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Exploring the social impacts of adopting autonomous vehicles in the supply chain

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Abstract (Structured abstract is submitted in another document)

Introduction

Autonomous vehicles (AVs) have served the logistics sector in the form of automated guided vehicles (AGVs) for decades. With the advent of Industry 4.0 (In 4.0 – the Fourth Industrial Revolution) in 2011, significant advances have been witnessed (Schwab, 2016). Rapid development of innovations such as robots and drones indicates wider adoption across the industry (Tang and Veelenturf, 2019). Logistics giants such as Alibaba and JD.com in China, and DHL and Amazon in Europe and the USA are applying or testing autonomous vehicles for use in supply chain processes including distribution and storage (Merlino and Sproģe, 2017; Mohamed *et al.*, 2020). Further, Zipline is a successful drone delivery service provider in medical supplies for African countries (Scott and Scott, 2017). However, compared with the rapid progress of technology, current academic research and development of knowledge in this area is lagging behind (Van Meldert and De Boeck, 2016; Monios and Bergqvist, 2020), especially in freight transport (Flämig, 2016; Van Meldert and De Boeck, 2016). Previous studies have focussed particularly on developing the drone Vehicle Routine Problems (VRP) or Travelling Salesman Problem (TSP), to minimise costs and negative environmental externalities from a number of perspectives (Murray and Chu, 2015; Ha *et al.*, 2018). These studies have demonstrated significant positive economic and environmental sustainability performance (Tang and Veelenturf, 2019). The social perspective has received less focus.

There are a number of relevant social issues in this context. The adoption of AVs has the potential to improve traffic safety, with over ninety percent of fatal road crashes due to human errors, e.g., fatigued driving in long-haul freight transport (McManus and Rutchick, 2019; Wang and Li, 2019). While the adoption of AVs in employment remains controversial – mitigating of potential labour shortage in logistics (Fawcett and Waller, 2014), versus unemployment and job replacement (Heard *et al.*, 2018). In addition, risks such as privacy and data security issues (Tatham *et al.*, 2017), and vehicle crashes (Wang and Li, 2019) undermine public acceptance. These social concerns lead to strict regulations that restrict the further deployment of AVs. Both unmanned ground vehicles (UGVs) and unmanned aerial vehicles (UAV) are currently not allowed to operate logistics tasks without human monitoring or intervention in public areas (Van Meldert and De Boeck, 2016). Hence, when considering the adoption of AVs in supply chain processes, these social issues should not be ignored. To be specific, the social demands raised by stakeholder groups, and the potential social impacts on them must be considered, to allow supply chain organisations to create value for the stakeholders (Hörisch et al., 2010) and improve their quality of lives (Serrano-Hernandez et al., 2022). Gaining social approval is essential to the wider adoption the AVs in logistics (Kim et al., 2022; Kurniawan et al., 2021).

The difficulty in measuring social sustainability that has led to less attention compared to other two dimensions of sustainability. Whereas, economic and environmental sustainability can be measured using unified quantitative measures, Ahi and Searcy (2015a) argue that social sustainability can only be presented by indicators that considered as the signs of showing the condition or existence. Under general circumstances, themes including human safety, labour conditions, welfare and community development are useful measures of the social performance of the supply chain (Ahi and Searcy, 2015b). In addition, Ahi and Searcy (2015a) suggested that there is a need for the development of context-based metrics for social sustainability. Following this call, this paper aims to identify the social impacts of adopting autonomous vehicles that link with the general social indicators of supply chain sustainability.

This paper explores the social supply chain sustainability of adopting AVs. A systematic reviewing of existing literature can provide authors with the current state of the research in this area and form a conceptual base for the further research from collecting and synthesising information systematically and transparently with minimised biases (Tranfield et al., 2003; Durach et al., 2017). This paper identifies the social impacts of autonomous vehicle adoption on supply chain processes, and explores how this adoption affects supply chain social sustainability and the associated stakeholders. Thus, the following research questions are proposed:

1. What are the social impacts on the supply chain of adopting autonomous vehicles?
2. How does autonomous vehicles adoption affect the social dimension of supply chain sustainability?

The paper is organised as follows. Section 2 introduces the methodology, followed by section 3, which analyses descriptive characteristics and thematic content of the identified literature in order to answer the review questions. The proposed model is presented in chapter 4 accompanied with a discussion of the literature and concluding remarks with research limitations and future directions.

Methodology

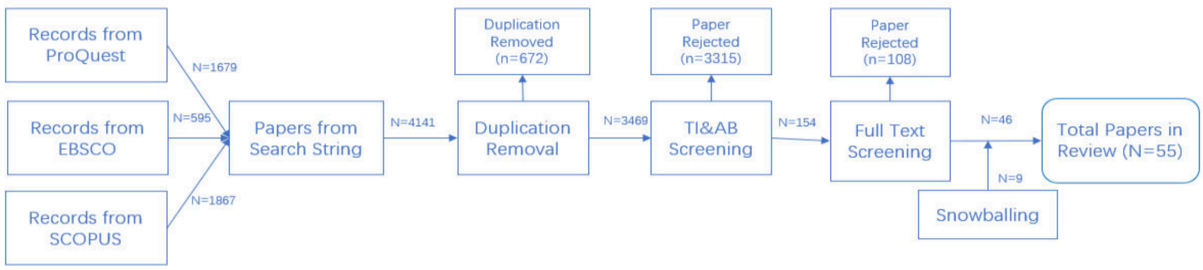
This paper follows a typical systematic literature review (SLR) process which include searching, criteria forming, screening, extracting and synthesising.

Three search strings are developed based on key terms: “supply chain management”, “social sustainability”, and “autonomous vehicles”. The combined search strings are used in three databases: ProQuest, EBSCO and Scopus, initially identifying 3593 papers.

In order to ensure the rigour of the SLR, inclusion and exclusion criteria are developed. The criteria include categories such as English language, academic peer-reviewed source (academic journals, conference proceedings), papers with research context and topic that explicitly discuss social implications and impacts of autonomous vehicles in the freight supply chain. Quality assessment criteria are developed to ensure the quality of the literature identified and robustness of arguments formed from the SLR which are based on the literature selected (Tranfield et al., 2003). The assessment criteria cover theory robustness, methodology, findings and contribution, following the method proposed by Pittaway et al. (2004).

Two rounds of screening including title & abstract and full-text are conducted following the criteria. Figure 1 shows the whole process of the SLR.

Figure 1. Paper searching and selection process



After screening, the extracting and synthesising step is to gather information including title, author, publication, study nature, method, findings and limitations etc. in a set of Excel sheets for analysis.

<u>Findings</u>

In terms of the thematic findings, both positive and negative social impacts in commercial and humanitarian logistics contexts are included.

Positive social impacts

The positive social impacts include the four following categories: speed, reduced traffic congestion, health and safety and employment.

Speed is a major advantage for UAVs and UGVs (Perussi et al., 2019; Marsden *et al.*, 2018; Pani *et al.*, 2020). The advantage in delivery speed reduces customer lead-time. Further, more customised delivery services are available – delivery to the specific destination in chosen time-slot to the exact customer (Mangiaracina *et al.*, 2019; Kellermann et al., 2020), and therefore avoiding inefficiency in delivery failure and repetitive delivery. Such advantage is essential for delivering medical and humanitarian supplies in emergency (Cheema et al. 2022; Haula and Agbozo, 2020).

The speed advantage for AVs is related to reduced traffic congestion. UAVs are able to utilise low-altitude air space and flyover the road traffic (Mohamed *et al.*, 2020), so that they are not affected by urban ground traffic congestions. For the UGVs, although still using ground infrastructure, they are believed to accelerate the road traffic flow by optimising vehicle speed and distance, so as to reduce the congestion (Sohrabi et al., 2020). Also, some last-mile UGVs deliver consumer parcels via pavements or special lanes which do not occupy public roads, which further benefits road congestion (Fagnant and Kockelman, 2015). As Rejeb et al. (2021) argued, logistics tasks can be optimised due to high mobility of AVs.

Safety is another major social impact. UGVs are able to enhance workforce safety and health by operating in hazardous working environments (Bechtsis *et al.*, 2017, 2018; Rejeb et al., 2021) and reducing workplace accidents (Llopis-Albert et al., 2019) that eliminate casualties of employment (Hwang et al., 2019). Moreover, since the human driver errors cause more than 90% of traffic accidents, the introduction of UGVs for long-haul road freight transport will enhance traffic safety for the traffic users and the load carried (Sen *et al.*, 2020). For the end-customers of last-mile delivery services, UGVs are considered as a safe alternative to provide touchless delivery service to reduce the spread of contagious diseases, particularly in the COVID-19 scenario (Rai et al., 2022; Kapser et al., 2021). Regarding products in the pipeline of the supply chain, AVs are capable of improving their safety by property surveillance and providing timely product information (Sellevold *et al.*, 2020). Logistics managers are able to timely monitor the inventory levels to adjust operations based on the inventory information provided by the AVs.

The benefits to employment centre on creating new jobs: highly-skilled positions such as AV remote operators and maintenance engineers (Bechtsis *et al.*, 2017, 2018; Sen *et al.*, 2020), so that employees with multiple skills are in demand. Also, AVs are believed to be a solution to the future labour shortage in the supply chain (Engholm et al., 2021), caused by fewer young workers (Hwang et al., 2019) and retiring experienced employees (Kim et al., 2022).

Negative social impacts

It cannot be denied that, the unreliability of AVs is potentially causing safety threats to the public and to the security of the payload to be delivered due to the incidents such as collision, loss of signal and extreme weather (Mohamed *et al.*, 2020; Marsden *et al.*, 2018). Aydin (2019) pointed out that UAVs may also be potentially used for conducting a terrorist attack, and Rao et al. (2016) argued that drones are potentially invading airspace for commercial aviation, which are considered significant safety threats to society.

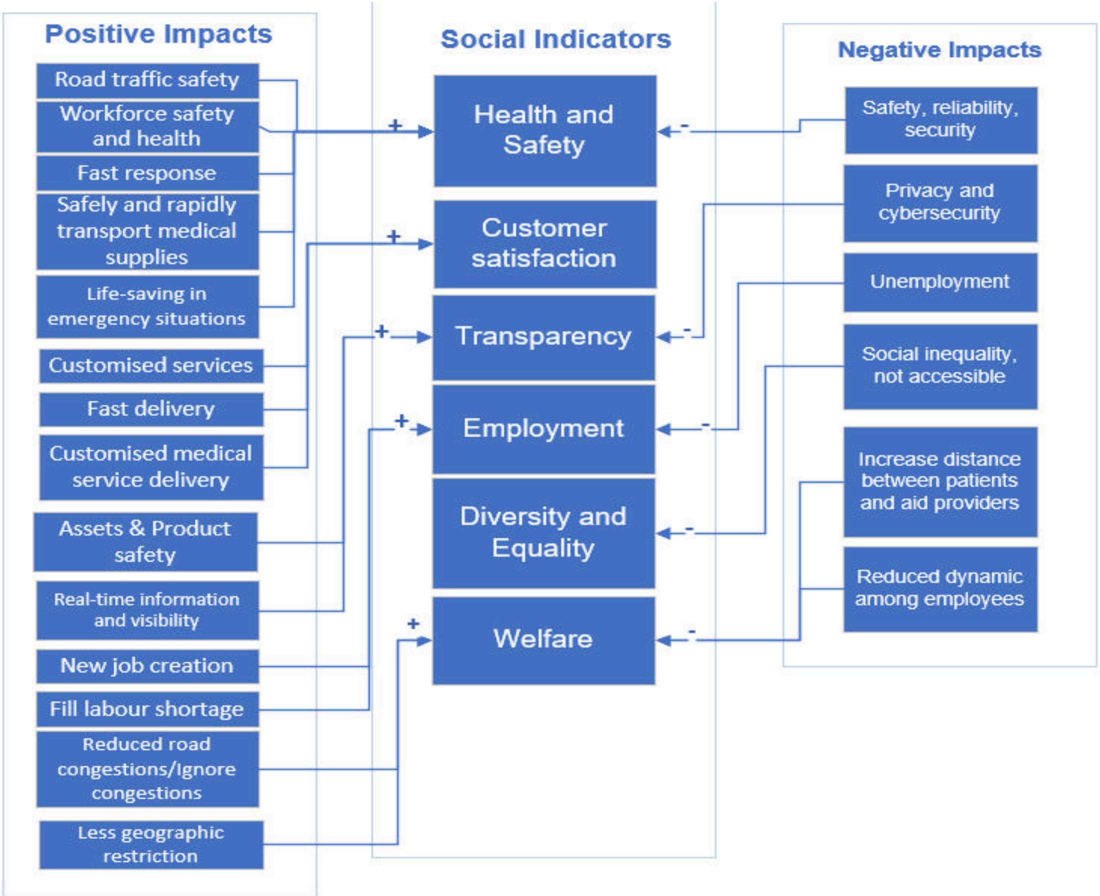
Tightly correlated with safety problems, weak cybersecurity is another negative impact. Cyberattacks of AV software systems can lead to the mis-delivery of the parcels to wrong address, as well as the leak of customers' personal information and threat to privacy (Nelson *et al.*, 2019; Rai et al., 2022). Customers served by AVs are worried about the leak of their information which could be used for unethical purposes.

Replacing human workers with AVs leads to significant negative impacts in the supply chain that will cause unemployment in the freight transport process (Sohrabi et al., 2020; Marsden *et al.*, 2018), and reduced communications among employees in the work place (Soni and Soni, 2019). Although there is an argument of the possibility of transformation of jobs (Klumpp, 2018) and employee role-changing (Vlachos et al., 2021) for those who are to be replaced, that requires employees to be capable to learn new skills, otherwise they will be redundant.

Discussion

The collection of positive and negative impacts of AV deployment in supply chain serves to answer the first research question. The identified impacts provide the basis for research question two, which connects social impacts with social sustainability indicators. In this context, 6 indicators from the general scenario (Ahi and Searcy, 2015b) are potentially connected with the identified impacts. Figure 2 indicates the proposed connections.

Figure 2. Proposed connections between indicators and impacts



Health and Safety

Stakeholder health and safety is a major issue in the supply chain. Road freight transportation plays an important role in logistics, and traffic safety remains a significant issue. The majority of fatal road traffic accidents are caused by human driver – mainly due to fatigue and alcohol or drug abuse (Gružauskas et al., 2018). Accompanied with the implementation of smart sensors, autonomous vehicles can reduce accidents and improve road safety (Gružauskas et al., 2018). Also, AV deployment in supply chain helps enhance workforce safety and health by operating in hazardous working environments (Bechtsis *et al.*, 2017, 2018) and reducing workplace accidents (Llopis-Albert et al., 2019). In addition, AVs provide touchless delivery alternative to customers, especially during a pandemic such as COVID-19 (Pani *et al.*, 2020). In the humanitarian context, the advantages in fast response and travel speed of drones are considered crucial in saving lives in emergency situations (delivery of AED or snake antivenom), reducing morbidity significantly (Poljak and Šterbenc, 2019).Therefore, the deployment of AVs in the supply chain improves health and safety of employees, traffic users and end-customers. However, the immaturity of the technology brings new safety risks. Navigation system malfunctions will lead to drone crashes that lead to casualties (Kellermann et al., 2020). Similar accidents may also occur among the UGVs due to hardware issues, even though human drivers are replaced (Fagnant and Kockelman, 2015). Hence, it is still a subject of debate as whether the deployment of AVs will improve stakeholder health and safety overall.

Customer satisfaction

The rise of e-commerce and urbanisation leads to the increasing importance of urban logistics. Especially B2C last-mile logistics (Marsden *et al.*, 2018) that calls for customer-oriented last-mile delivery (Kapser and Abdelrahman, 2020). AVs are a feasible solution to these challenges, to satisfy the customers' needs (Merlino and Sproģe, 2017). UAVs can operate on direct and uninterrupted routes to conduct delivery tasks ignoring the ground traffic and congestion (Kellermann et al., 2020), which is a competitive advantage compared with conventional ground vehicles. In the healthcare context, AVs' capability for transporting customised medical supplies is more significant. When there is a demand for specific medical support, AVs can respond rapidly and deliver the most suitable medical equipment and medicines to the recipients (Dhote and Limbourg, 2020). The deployment of AVs in the healthcare supply chain enhances responsiveness to serve patients (Ding, 2018). Hence, deploying AVs will improve the customers' satisfaction for home delivery services.

Transparency

Real-time visibility of the asset and product flows of the supply chain is crucial to efficiency, and it is especially challenging where infrastructure is poor (Sellevold *et al.*, 2020). AVs have advantages in load traceability compared to conventional vehicles (Sellevold *et al.*, 2020) – logistics managers are able to have a clear view of the freight status. Stakeholders can have better access to product flows when freight transport is conducted by AVs. However, the increased transparency also leads to concerns of cybersecurity. AVs are vulnerable to cyber-attack or hacking which could cause potential physical losses (Poljak and Šterbenc, 2019). In addition, drone malfunctions could lead to crashes which threaten public safety (Poljak and Šterbenc, 2019). Customers' personal data can be hacked and stolen during an attack, which threatens their privacy (Kellermann et al., 2020). Hence, it is controversial whether deploying AVs will positively or negatively affect the transparency performance of the supply chain.

Employment

The predicted shortage of labour in the logistics sector in the next decade motivates the adoption of AVs, which requires higher skilled workers with higher skills and ability to multi-task. A workforce which is capable of new technology-related tasks, such as monitoring, operating or programming AVs, will be increasingly competitive and in demand in the labour market (Sohrabi et al., 2020). Therefore, new job opportunities will be created supporting AVs from an engineering perspective such as autonomous truck and infrastructure maintenance (Sen *et al.*, 2020). Nevertheless, the replacement of low-skilled workers (Ding, 2018) and those with limited transferable skills (Nikitas et al., 2021) who are unable to cope with "job transformation" may lead to unemployment. Hence, whether AVs will improve employment performance for the supply chain overall requires further investigation.

Diversity and equality

As Tang and Veelenturf (2019) argued, implementation of AVs will aggravate social inequality, and will enlarge the gap between the social classes. AV delivery services require customers to have smart devices and be educated to a higher level (Tang and Veelenturf, 2019), while the poor class have less access to the facilities and education (Wang et al., 2021). As a result, the deployment of AVs will negatively impact equality and diversity in the supply chain.

Welfare

Welfare covers two aspects: human interaction and traffic congestion. AVs in the supply chain are considered to reduce human interactions, both in work places like warehouses or manufacturing plants (e.g., reduced employee interactions and contribution in decision making) (Soni and Soni, 2019), and in last-mile deliveries (e.g., increased mental distance between recipients and the deliverers) (Tatham *et al.*, 2017). Hence, AV deployment is decreasing human interaction and potentially welfare in the supply chain.

From the traffic congestion perspective, UGVs on the road can autonomously optimise and keep the distance from other vehicles, so that the flows of UGVs are faster and smoother (Sohrabi et al., 2020). According to Gružauskas et al. (2018), UGVs may relieve congestion on highways, for long-haul large batch freight transportation. Also, UAVs use low-altitude air space instead of roads on the ground (Mangiaracina *et al.*, 2019) so that they ignore the geographic limitations and utilise the fastest and most direct routes for delivery (Mohamed *et al.*, 2020). As a result, AV deployment is improving the road traffic aspect of welfare performance of the supply chain.

Conclusion

This paper presents an SLR which helps to understand the social impacts of AV adoption in the supply chain. Both positive and negative impacts of UAVs and UGVs adopted in commercial and humanitarian supply chains are synthesised. In addition, this paper proposes a framework that connects the identified social impacts and supply chain social sustainability indicators, so as to investigate the social sustainability performance of AV adoption in the supply chain. This SLR is, to the authors' knowledge, the first piece of work on the social sustainability of both UGVs and UAVs in commercial and humanitarian logistics contexts.

This study has a few limitations. First, the context is still in its infancy and more research is called for into the social sustainability of AV adoption in the supply chain. Secondly, empirical data has been collected in Germany, America and mainland China which indicates that current findings cannot currently be generalised. Finally, the review is limited to articles written in English and does not consider contributions published in other languages.

This paper provides several future research paths. First, more empirical studies need to be conducted to investigate how AV adoption explicitly affects specific stakeholders based on the requirements of supply chain social sustainability research. Also, the data should be collected from more geographical contexts to achieve more generalisable results. In addition, since there is still lack of empirical research in social sustainability theorising, more qualitative research such as interviews and Delphis should be conducted to further conceptualise the social sustainability implications of adopting AVs in the supply chain.

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