applied sciences

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Editorial

Advances in Vehicle Dynamics and Road Safety: Technologies, Simulations, and Applications

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1. Introduction

Alongside various road safety aspects, vehicle dynamics play a crucial role in enhancing the quality of life in modern society within a holistic traffic safety framework [1]. According to a report by the World Health Organization, the number of road accident fatalities has been gradually declining worldwide, but the 1.19 million lives lost on the roads and the disparity in crash rates among different regions remain disproportionately high, considering technological advancements and the vast resources allocated towards road safety [2]. The risks posed by different road transport systems are particularly relevant in the context of increasing mobility and travel. The main pillars for Safe System Approach (SSA) in terms of road safety cover safe road users, vehicles, speeds, roads, and post-crash care; moreover, the potential of the SSA is further enhanced by safety systems based on modern technologies such as vehicle active and passive safety [3–5], advanced driver-assistance systems (ADAS) [6,7], computer-based accident and systems operation simulations and co-simulations [8–10]. A separate and distinct focus on achieving Vision Zero on the road [11] relates to autonomous vehicle control technologies [12,13].

While the behavior of road users is widely acknowledged as a significant factor contributing to contributory accidents [14], the interaction between vehicles, road users, and the road itself (the traffic environment) is considered to be a more rapid, engineered element affecting road safety [15–17]. It is important to recognize that the vehicle plays a key role in interactions with both the driver and the road, so the comprehensive development of safety technologies can help to further reduce road accidents. From this perspective, the technological development of various aspects of vehicle dynamics leads to both safety and sustainability aspects in road transportation [18,19].

A new approach involving modern technologies such as optimization techniques, artificial intelligence, efficient complex computational algorithms, or advanced decision-making models is needed to solve both classical automotive dynamics or road safety issues as well as the transport problems of today or the near future. In this scope, the presented Special Issue summarizes research focusing on vehicle dynamics and road safety issues, including advanced technologies, simulations, and the practical application of various technical solutions. The methods presented not only speed up the problem-solving process, but the methods developed allow the inclusion of many more variables by linking the study to modern complex problems. Depending on the specific publication of this issue, new variables used include different driver models (with a steering and braking feel approach), the effect of crosswinds on vehicle stability, specific vehicle properties (kinematics, compliance, and tire model), or the design of an artificial neural network. The proposed research articles also cover real-life issues of safe and effective cargo transportation, road accident research, vehicle technical reliability, or inspections where modern tools and intelligent process management are implemented. However, current research cannot be imagined without virtual or simulation models applicable for the development of autonomous driving, vehicle chassis design, or traffic situations.

Citation: Sokolovskij, E.; Žuraulis, V. Advances in Vehicle Dynamics and Road Safety: Technologies, Simulations, and Applications. *Appl. Sci.* **2024**, *14*, 3735. https://doi.org/10.3390/app14093735

Received: 15 April 2024
Revised: 23 April 2024
Accepted: 24 April 2024
Published: 27 April 2024

This Special Issue contains twenty-three articles, a brief overview of which is presented in the second chapter. The purpose of this review is to encourage readers to delve deeper into specific research on the topic of vehicle dynamics and road safety, sharing the latest research in the field.

2. An Overview of Published Articles

The article by Islam et al. (contribution 1) explores the correlation between annual road accidents and various indicators, such as demographics, economics, passenger and freight movement, as well as investment in road infrastructure. Their study utilizes artificial neural networks, multiple linear regression, and Poisson regression analysis techniques.

In the second article published in this Special Issue, Woo et al. (contribution 2) address the problem of the increasing complexity of vehicle development by employing a virtual prototype to set chassis design targets for high-performance cars. Their proposed methodology eliminates the process of trial and error, allowing them to achieve significant savings.

Li et al. (contribution 3) introduced a multi-object PID differential braking-control approach aimed at enhancing the yaw stability and path-tracking performance of liquid tank semi-trailers on low-adhesion roads while turning. This approach uses the tractor yaw rate, semi-trailer yaw rate, and articulation angle as control parameters. Simulation results show that the proposed approach can effectively improve the yaw stability and path-tracking performance of liquid tank semi-trailers during turns on low-adhesion roads.

El Hajjami et al. (contribution 4) developed an innovative adaptive sliding mode controller in observance of the robust law to address disturbances and uncertainties in the longitudinal dynamics of autonomous ground vehicles. The effectiveness and advantages of this approach were assessed through simulations and comparative studies.

In his article, Gorzelańczyk (contribution 5) attempts to forecast the number of road accidents by state in Poland. He conducted an analysis of the annual data of police statistics on the number of road accidents in Poland for the period from 2000 to 2021, also analyzing the number of road traffic accidents in Poland upon the prediction of the number of traffic accidents in 2022–2031. The results of this study reveal that a decrease in the number of accidents is also expected in the upcoming years.

The aim of the sixth article by Tian et al. (contribution 6) is to effectively assess the impacts of various driving conditions on the lateral stability of vehicles, producing a practical recommendation for pavement maintenance when it comes to rutting. The results show that the devised methodology demonstrates satisfactory performance in evaluating the effect of various impact factors on the lateral stability of vehicles when traversing rutted roads. The outcomes of this research may contribute to the provision of guidelines for controlling the main adverse conditions and making decisions on pavement maintenance.

The research by Batarlienė and Bazaras (contribution 7) focuses on heavy transport, which disrupts supply systems and affects timely customer service. The article aims to analyze the hurdles of the first and last mile and the role and significance of heavy transport in urban logistics. Based on the research results, the authors propose a recommendation for the development of small cargo collection and distribution services using self-service terminals located on the outskirts of cities.

Vaičiūnas et al. investigate the consistency of rail wheel damage measurements (contribution 8) in their articles. The authors analyzed the repeatability of measurements concerning the dependence of the vertical force on wheel-rolling surface damage and proposed methods to enhance consistency. Their article presents the dependence identified by the authors and discusses how the repeatability of wheel damage measurement is influenced by the speed of the rolling stock.

The article by Qin et al. (contribution 9) analyzes the lateral instability mechanism and influencing factors of the civil aircraft towing taxi-out system using computer virtual simulation technology, with Boeing 737–400 and AM210 tractors as focal points. The results reveal that the "jack-knifing" phenomenon is attributed to the lateral instability of the system when the sliding speed exceeds 15 km/h, accompanied by lateral slip conditions.

The conclusion of this study may provide a theoretical basis and guidance for the safe application of the new taxi-out departure mode.

In their article, Alomari et al. (contribution 10) investigated the potential impacts of speeding violations in the United States, encompassing the top ten states with the highest crash rates. Several variables associated with drivers, surroundings, vehicles, roads, and weather were investigated. Three different machine learning algorithms were used to predict speeding violations. The research results revealed that age, accident year, road alignment, weather conditions, the time of the accident, and speed limits are the key factors. Understanding how these factors affect speeding violations helps decision-makers devise strategies to reduce these violations and enhance road safety.

In the eleventh article, Koné et al. (contribution 11) present a novel method aimed at assessing the sensitivity of autonomous vehicles to logical situations and events before their use to generate specific scenarios for simulators. They proposed a characterization of the inputs used in sensitivity analysis and an approach to establishing a distribution function that facilitates the selection of situations and events based on their importance in terms of sensitivity.

Matijošius et al. (contribution 12) conclude that determining the priority of the forces that act on vehicles transporting wooden logs is crucial for accurately modeling the transport parameters of this cargo. The authors of the article use an analytical survey, an expert survey, and its analysis, as well as various methods to determine correlations. The research results revealed that the main forces that affect vehicles transporting logs manifest in the following order of priority: inertial forces, gravity forces, frictional forces, and centrifugal forces.

Innovative pre-crash systems are expected to contribute to mitigating unavoidable accidents. However, there are no standardized testing methods for pre-crash systems. In their work, Putter et al. (contribution 13) propose a novel validation and safety assessment strategy for a perception-based crash severity prediction function. The authors present an innovative unsupervised machine learning methodology for generating specific and logical test scenario catalogs leveraging K-Means++ and k-NN algorithms.

The article by Barbosa et al. (contribution 14) introduces a multidisciplinary approach aimed at understanding the impacts of rising temperatures on the retention of particulate pollutants, including heavy metals and microplastics, within road pavement materials. A soil with a particle size distribution similar to road dust was chosen for the analysis. The analysis results confirm that the viscoelastic properties of bituminous mixtures can contribute to retaining particles within the pavement under increased temperatures. The article paves the way for the development of innovative road pavement bituminous mixtures that can minimize the release of road particulate pollutants, enhancing resilience and sustainability under extreme weather conditions.

The work by Wang et al. (contribution 15) presents a five-degree-of-freedom nonlinear dynamic model of a vehicle with braking torque, transforming the model into an equivalent system in application of the D'Alembert principle. The equilibrium points of the equivalent system are determined by employing an improved hybrid algorithm that combines the genetic algorithm and the sequential quadratic programming method. By analyzing the bifurcation characteristics of the equilibrium points, the stability boundary at the specified initial longitudinal velocity is determined, establishing the three-dimensional stability region. The results reveal that with increasing braking torque, the number of equilibrium points increases from one to three. The proposed equilibrium bifurcation method effectively addresses the stability region of the equivalent system, with solution results aligning consistently with those of the original system stability region.

The paper by Tapak et al. (contribution 16) presents the key findings of the use of smart phone applications in the periodic technical inspection process. The authors noticed that advancements in smart technologies allow for improving the efficiency and effectiveness of vehicle inspections. They specifically focused on the Republic of Slovakia, describing the transition of technical inspections towards smart technologies in this country. The aim

was to exploit new technologies and improvements without a dramatic increase in costs. The paper discusses the outcomes of the first two years of using this application at every technical inspection station in Slovakia.

The main objective of the research by Islam and Gazder (contribution 17) was to evaluate and rank the important and supporting factors influencing traffic crashes on the road. To identify the key causes of accidents, the proportion-based analytic hierarchy process was used to order the factors in terms of their relative importance. The city of Al-Ahsa (Saudi Arabia) was used in the research.

In their research, Qu et al. (contribution 18) introduce a decision model based on the lane-changing game characteristics of intelligent connected vehicles aimed at studying the lane-change interaction characteristics of intelligent connected vehicles and mitigating the risk associated with vehicle lane-changing decisions. The results show that the decision-making system based on the lane-changing characteristics of intelligent connected vehicles converges to various optimal strategy combinations under different traffic conditions. This model effectively alleviates decision-making conflicts and reduces the risk of vehicle collisions.

The research conducted by Woo et al. (contribution 19) aims to explore steering feel by examining a steering system and the logic behind electric power steering. Steering feels defined based on prior research and is discussed along with methods for its evaluation. Through a sensitivity analysis involving modeling of both our developed vehicle and a competitor renowned for its exceptional steering feel via a multi-body simulation, the authors propose a straightforward method for determining parameters associated with steering feel to achieve the desired steering characteristics. By modifying the electric power steering control system, the authors successfully achieve a steering feel in the vehicle that meets the desired steering characteristics.

The study by Li et al. (contribution 20) delved into the impact of pavement aggregate grain size on the interaction between tires and pavement during the late stages of pavement skid resistance. A three-dimensional finite element tire–pavement contact model developed using ABAQUS was used to analyze the contact interaction between each simplified pavement type and the tire under conditions of steady-state rolling and braking. The concept of occlusal depth was proposed and used to characterize pavement skid resistance. The results revealed that under steady-state rolling conditions, the maximum contact stress of the simplified pavement rose with the mean texture depth of the pavement, while the contact area decreased.

In his paper, Santarsiero (contribution 21) aims to list the technical problems and solutions in bridge refurbishment interventions for increasing traffic safety, such as, for example, installing code-conforming railings, which often require structural retrofit of bridge elements supporting the railing. The researcher describes several technical solutions, presenting their critical comparison. The economic analysis conducted highlights the impact of the slab retrofit on the total cost of the intervention.

The study by Tunay et al. (contribution 22) aimed to find out how steering inputs by drivers affect the dynamic reaction of a heavy-ground vehicle to crosswinds. They used a two-way interaction between vehicle dynamics and aerodynamic simulations in their research. The steering inputs of drivers were modeled using a driver model taken from prior research presented in the literature, allowing for the reproduction of the steering responses of a human driver. The findings of the study revealed that the steering inputs made by drivers have a significant impact on vehicle response to crosswinds.

The research conducted by Čižiūnienė et al. (contribution 23) employed theoretical methodologies to characterize the primary force exerted by vehicles in the transportation of bulk and liquid commodities. Expert assessment was used to determine the significance of indicators related to individual criteria that affect the transportation of bulk and liquid cargoes, along with the identification of their interrelationships. This involved comparing various factors in the transportation process of bulk and liquid cargoes, such as the different

forces involved, criteria like centrifugal force, hazardous factors, critical tank filling levels, and factors affecting vehicle dynamics.

3. Conclusions

The topics of this Special Issue cover a wide range of modern engineering-based technologies and measures applied to tackle road safety issues or enhance ride comfort through land transport. Road accident statistics oblige us to act in all areas concerned; thus, the development of research on vehicle dynamics, together with the incorporation of new phrases such as artificial neural networks or autonomous driving, must be continuously pursued. This Special Issue allows readers to choose and explore scientific trends on the topic of their personal interest, discover a contemporary critical approach, and become familiar with the proposed research methods.

In summary, the articles collected in this Special Issue represent the latest research in the field of vehicle dynamics and road safety. The authors of the articles represent different countries in the world, and the geography of the publications is very wide. Therefore, readers have the opportunity to familiarize themselves with the progress and achievements of individual countries in this field and to assess the peculiarities, similarities, and differences of the solutions applied in different countries. Thus, this Special Issue is not limited to the context of a specific country or region but presents much broader insights into the issues of vehicle dynamics and road safety. Nevertheless, the themes with the greatest potential for scientific growth, which are also included in this publication, must be highlighted. Thus, it is important to highlight the publication's coverage of advanced solutions for autonomous driving research, climate change aspects in transport, vehicle functional safety, and driver assistance systems based on prediction or machine learning techniques.

Conflicts of Interest: The authors declare no conflicts of interest.

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