documents state that the first accident with victims took place on August 31, 1869. Mary Ward was with her husband and her cousins (the Parson brothers), on a trip with an experimental, steam vehicle. In a tighter turn, Mary lost her balance and fell, being trampled on by the wheel of the vehicle.

The first road accident in the world was officially recorded on May 30, 1896, in New York [5][6]. Henry Wells, who was driving an electric car, bumped into a cyclist Evelyn Thomas. Fortunately, Evelyn was left with only one fractured leg. In the same year, a few months later, on August 17, 1896, the first fatal accident in the world occurred in London. During the presentation of the new car, driven by Arthur Edsell, a 44-year-old woman Bridget Driscoll, mother of two children, was hit.

The first road accident that resulted in the death of the driver occurred on February 12, 1898. It took place in Great Britain and the victim was Henry Linfield [4]. It seems that the steering system failed, and the car hit a tree. The driver died the next day. Thus, mankind began to pay the disastrous price of one of the most brilliant manifestations of technical progress – the automobile, the dizzying pace of development of which is accompanied by an equally rapid increase in the number of victims.

Urbanization and rapid motorization of the world's population are accompanied by an increase in the number of road accidents, in which people die, are traumatized and injured. According to the latest estimates of the World Health Organization (WHO), approximately 1,4 million people die in traffic accidents each year, and up to 50 million are injured by bodily injury, which often leads to disability [5][7].

Victims of road accidents, their families, and countries in general, suffer significant economic losses, related to the treatment and loss of productivity of the deceased, left with disabilities or caring for traumatized relatives. These deaths and traumas have a huge impact on the families of the victims, whose lives often change irreversibly as a result of these tragedies, as well as on other communities where the victims have lived and worked.

The social topicality of the problem consists in the fact that thousands of people die and remain crippled, these constituting, in their great majority, the active, apt of work part of the population. These losses consist of expenses for the payment of disability benefits and pensions, for treatment, production losses and administrative expenses: criminal investigation, court, etc. Economic losses also include damage resulting from damage to cargo, vehicles, road construction, production delays, traffic, etc. Therefore, reducing the damage from road accidents is a task of great socio-economic importance.

Road accident statistics in developed countries are similar to statements on the battlefields of the world. Road accidents cost most countries about 1-3% of gross domestic product (GDP), and globally are about $ 518 billion of which about $ 100 billion in developing countries, twice the amount of financial assistance of them [5][8][9]10][11].

In Europe, the price paid for morbidity is still extremely high. Every year on the roads of the European Union in road accidents over 120000 people die and another about 2,4 million are traumatized. The cost of directly measurable road accidents is around € 45 billion. Indirect costs are three or even four times higher. The annual value is about € 160 billion, the equivalent of 2% of GDP in the European Union [5][8][9][10], in the CIS countries – € 8,4 billion, the equivalent of 1,5% of GDP. The cost of a human life lost in a car accident is estimated differently from country to country, in Europe averaging € 1 million [5][12].

The risk of road accident mortality is higher in countries with lower levels of development. Even in high-income countries, the probability of being hit by a car accident is higher among people with lower socio-economic

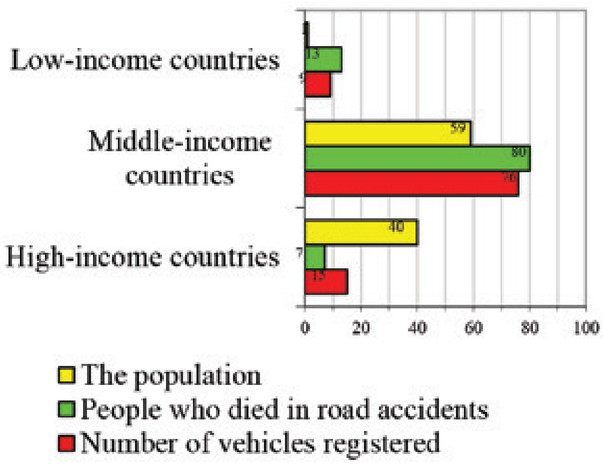


Fig. 1. Population share, number of deaths caused by road accidents and number of vehicles registered by groups of countries with different levels of per capita income, year 2016, %

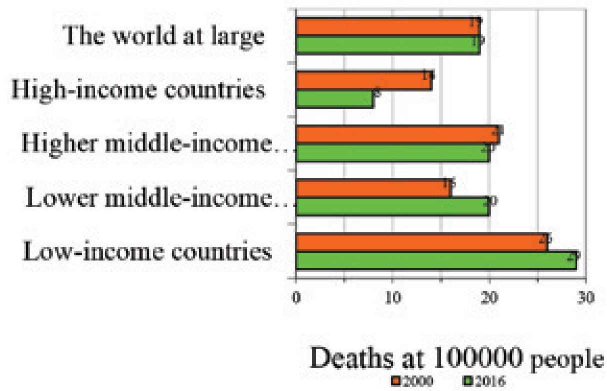


Fig. 2. Mortality rate in road accidents by groups of countries with different levels of per capita income, years 2000 and 2016, the number of deaths caused by road accidents per 100000 people

status. Over 90% of road accident deaths occur in low- and middle-income countries [7][11][13].

## 2. ANALYSIS OF THE SITUATION WITH ROAD SAFETY

The disproportionately high burden of road accident mortality in middle-income countries is indicated by the fact that these countries account for 80% of road accident deaths, 76% of the world's population and only 59% of the world's registered motor vehicle fleet (figure 1).

The share of deaths in road accidents in high-income countries is 11 times lower (7%), and the share of the world fleet of registered vehicles is only 1,5 times lower (40%). In low-income countries, the level of motorization is still low, and the share of the world's population concentrated in them (9%). The share of deaths caused by road accidents (13%) is higher than the share of the world fleet of registered vehicles (1%) [7].

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Worldwide, deaths due to road accidents accounted for approximately 19 deaths per 100000 people in 2016, according to WHO estimates. The highest value of the indicator is noted in low-income countries – 29,4 per 100000 people, and in high-income countries is 3,7 times lower – 8,0 per 100000 people (figure 2). In countries with higher and lower average incomes, this indicator is practically the same, slightly exceeding the world average, but the changes compared to 2000 were the opposite. In countries with a higher average income, deaths in road accidents decreased from 21,5 to 19,7 per 100000 people, and in countries with a lower average income increased from 16,4 to 19,9 at 100000 people. The largest decrease in road accident deaths occurred in high-income countries, where it fell by 5,5 points – from 13,5 to 100000 people in 2000 to 8,0 in 2016. Low incomes, road traffic deaths increased by 3 points – from 26,3 deaths per 100000 people in 2000 to 29,4 in 2016 [7].

The mortality rate in road accidents varies significantly between WHO regions. The highest mortality rate in road accidents is the African region (27,8 cases per 100000 people), three times lower – in the European region (9,3 cases per 100000 people). Compared to 2000, the road accident mortality rate decreased in three WHO regions: 5,2 points in the European region, 3,3 points in the Western Pacific region and only 0,3 points in the Eastern Mediterranean region (figure 3). In the other three WHO regions, the road accident mortality rate increased, especially by 5,4 points in the South-East Asia region (from 15,6 to 21,0 per 100000 people). In the American region, the mortality rate increased slightly, remaining almost at the same level as at the beginning of the century (15,9 per 100000 people in 2016 compared to 15,8 in 2000).

Significant differences in road accident mortality rates are also observed between countries in the same region. The number of deaths in road accidents and the number of registered vehicles contained in the database of the *Global Health Observatory* allow the estimation of the number of deaths in road accidents per 1000 registered vehicles. There is no clear link between these indicators, as many depend on the technical characteristics of the vehicles, the quality of the road infrastructure, compliance with road safety rules and a number of other factors. However, the correlation of these two indicators provides an additional picture of the state of road safety.

In the *WHO African region*, the road accident mortality rate ranges from 13,7 per 100000 inhabitants on the island of *Mauritius* to 35,9 in *Liberia*. In half of the countries (without 25% of the countries with the lowest and 25% with the highest incomes), the value of the indicator varies from 24,9 to 30,0 per 100000 people, with a median value of 27,6. In addition to *Mauritius*, the mortality rate is lower than the world average in the *Seychelles* (15,9 per 100000 people), which are the only ones in this group of countries with a high level of national income.

The number of road accident deaths per 1000 registered vehicles ranges from 0,3 in *Mauritius* to 53 in *South Sudan*, with an average of about 7. In addition to *South Sudan*, the *Central African Republic*, *Ethiopia*, *Togo*,

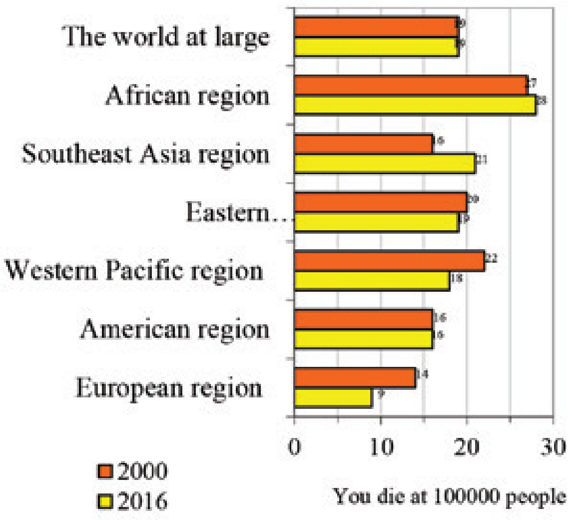


Fig. 3. Road accident mortality rate by WHO regions, years 2000 and 2016, number of deaths caused by road accidents per 100000 people

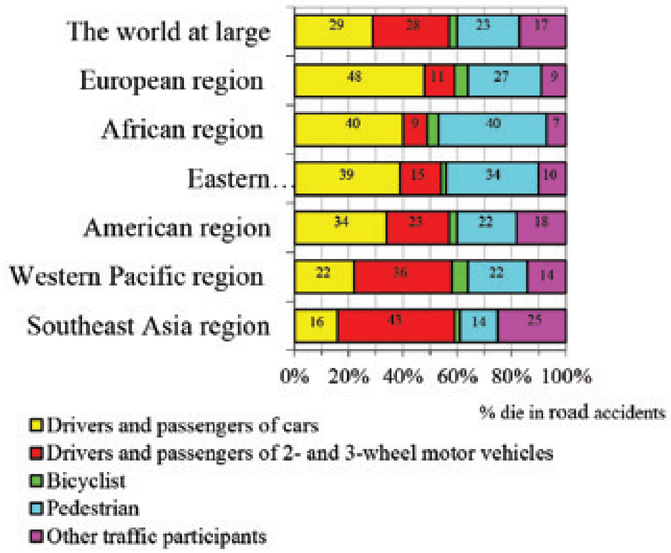


Fig. 4. Mortality rate in road accidents by WHO regions, number of deaths caused by road accidents per 100000 people

*Burundi* and *Madagascar* have a high number of road deaths per 1000 vehicles (from 30 to 41 road accidents per 1000 registered vehicles).

Among the countries in the *WHO American region*, the value of the road accident mortality rate varies from 5,6 per 100000 people in *Barbados* to 35,4 in *Saint Lucia*. However, in most countries in the region the mortality rate is in a narrower range – from 12,4 to 20,9 per 100000 people, with a median of 14,4 per 100000 people. In the most motorized countries of the region, the mortality rate in road accidents is relatively low – 12,4 per 100000 people in the *US*, 5,8 – in *Canada*. The number of deaths caused by road accidents per 1000 registered vehicles varies from 0,1 in *Canada*, the *United States* and *Barbados* to 12 in *Guyana*. Excluding *Guyana*, in the countries of the *American region*, the mortality rate in road accidents does not reach 2 per 1000 vehicles. The *WHO European region* is characterized by the largest differences in road accident mortality, in low-income countries is almost three times higher than in high-income countries (18,6 and 6,3, respectively per 100000 people). The number of road accident deaths per 100000 permanent residents is from 2,7 in *Norway* and *Switzerland* to 18,1 in *Tajikistan*. In most countries, the mortality rate ranges from 5,3 to 10,6, with an average of 7,4 deaths per 100000 people. Among the countries in the *WHO Eastern Mediterranean region*, the road accident mortality rate ranges from 9,3 deaths per 100000 people in *Qatar* to 28,8 in *Saudi Arabia*. In most countries in the region, the indicator has values between 16,5 and 25,4 per 100000 people with a median value of 20,1 per 100000 people.

The number of road accident deaths per 1000 registered vehicles varies between 0,2 in *Qatar* and 65 in *Somalia*. In addition to *Somalia*, *Afghanistan* and *Sudan*, where the value of the death rate is about 8 deaths in road accidents per 1000 vehicles, the rest of the countries in the region are characterized by low values of the mortality rate, not exceeding 2 deaths in road accidents per 1000 vehicles. Among the countries in the *WHO South-East Asia region*, *Thailand* (32,7 deaths in road accidents per 100000 people) and the *Maldives* (0,9) stand out with extreme values. In other countries in the region, the value of the mortality rate varies from 12,2 per 100000 people in *Indonesia* to 22,6 in *India*. The number of road deaths per 1000 registered vehicles ranges from zero in the *Maldives* to 8,7 in *Bangladesh*.

Among the countries in the *WHO Western Pacific region*, with extreme mortality rates, there are also two countries – the island state of *Micronesia* (1,8 deaths in road accidents per 100000 people) and *Vietnam* (26,4), in the other countries in the region have a road accident mortality rate between 2,8 in *Singapore* and 23,6 in *Malaysia*. In 8 countries in the region, the road accident mortality rate is less than 10 deaths per 100000 people (including *Australia*, *New Zealand*, *Japan* and *South Korea*), in the other thirteen countries it exceeds 11 deaths per 100000 people. In urbanized countries, 70% of traffic accidents are concentrated on road networks in localities, where the most vulnerable category of road users are pedestrians, and 30% occur on roads outside localities, which are characterized by high severity of consequences [12]. Thus, the greatest potential to reduce the general level of damage is to reduce the number of road accidents in localities, and the greatest potential to reduce the general severity of road accidents – reducing the number of accidents on roads outside localities. Among the victims of road accidents, men visibly predominate, in addition, their share increased from 72% in 2000 to 74% in 2016 (*figure 5*), so in recent years there have been almost three times more men among the victims road accidents, than women [7][14][15].

More than half of those who died in road accidents, 58% in 2000 and 55% in 2016, are people aged between 15 and 49, i.e at the age of greatest economic activity and labor productivity, of which about 80% are men (*figure 6*). Road injuries are the leading cause of death for children and young people aged 5 to 29 years [7][16]. The proportion of deaths caused by road accidents is the highest among those aged 15 to 29 and increased by 3,2 percentage points compared to 2000 – from 10,9% to 14,1% in 2016. Compared to 2000, the number of children who died in road accidents decreased: by 13% by children aged 5-14, by 18% by girls up to 5 years of age and by 7% by their male colleagues. The number of deaths in road accidents over the age of 15 has increased for all age groups, especially significantly at the age of 50-59 (men – by 69%, women – by 57%) and older. During the years 2000-2016, the mortality rate in road accidents practically did not change, increasing only by 0,3 points (from 18,5 to 18,8 per 100000 people), but as a result of the multidirectional

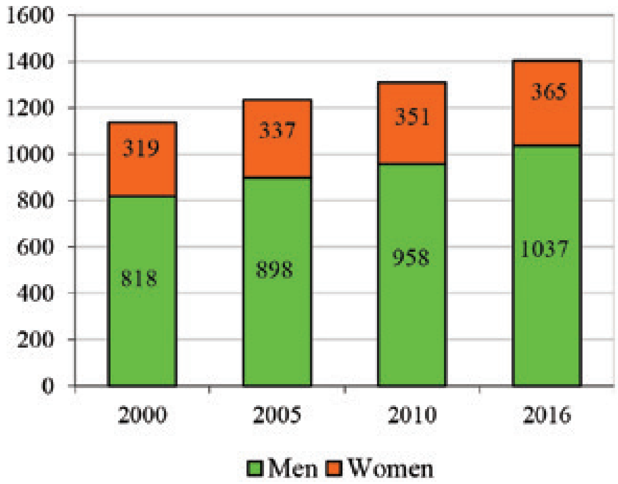


Fig. 5. Number of deaths caused by road accidents by sex, the world, 2000, 2005, 2010 and 2016, thousands of people

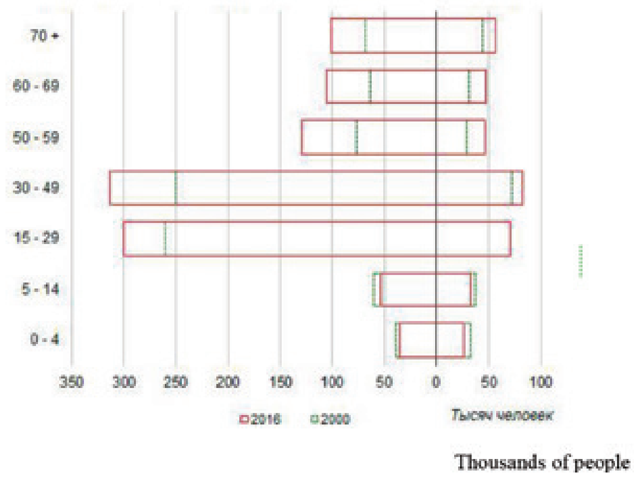


Fig. 6. Distribution of deaths caused by road accidents by sex and age, the world, 2000s and 2016, thousands of people

changes of mortality in other causes of death, its position among the leading causes of death has increased. The WHO forecast for 2030 indicates a shift in road accidents from 9th to 5th place due to deaths [13].

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Worldwide, more than half of those killed in road accidents are the most vulnerable road users – pedestrians (23%), cyclists (3%) and motorcyclists (28%). Another 29% of those who died in road accidents belong to drivers and passengers of cars, and the remaining 17% – toother road users [7][13][17][18]. The situation varies significantly between regions of the world. In most low- and middle-income countries, the percentage of road accident victims, such as pedestrians, cyclists, drivers, and passengers of two- and three-wheeled motor vehicles, is significantly higher than in high-income countries. For example, in the WHO African region, 40% of all road accident deaths are due to pedestrians, and in the WHO West Pacific region 36% are to motorcyclists, i.e. drivers and passengers of 2- or 3-wheel motor vehicles (figure 4). Drivers and passengers represent between 16% of those killed in road accidents in the South-East Asia region to 48% in the European region. Pedestrians account for about a quarter of road accident deaths in all regions except the African region (40%), the Eastern Mediterranean region (34%) and the Southeast Asia region (14%). The rapid development of road traffic in the Republic of Moldova, determined by the increase of the national vehicle park, which at the beginning of 2020 constituted (without the districts on the left bank of the Dniester and Bender municipality) 1031481 transport units, of which: 648779 cars, 193055 trucks, 21087 buses and minibuses, 49983 tractors, 44462 motorcycles, 74115 trailers and semi-trailers, with the ever-increasing demands of the market economy, are currently an indisputable reality [19]. In the Republic of Moldova, as in other states, road trauma presents a major danger to the population threatening people's lives and health, causing considerable socio-economic damage. Road accidents are one of the leading causes of death. They take place for several reasons, of which they are both technological and human.

But the risk of being involved in a road accident is often influenced by third party factors, such as the month of the year, the day of the week, the time of day, the weather conditions, the quality of the road surface etc. In all countries of the world there is a record of road accidents, and the causes of their challenge are analyzed. This is necessary to be able to undertake a complex of technical-organizational measures to prevent them. This issue is also receiving special attention from international organizations. The analysis of the road accident statistics during the years 2000–2019 in the Republic of Moldova (table 1) indicates that on the territory of the country were registered 52383 (on average 2619 per year) serious road accidents, as a result of which 7702 died (385 per year) people, and another 63560 (3178 per year) were traumatized. The severity index of road accidents (the number of deaths per 100 victims) in the country in the last twenty years is 10,81 [5][8][9][20][21][22][23][24][25].

Reducing damage from road accidents is a task of great socio-economic importance. Although the figures do not give us a complete picture of the real state of affairs in this sphere of human life, we cannot do without statistical data. According to the data presented (figure 7), the most unfavorable in this period, in terms of the number of road accidents, were the years 2002 and 2010, when 2899 and 2930 road accidents were registered respectively. A slightly lower number of road accidents were recorded in 2008 and 2011. For the first time, the number of people who died as a result of road accidents exceeded 500 people in 2008 and fell below 300 in 2013. The number of traumatized people, the worst was also the year 2010, when 3747 traumatized people were registered. In another four years (2002, 2008, 2011 and 2012) the number of traumatized people

Table 1. Frequency of road accidents (years 2000–2019)

| Year | Road accident | Deceased | Traumatized | Coefficient of severity of road accident consequences |
|---|---|---|---|---|
| 2000 | 2580 | 406 | 3147 | 11,43 |
| 2001 | 2666 | 410 | 3277 | 11,12 |
| 2002 | 2899 | 412 | 3505 | 10,52 |
| 2003 | 2670 | 424 | 3215 | 11,65 |
| 2004 | 2447 | 405 | 2888 | 12,30 |
| 2005 | 2289 | 391 | 2770 | 12,37 |
| 2006 | 2298 | 382 | 2807 | 11,98 |
| 2007 | 2437 | 464 | 2984 | 13,46 |
| 2008 | 2875 | 508 | 3511 | 12,64 |
| 2009 | 2755 | 487 | 3297 | 12,87 |
| 2010 | 2930 | 452 | 3747 | 10,76 |
| 2011 | 2826 | 443 | 3535 | 11,14 |
| 2012 | 2712 | 441 | 3510 | 11,16 |
| 2013 | 2603 | 295 | 3221 | 8,39 |
| 2014 | 2564 | 324 | 3080 | 9,52 |
| 2015 | 2527 | 297 | 3021 | 8,95 |
| 2016 | 2479 | 311 | 2928 | 9,60 |
| 2017 | 2640 | 302 | 2993 | 9,17 |
| 2018 | 2614 | 274 | 3123 | 8,03 |
| 2019 | 2572 | 274 | 3001 | 8,37 |
| **Total** | **52383** | **7702** | **63560** | **10,81** |

Table 2. Frequency of road accidents by categories (years 2000–2018)

| The type of accident | Road accident | Average annual value | % of the total number of road accidents |
|---|---|---|---|
| Collision of vehicles | 14023 | 738,05 | 28,15 |
| Vehicle overturning (reversal) | 4455 | 234,47 | 8,95 |
| Buffering with a stationary vehicle | 657 | 34,58 | 1,32 |
| Buffering with an obstacle | 5984 | 314,95 | 12,01 |
| Buffering a pedestrian | 20019 | 1053,63 | 40,19 |
| Bumping into a cyclist | 1754 | 92,32 | 3,52 |
| Buffering with an animal-drawn vehicle | 557 | 29,32 | 1,12 |
| Other types of road accidents | 2362 | 124,32 | 4,74 |
| **Total** | **49811** | **2621,63** | **100** |

exceeded 3500. It should be mentioned that, in addition to serious accidents, there are about 11,000 other road accidents resulting in material damage.

After reaching a peak in 2002, the frequency curves of road accidents began to decrease by about 200 accidents per year reaching the minimum of the period analyzed in 2005. Since 2006, the frequency curve of road accidents began to rise again, slowly but steadily, which is as natural as possible in the conditions of the low road discipline of drivers, the operation of vehicles with technical deficiencies, that travel on roads far from being perfect. The increase continued until 2010 (except for 2009), when the maximum of the analyzed period was reached, after which it started to decrease slowly reaching a new minimum value in 2016. In the last two years there is a slight reduction in the number of accidents road.

In the last seven years, the number of people who died in road accidents has dropped below 300 times, and in the last two years the lowest number of people who have died in road accidents has been recorded. Also, in the last seven years, the coefficient of severity of the consequences of road accidents has dropped below the figure 10. In such a situation, the decrease in the number of road accidents lately makes us happy, but also warns us. As world practice shows, crises appear and disappear. The roots of evil, however, remain, a truth confirmed by the experience of our country.

Of the total number of road accidents (*figure 8*), the largest part is:

• tamponade of a pedestrian – 20019 road accidents (on average 1054 per year (*table 2*), which constitutes 40,19% of the total number of road accidents committed in the reference period);

• vehicle collision – 14023 (738 – 28,15%);

• buffering with an obstacle – 5984 (315 – 12,01%).

At the same time, according to the severity of the accidents in the reference

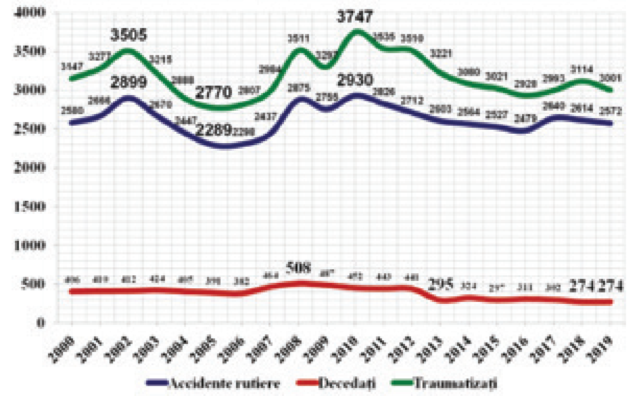


Fig. 7. Frequency of road accidents (2000–2019)

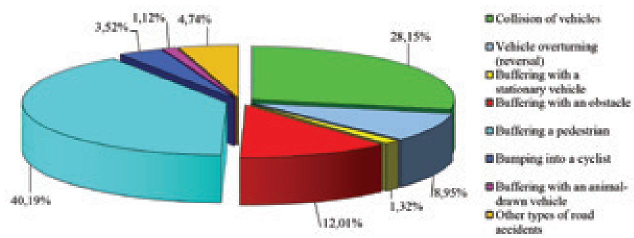


Fig. 8. Frequency of road accidents by categories (years 2000–2018)

period, the following were highlighted: collision with a stationary vehicle, overturning vehicles, collision with a cyclist, collision with an obstacle, collision with a pedestrian, where the severity index sometimes far exceeds the average annual value the seriousness of the consequences of road accidents.

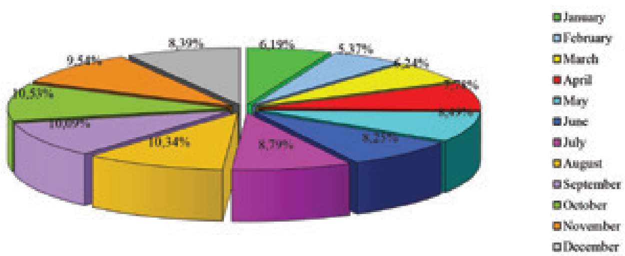


Fig. 9. Frequency of road accidents after the months of the period (2000–2019)

The distribution of road accidents by month (*figure 9*) shows that the most dangerous from the point of view of road traffic were the months:

- October – 5515 (on average 276 per year (*table 3*), which constitutes 10,53% of the total number of road accidents committed during the reference period);
- August – 5416 (271 – 10,34%);
- September – 5287 (264 – 10,09%);
- November – 4999 (250 – 9,54%).

At the same time, according to the severity of the consequences of the accidents in the reference period, the months (except 2019 year) were highlighted:

- ✓ November – 12,65;
- ✓ December – 12,38;

Table 3. Frequency of road accidents by months of the period (2000–2019)

| Months | Road accident | Deceased (without the year 2019) | Traumatized (without the year 2019) | % of the total number of road accidents | Coefficient of severity of road accident consequences (without the year 2019) |
|---|---|---|---|---|---|
| January | 3243 | 462 | 3795 | 6,19 | 10,85 |
| February | 2811 | 368 | 3205 | 5,37 | 10,30 |
| March | 3268 | 427 | 3758 | 6,24 | 10,20 |
| April | 4074 | 500 | 4706 | 7,78 | 9,60 |
| May | 4448 | 586 | 5115 | 8,49 | 10,28 |
| June | 4324 | 546 | 5060 | 8,25 | 9,74 |
| July | 4605 | 646 | 5456 | 8,79 | 10,59 |
| August | 5416 | 818 | 6379 | 10,34 | 11,37 |
| September | 5287 | 698 | 6277 | 10,09 | 10,01 |
| October | 5515 | 874 | 6310 | 10,53 | 12,17 |
| November | 4999 | 809 | 5588 | 9,54 | 12,65 |
| December | 4393 | 694 | 4910 | 8,39 | 12,38 |
| **Total** | **52383** | **7428** | **60559** | **100** | **10,93** |

Table 4. Frequency of road accidents by days of the week (2000–2019)

| Days of the week | Road accident | Deceased (except 2012, 2013 and 2019 years) | Traumatized (except 2012, 2013 and 2019 years) | % of the total number of road accidents | Coefficient of severity of road accident consequences (excluding 2012, 2013 and 2019 years) |
|---|---|---|---|---|---|
| Monday | 7755 | 1129 | 8378 | 14,80 | 11,88 |
| Tuesday | 7060 | 859 | 7174 | 13,48 | 10,69 |
| Wednesday | 6901 | 776 | 6750 | 13,17 | 10,31 |
| Thursday | 7052 | 766 | 7090 | 13,46 | 9,75 |
| Friday | 7782 | 958 | 7727 | 14,86 | 11,03 |
| Saturday | 7694 | 1058 | 7905 | 14,69 | 11,80 |
| Sunday | 8139 | 1146 | 8804 | 15,54 | 11,52 |
| **Total** | **52383** | **6692** | **53828** | **100** | **11,06** |

- ✓ October – 12,17;
- ✓ August – 11,37.

According to statistical data, among the months with the highest number of people killed in road accidents are October, August and November, with a share of 11,77% (average 46 per year), 11,01% (43) and 10,89% (43) respectively of the total number in the reference period, and among the months with the lowest share – February, March and January (4,95% (19), 5,75% (22) and 6,22% (24) respectively).

The monthly dynamics of those traumatized in road accidents place August, October and September in the first positions, with a share of 10,53% (on average 336 per year), 10,42% (332) and 10,37% (330) respectively from the total number in the reference period, and on the last positions, the same months as for the deceased persons – February, March and January (5,29% (169), 6,21% (198) and 6,27% (200) respectively).

The distribution of road accidents by the days of the week (*figure 10*) shows that the most dangerous from the point of view of road traffic were the days of:

- ➢ Sunday – 8139 road accidents (on average 407 per year (*table 4*), which is 15,54% of the total number of road accidents committed in the reference period), then follow the days of:
- ➢ Friday – 7782 (389 – 14,86%);
- ➢ Monday – 7755 (388 – 14,80%);
- ➢ Saturday – 7694 (385 – 14,69%).

At the same time, according to the severity of the consequences of the accidents in the reference period, the days were highlighted (except 2012, 2013 and 2019 years):

- ✓ Monday – 11,88;
- ✓ Saturday – 11,80;
- ✓ Sunday – 11,52;
- ✓ Friday – 11,03.

Following the analysis of statistical data, it was found that the highest number of people who died in road accidents were recorded on Sundays and Mondays, with a share of 17,12% (average 67 per year) and 16,87% (66) respectively from the total number in the reference period, and the days with the lowest share – Thursday and Wednesday (11,45% (45) and 11,60% (46) respectively). On Sundays and Mondays, with a weight of 16,36% (on average 518 per year) and 15,56% (493) respectively of the total number in the reference period of those traumatized in road accidents are placed on the first positions, and on the last, the same days as for the deceased, only in reverse order – Wednesday and Thursday (12,54% (397) and 13,17% (417) respectively).

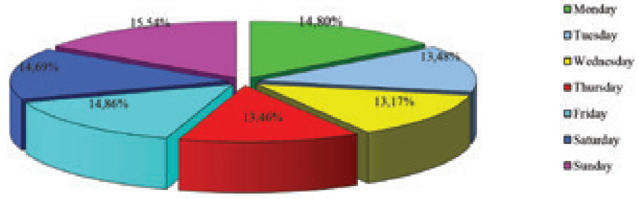


Fig. 10. Frequency of road accidents after weekdays (2000–2019)

The distribution of road accidents after the hour of happening (*figure 11*) shows that the most dangerous from the point of view of road traffic were the periods:

- ➢ 18–20 – 7533 road accidents (on average 377 per year (*table 5*), which constitutes 14,38% of the total number of road accidents committed in the reference period);
- ➢ 16–18 – 7153 (358 – 13,66%);
- ➢ 20–22 – 5883 (294 – 11,23%);
- ➢ 00–06 – 5801 (290 – 11,07%).

At the same time, according to the severity of the consequences of the accidents during the reference period, the hours were highlighted (except 2012, 2013 and 2019 years):

- ✓ 00–06 – 15,73;
- ✓ 22–24 – 14,47;
- ✓ 20–22 – 14,46;
- ✓ 18–20 – 12,46;
- ✓ 06–08 – 11,14.

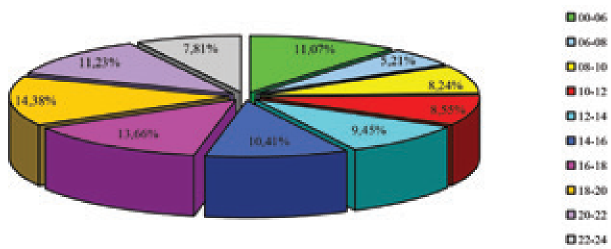


Fig. 11. Frequency of road accidents after daylight hours (2000–2019)

Table 5. Frequency of road accidents by day (2000–2019)

| Day time | Road accident | Deceased (except 2012, 2013 and 2019 years) | Traumatized (except 2012, 2013 and 2019 years) | % of the total number of road accidents | Coefficient of severity of road accident consequences (except 2012, 2013 and 2019 years) |
|---|---|---|---|---|---|
| 00–06 | 5801 | 1234 | 6612 | 11,07 | 15,73 |
| 06–08 | 2727 | 386 | 3080 | 5,21 | 11,14 |
| 08–10 | 4315 | 354 | 4571 | 8,24 | 7,19 |
| 10–12 | 4479 | 325 | 4571 | 8,55 | 6,64 |
| 12–14 | 4948 | 395 | 4887 | 9,45 | 7,48 |
| 14–16 | 5451 | 421 | 5617 | 10,41 | 6,97 |
| 16–18 | 7153 | 841 | 7149 | 13,66 | 10,53 |
| 18–20 | 7533 | 1042 | 7323 | 14,38 | 12,46 |
| 20–22 | 5883 | 978 | 5786 | 11,23 | 14,46 |
| 22–24 | 4093 | 716 | 4232 | 7,81 | 14,47 |
| **Total** | **52383** | **6692** | **53828** | **100** | **11,06** |

Table 6. Frequency of road accidents involving pedestrians (2000–2018)

| Year | Road accidents involving pedestrians | % of the total number of road accidents | Road accidents involving children | % of the total number of road accidents |
|---|---|---|---|---|
| 2000 | 1269 | 49,19 | 491 | 19,03 |
| 2001 | 1237 | 46,40 | 496 | 18,60 |
| 2002 | 1369 | 47,22 | 518 | 17,87 |
| 2003 | 1289 | 48,28 | 440 | 16,48 |
| 2004 | 1122 | 45,85 | 373 | 15,24 |
| 2005 | 1041 | 45,48 | 342 | 14,94 |
| 2006 | 1006 | 43,78 | 316 | 13,75 |
| 2007 | 1054 | 43,25 | 360 | 14,77 |
| 2008 | 1079 | 37,53 | 635 | 22,09 |
| 2009 | 1066 | 38,69 | 536 | 19,46 |
| 2010 | 1071 | 36,55 | 544 | 18,57 |
| 2011 | 1006 | 35,60 | 564 | 19,96 |
| 2012 | 935 | 34,48 | 557 | 20,54 |
| 2013 | 980 | 37,65 | 485 | 18,63 |
| 2014 | 886 | 34,56 | 411 | 16,03 |
| 2015 | 831 | 32,88 | 357 | 14,13 |
| 2016 | 835 | 33,68 | 387 | 15,61 |
| 2017 | 997 | 37,77 | 371 | 14,05 |
| 2018 | 946 | 36,20 | 414 | 15,84 |
| **Total** | **20019** | **40,19** | **8597** | **17,26** |

- exceeding the established speed and speed inappropriate to the road conditions;
- non-compliance with handling rules;
- not giving priority to pedestrians;
- drunk driving.

Road accidents involving pedestrians constitute about 40% (2000-2018) of the total number of accidents (*table 6*) [5][25]. Most accident situations are characteristic of localities, where their share is much higher. They are created in places where pedestrians frequently appear at pedestrian crossings, road vehicle stations, intersections, markets, places often frequented by children etc. Every ninth road accident was caused by pedestrians (5357, or 10,75% of the total number of road accidents during the years 2000-2018) [5][25].

According to the statistical data, among the time intervals with the highest number of people who died in road accidents, the time intervals between 00-06, 18-20 and 20-22 stand out, with a share of 19,17% (in 73 per year per year), 16,19% (61) and 15,19% (58) respectively of the total number in the reference period, and among the time intervals with the lowest share – 10-12 and 08-10 (5,05% (19) and 5,50% (21) respectively).

For those traumatized in road accidents on the first positions are the time intervals between 18-20, 16-18 and 00-06, with a weight of 14,16% (on average 431 per year), 13,82% (421) and 12,78% (389) respectively of the total number in the reference period, and on the last positions – 06-08 and 22-24 (5,96% (181) and 8,18% (249) respectively).

According to statistics, most of the number of road accidents occurred through the fault of drivers: 44886 (on average 2244 per year, which is 85,69% of all road accidents committed in the country during the years 2000-2019).

Analyzing the violation of traffic rules committed by drivers, which lead to road accidents, it was found that the highest number of accidents occurred as a result of the following causes:

The violations committed by pedestrians that led more frequently to road accidents were:

- crossing the street without being insured beforehand;
- crossing the street in forbidden places;
- irregular driving on the road;
- unexpected exit from vehicles, obstacles.

The number of road accidents in which children suffered is 8597 or 17,26% of the total number of road accidents, as a result of which 602 or 8,11% of the total number lost their lives and 8757 children or 14 were traumatized 46% (*figure 12*). 1810 road accidents were the children's fault. 114 of them died and 1682 children were traumatized. More than half of those killed and traumatized in road accidents are people aged 30-64, followed by those aged 17-24, 24-30 and 64+, together accumulating about 30% of the number of people died and traumatized in road accidents. Referring to the location of road accidents on a national level, it is found that the most frequent events occur in localities, over 70% of the total number of road accidents. Most road accidents were registered in

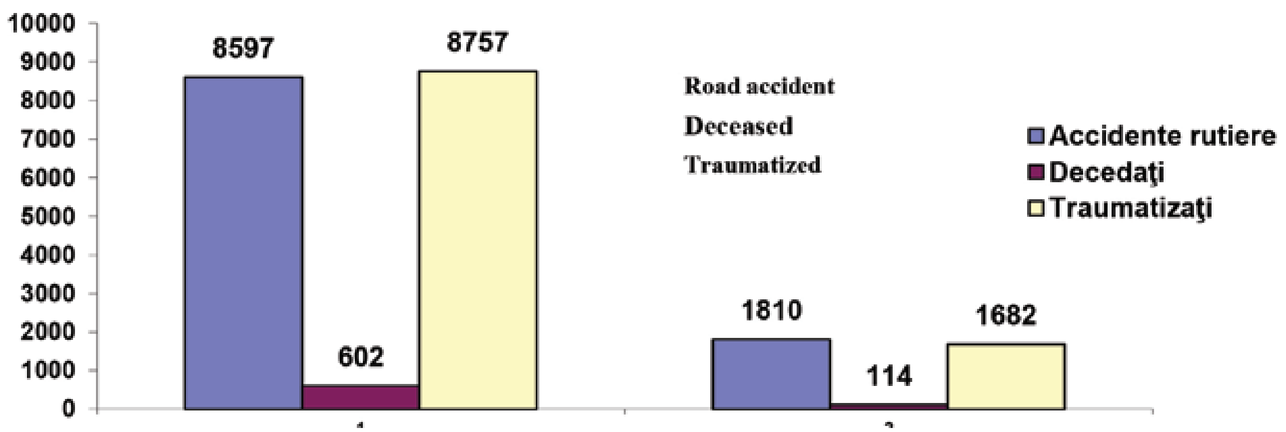


Fig. 12. Children who suffered in road accidents (2000–2018)

*Chisinau*, over 45%, followed by *Orhei*, *Balti*, *Ialoveni*, *ATU Gagauzia*, with a share of 3-5% each.

Lately, road accidents involving public transport is growing steadily from year to year. Most cases involving public transport take place in *Chisinau*.

## 3. CONCLUSION

The analysis of road accidents worldwide, European, and national in the reference period, is largely superficial and does not provide a clear answer about the model, which determines the number of victims. For detailed investigation, systematic information is not sufficient, such as the circumstances of the traffic accident, the location and time when they occurred, the causes and factors that contributed, the condition of the driver, the vehicle etc. Every 23 seconds a person dies on the roads around the world. The statistics of road accidents are alarming, about 1,4 million people die, and another up to 50 million are seriously traumatized. The experience of many separate countries shows that these tragedies can and must be stopped.

In this context, the *United Nations* (*UN*) *General Assembly* considers road mortality and road accident injuries an obstacle to the achievement of the *Millennium Development Goals*. As is well known, to solve this extremely important problem of modern society, the *UN* in collaboration with the *WHO* has proclaimed the years 2011-2020 as a *Decade of Actions for road traffic safety*, globally. The primary goal of this *Decade* is to significantly reduce the number of road disasters, namely by taking various measures at the national level in each state. At the same time, to achieve the objectives, the *Global Plan for the Decade of Action for Road Safety 2011-2020* was elaborated, which provides a general framework of activities over the years, improving the safety of road infrastructure and transport networks, developing vehicle safety systems, improving the behavior of road users, as well as the improvement of post-accident assistance systems [26]. Thus, in 2011 the *Republic of Moldova* together with hundreds of states around the world committed itself to fight against the neglect of the field of road traffic safety and to draw special attention to these catastrophes, which bring great damage to both Public Health and National Economy. Starting from the importance of human life and state responsibilities in this regard, following the signing by the *Republic of Moldova* of the *UN Resolution* on the declaration of the years 2011-2020 *„Decade of actions in the field of road safety"*, by Government Decision nr. 1214 of December 27, 2010, the *National Strategy for Road Safety* (*SNSR*) was approved, and on December 21, 2011, by Government Decision nr. 972 of 21.12.2011, the Action Plan on the implementation of *SNSR* was approved [23][24][27].

The goal of reducing the number of road deaths by 50% by 2020 has not been achieved globally or nationally. But this should not be an obstacle to continuing the fight and achieving the proposed goal in the next decade. In this context, it should be mentioned that the activity in the field of road traffic safety is a complex one and requires the involvement of the authorities from the central, local level to the civil society and each person.


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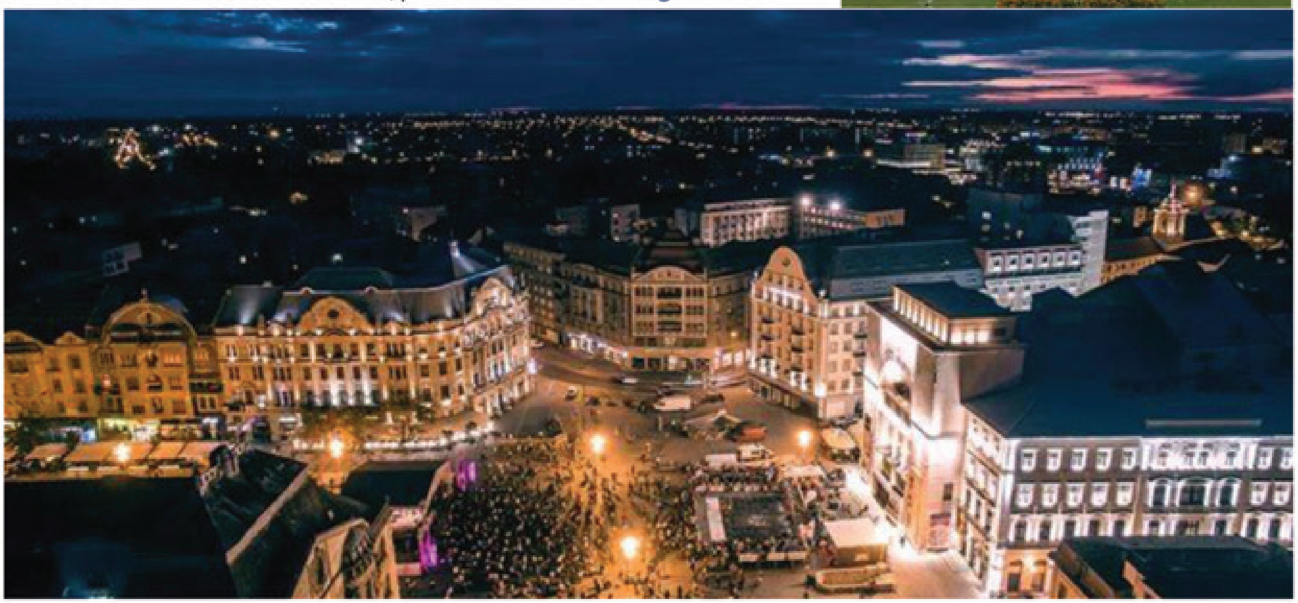

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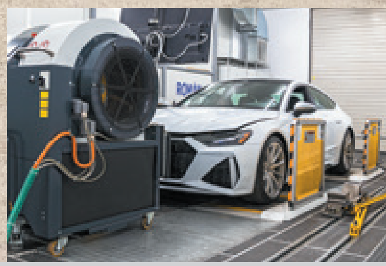


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