Original Research Article

The Positive Impacts of Artificial Intelligence in Highway Transport

ABSTRACT

This Master's thesis titled "The Positive Impacts of Artificial Intelligence in Highway Transport," explores the transformative effects of artificial intelligence in highway transport from the perspective of users and stakeholders. Focusing on key areas such as traffic control/management, smart traffic lights, predictive maintenance, and autonomous vehicles [7][8], the study employs an in-depth survey analysis using questionnaires. Results indicate notable improvements, with a 24.9% increase in traffic safety, 23.6% reduction in congestion, 15% boost in mobility, 14.7% enhancement in sustainability, and a 21.7% increase in efficiency. These findings offer insights into user/stakeholder perceptions of current artificial intelligence applications in highway transport and their potential benefits. The thesis also evaluates limitations to artificial intelligence implementation in highway transport, providing valuable perspectives for policymakers, industry stakeholders, and researchers.

Keywords: Artificial Intelligence; highway transport; positive impacts; autonomous vehicles; sustainability; congestion; mobility; stakeholders.

1. INTRODUCTION

Transportation is an essential aspect of human life, enabling the movement of people and goods from one place to another. Transport is one of the main pillars of our society. The ubiquitous availability of transport opportunities and the possibility to reach almost any place in the world in a limited amount of time has fuelled and sustained globalization and the unprecedented economic growth of the last century [1]. The challenges that transportation specialists confront includes poor safety record, CO2 emissions, wasted energy, capacity problems and unreliability. The interest of transportation researchers and practitioners in applying artificial intelligence models to address some of the aforementioned difficulties has grown in recent years to improve the safety, efficiency, and environmental compatibility of transportation systems[7][8][9]. Highway transportation is the backbone of the global transportation system, accounting for more than 90% of total transportation worldwide. However, the highway transport system is facing numerous challenges, including traffic congestion, air pollution, accidents, and deteriorating infrastructure.

European Commission (2019f) describes Artificial Intelligence as systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals [2]. One of the prime areas where artificial intelligence will make its most paradigm-shifting impact is transport [3]. Promising artificial intelligence applications in mobility and

logistics are, for example, self-driving vehicles (cars, trucks, trains, barges), smart electric charging, predictive maintenance, self-learning energy and emission management, cooperative mobility, sharing economy and self-organising logistics [2]. This new breed of artificial intelligence-based mobility, despite its machine-orientation, has to be a user-centred technology that “understands” and “satisfies” the human user, the markets and the society as a whole [3].

Some of the current state-of-the-art artificial intelligence applications in highway transport that will be discussed in the research paper are as follows; Traffic Control/Management And Smart Traffic Lights, Autonomous Vehicles, Predictive Maintenance in Asset Management
The market for artificial intelligence technologies for traffic management is confidently leading in the field of hardware sales. This market segment is becoming a key aspect of traffic management. The data captured by the hardware is the backbone of the intelligent traffic system functions. The hardware includes sensors, outdoor cameras, automatic identifiers and vehicle locators using GPS (Global Positioning System) [4].
Autonomous Driving is arguably the next disruptive innovation[5].Predictive maintenance is the continuous monitoring of an asset's or system's condition throughout its life cycle in order to forecast when maintenance is required[11][12]. Predictive maintenance and asset management are critical components of highway transport, which can be significantly improved with the application of Artificial Intelligence.

2. METHODOLOGY

Survey Design and Questionnaire Structure

The survey questionnaire was meticulously designed to encompass diverse aspects of artificial intelligence applications in highway transport. It consisted of a total of 20 questions, divided into four sections:

Section 1: Demographic Information (3 questions)

This section will collect information about the participants, such as their age, gender, and occupation.

Section 2: Current State-of-the-Art Artificial IntelligenceApplications (5 questions)

This section will gather information on the current state-of-the-artartificial intelligence applications in highway transport and their effectiveness in improving safety, reducing congestion, and enhancing the overall efficiency of transportation systems.

Section 3: Benefits of Artificial Intelligence in Highway Transport (7 questions)

This section will examine the potential benefits of using artificial intelligencein highway transport, such as improving safety, reducing congestion, and enhancing the overall efficiency of transportation systems.

Section 4: Challenges and Limitations (5 questions)

This section will investigate the challenges and limitations of implementing artificial intelligence in highway transport, such as technical limitations, regulatory barriers, and ethical considerations.

The survey questions will be designed to ensure that the responses provide the necessary information to address the research questions and achieve the research objectives.

Survey Distribution

Utilizing digital platforms like Jot form, the survey was disseminated across various online channels, including social media, transportation forums, academic networks, and industry-specific groups. The survey was accessible for a predetermined period to obtain a broad and representative sample.

Data Analysis:

The data collected through surveys, will be analysed using descriptive statistics and Microsoft Excel as the tool for analysis. Descriptive statistics will be used to summarize and present the survey results.

MATHEMATICAL MODEL

This model is for further research.To represent my thesis results in the multiple regression model, numerical values can be assigned to each category and create a model based on the reported percentages [6]. Let's assume the positive impact of artificial intelligence in highway (Y) is influenced by the percentage of respondents mentioning each artificial intelligence application.

The model would look like this:

$$Y = b0 + b1X1 + b2X2 + b3X3 + b4X4 + \varepsilon$$

Where:

Y is the positive impact on the highway.
$b0$ is the y-intercept, representing the baseline positive impact when all variables are zero.
$b1$ represents the impact of autonomous vehicles on Y.
$b2$ represents the impact of intelligent traffic management systems on Y.
$b3$ represents the impact of predictive maintenance systems on Y.
$b4$ represents the impact of smart traffic lights on Y.
$X1$, $X2$, $X3$, $X4$ are the percentages of respondents mentioning each artificial intelligence application, respectively
ε is the error term.

Now, interpret the coefficients $b1$, $b2$, $b3$, $b4$ to understand the relative impact of each artificial intelligence application on the positive impact of artificial intelligence in highway transport. This model allows you to quantify and analyse the contributions of different artificial intelligence applications, providing valuable insights for highway engineering.

3. RESULTS AND DISCUSSION

Current Artificial Intelligence Applications in Highway Transport

Figure 1. showcases the prevalence of various artificial intelligence applications in highway transport as per the respondents' feedback. It's evident that smart traffic lights received the highest acknowledgment by 84 respondents, making up 36.5%. Predictive maintenance systems by 37 respondents, comprising 16.1% and no respondents reported using other artificial intelligence applications in highway transport.

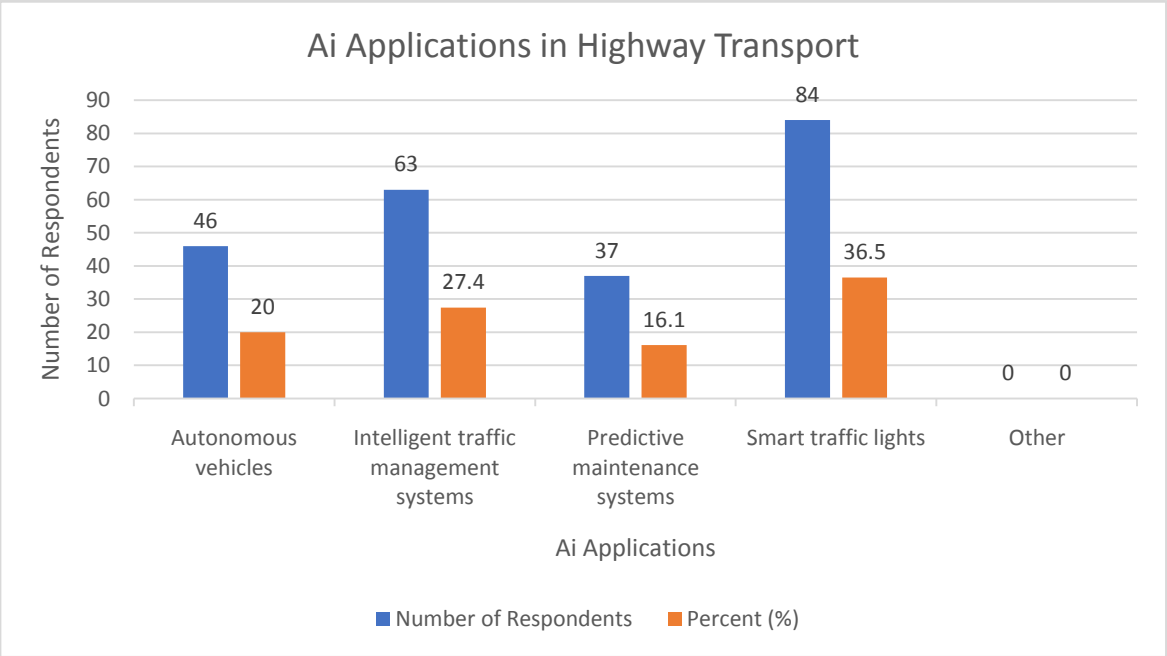

Fig. 1. AI Applications Chart

Perception of Potential Benefits of Using Artificial Intelligence in Highway Transport
Figure 2. showcases the potential benefits of using artificial intelligence in highway transport as perceived by the respondents. Improved safety and reduced congestion emerged as the most acknowledged benefits, closely followed by improved efficiency. Increased mobility and enhanced sustainability were also recognized but to a somewhat lesser extent.

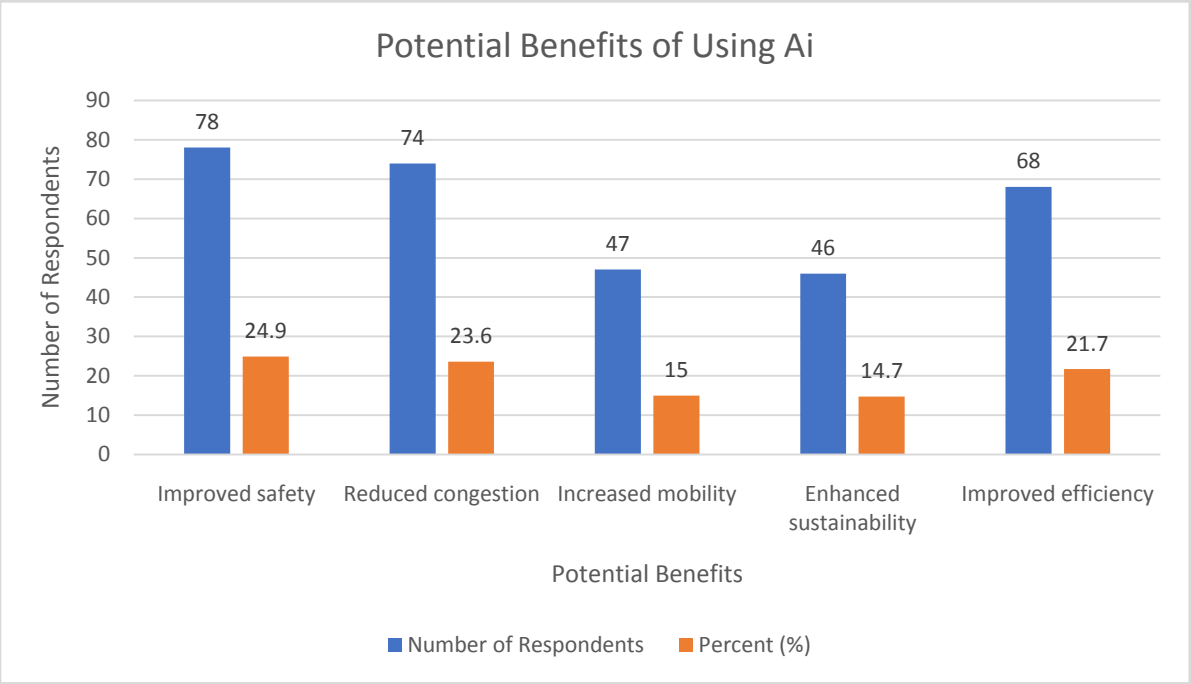

Fig. 2. Potential Benefits Chart
Addressing Risks and Limitations

The responses from the research survey signify various strategies suggested by respondents to mitigate the risks and challenges associated with implementing artificial intelligence in highway transport (Figure 3). The recommendations largely centre on regulatory frameworks, enhanced cybersecurity, algorithm transparency, and public engagement to address ethical concerns.

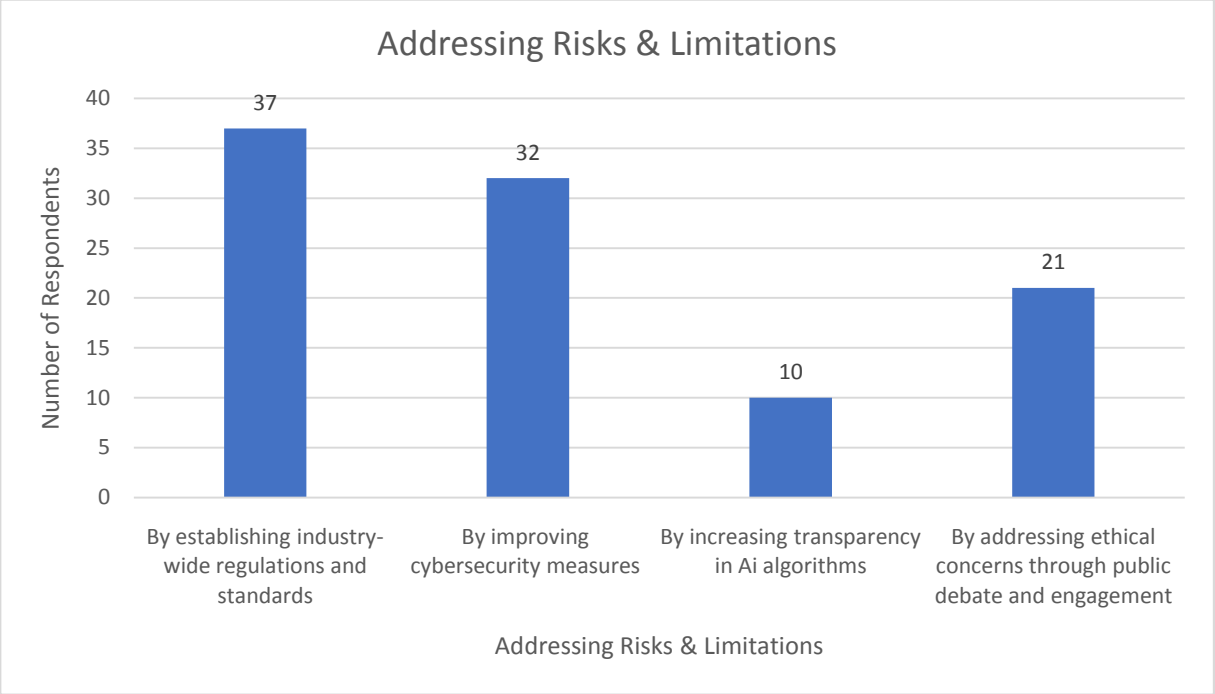

Fig. 3. Addressing Risks and Limitations Chart

4. CONCLUSION/DISCUSSION

With the primary aim of this research in mind which is to analyse and present the positive impact of artificial intelligence in highway transport from a stakeholder perspective, the summary of the results gotten from the analysis is discussed below.

The demographics results of this research survey shows that the participants weremajorly from age groups 20-29 and 30-39 while a lower percentage was from ages 40-49 and 50 above. This shows that the perception of artificial intelligence's positive impact in highway transport stems from amore tech-oriented and adaptable age group. From the analysis, 71% out of the 100 participants in the survey makes up the male gender and this is because the target audience for this research survey was majorly highway transport professionals which is evident in the occupational distribution with 60% responses from engineers which we all know is amale-dominated the time of this publication.The mathematical model is for further research. It comes into play when you want to represent the thesis results gotten from the survey in a multiple regression model. This model allows you to quantify and analyse the contributions of different AI applications, providing valuable insights for highway engineering.

Current State-of-the-art Artificial Intelligence Applications In Highway Transport

From the results, it's evident that the perceived current artificial intelligence applications in highway transport are smart traffic lights (36.5%.), autonomous vehicles (20%), intelligent traffic management systems (27.4%), and predictive maintenance systems (16.1%). These Artificial Intelligence applications has been reviewed by different other researchers [10][11][12] and holds great potential. The perception of these artificial intelligence applications' effectiveness in enhancing safety, reducing congestion and enhancing the overall efficiency of highway transport was majorly between "somewhat likely", "very likely" and "neutral". These responses show that there is a lot of optimism as regards artificial intelligence's positive impact in highway transport, also the respondents are open minded and willing to embrace these new technologies. Also, there is need for further research and awareness of how artificial intelligence can be positively impact the transport industry, particularly highway/road transport.

Benefits Of Using Artificial Intelligence In Highway Transport

In this research we focused on improved safety, reduced congestion and overall efficiency as the main areas of artificial intelligence positive impact in highway transport [7][8][9]. From the results, the perception of respondents show that reducing the number of human errors (38 respondents) and providing real-time traffic updates (37 respondents) are the major ways artificial intelligence can improve safety in highway transport. Optimizing traffic flow and providing alternative routes to avoid congestion are the major ways respondents (44 & 39 respondents respectively) perceive artificial intelligence to reduce congestion in highway transport. The results show that majority of the responses (65 out of 100 respondents) perceive that optimizing public transportation routes and schedules will enhance the overall efficiency of highway transport. From these results, it shows major areas users/stakeholders perceive artificial intelligence can be beneficial and also traffic issues that needs to be addressed from a user focused perspective.

Challenges And Limitations Of Implementing Artificial Intelligence In Highway Transport

From the various papers reviewed in this research [5], shows that there are different challenges facing the implementation and adoption of Artificial Intelligence in highway transport. This research focused on technical limitations, regulatory barriers and ethical barriers. The results of the survey conducted, shows the diverse perception of barriers to implementing artificial intelligence highway transport and more importantly various ways to address these issues which are; establishing industry-wide regulations and standards, improving cybersecurity measures, increasing transparency in artificial intelligence algorithms, addressing ethical concerns through public debate and engagement.

RECOMMENDATIONS

The recommendations for policymakers and transportation authorities to maximize the positive impact of artificial intelligence in highway transport are as follows;

1. Create awareness of artificialintelligence technology in the highway transport sector and provide resources/facilities for further research of how artificial intelligence positively impact the industry.
2. Partnership between research and automobile companies in order to address some of the technical issues facing the implementation of artificial intelligence in highway transport such as data privacy concerns.
3. Development of industry-wide standards and guidelines for the advancement and operation of autonomous vehicles and other artificial intelligence technologies in highway transport.
4. Training and equipping of talent with skills in the current artificial intelligence technologies
5. Engagement and cooperation between the public, government and transport industry in order to address some of the ethical concerns such as job displacement for human drivers.

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