INVESTIGATING THE STATE OF AUTONOMOUS VEHICLES ON SUPPLY CHAIN: A LITERATURE REVIEW

Introduction

Autonomous vehicles (AVs) have become part of the supply chain networks and have the possibility to revolutionize how distribution and logistics performance is done. These technological advancements in transportation and logistics are mostly important to the European market, where logistics and transportation play a key role in economic growth and stability. According to Transparency Market Research, the European perishable goods transportation market is estimated to grow at a compound annual growth rate (CAGR) of 3.3% from 2023 to 2031. Due to the sensitive nature of perishable and semi-perishable products, AV technology could help solve several long-standing challenges, such as reducing labor and operation costs (Hopkins, 2021), improving delivery time and fuel efficiency, optimizing routes, and improving supply chain resilience (Zhao & Lee, 2023; Smith, 2022; Johnson & Brown, 2021).

EU food and beverage industries largely impact regional economic growth; therefore, efficient logistic and supply change management is in high demand (Olencevičiūtė et al., 2016). Adopting AVs in the supply chain and logistics might overcome some challenges such as labor shortages, rising transportation costs, minimizing human error, optimizing fuel consumption, and improving the reliability of drivers and delivery efficiency (Khalafi et al., 2024; Marcucci et al., 2024).

This study examines AVs' economic impact on European food and beverage supply chains. With a focus on these sectors, the study explores how AVs can enhance supply chain resilience, reduce operational costs, and improve efficiency. We reviewed the main literature using SCOPUS to analyze economic models to quantify the benefits and cost savings AVs can deliver (Davis, 2023). It provides a comprehensive review of the transformative potential of AVs in these industries and fills existing research gaps.

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To attain its aims, this initiative will study many research issues. How do AVs affect European food and beverage supply chain resilience and efficiency? What is the impact of cutting costs with AVs on the economy? Finally, how does AV deployment help European businesses overcome labor shortages and fragmented regulations? These factors are significant as Europe automates transportation. Companies must compete in fast-changing marketplaces (Guo et al., 2024; Wilson, 2023; Thomas, 2022).

This study matters for several reasons. First, it examines the economic implications of AVs on European food and beverages, filling a large research gap. Second, industrial leaders considering AV technology to boost productivity and save costs are informed (Hernandez, 2023). Furthermore, this research informs policymakers about the pros and cons of AV integration. Policy and infrastructure complementary to each other will be developed. As a result of this study, academics can conduct AV and supply chain management research, which will be beneficial to them (Martin & Lopez, 2022).

Literature Review

The fact that AVs are increasingly integrated into supply chains means that their potential for solving some of the most critical logistical challenges is catching the attention of significant researchers and industry leaders. To understand the complete landscape of impacts that the AVs have on the supply chains, it will be relevant to explore the extant literature in respect of how AVs improve efficiency and reduce costs of the supply chains and build resilience within them. The following literature summarizes what could be considered the range of findings from various studies on logistics AV deployments, keeping in mind how these technologies stand to reshape operational strategies toward key persistent issues such as labor shortages and rising transportation costs.

Overview of AVs in Supply Chains

AVs have become one of the logistics industry's revolutionary innovations, particularly in terms of cutting operating costs and increasing supply chain efficiency. In fact, according to some recent studies, deployments of AVs into the supply chain help tackle key challenges such as labor shortages and volatility in transport costs. Khalafi et al. (2024) highlight this advantage, noting that integrating AV technology into logistics can foster strategic collaboration among stakeholders, leading to long-term improvements in financial sustainability. This includes benefits such as enhanced reliability and reduced operational costs. Additionally, Nagurney et al. (2021) demonstrated through game-theory modeling that the adoption of AVs has been successful in maintaining supply chain performance even in the presence of labor constraints. This adds support to the idea that AVs can further stabilize costs and produce more resilient logistics operations in the event of disruption (Nagurney, 2021; Nagurney et al., 2023).

In fact, AVs can be a potential solution to the issue common in logistics for quite some time and recently further propelled by growing demand and aging workforces in most regions. This will add to the possibility of deploying autonomous trucks in long-haul routes without compromising operational efficiency with minimum dependency on human drivers (Marcucci et al., 2020). For example, UPS and DHL have started testing AVs for last-mile deliveries, a segment where efficiency is paramount because of labor constraints and customer demands for speedier deliveries. Multiple studies have proved various advantages of AVs in their operational cost savings, whereby autonomous trucks can operate without rest breaks or driver shift limits, thus enhancing fleet utilization. Besides that, AV will go a step further to enhance route planning and save fuel with the intention of reducing frills associated with transport. These benefits are much sought after, during peak seasons when holidays fall because it is during these times that labor shortages most often worsen and the demands for logistics increase by a big margin (Howard & Dai, 2014; Cohen & Cavoli, 2019).

Global Application of AV Technology to Supply Chains

Globally, the applications of AV technology to the supply chains have been developing very fast, with key players across regions pressing ahead with the adoption of these systems. Guo et al. (2024) study the scheduling problems of green vehicles, including AVs, and report that multi-objective optimization models will play a vital role in improving both environmental and economic performance for fleets of AVs. This work stresses placing AVs within a broad sustainability framework, an imperative in line with global trends towards greener, more efficient transportation systems.

In the US, companies like Tesla, Waymo, and Uber Freight are setting the standard for AVs in logistics by utilizing completely autonomous trucks to complete long-distance journeys. In Europe, impetus has also gathered for testing AV technology in logistics, driven by private sector investment together with government support. Despite such developments, there are still lots of challenges, mainly regarding updated legal frameworks and public infrastructure, which should all be adapted to AVs. For instance, huge obstacles to the wide adoption of AVs are the regulatory fragmentations in Europe. In different countries, there are different rules concerning the spread of AVs. In Europe, companies such as DHL and DB Schenker have been pioneers in testing AV technologies in logistics, particularly for long-distance routes and last-mile delivery services. Furthermore, countries like Germany and Sweden, private sector investments in AVs are matched by government initiatives, making these countries leaders in the European AV market (Marcucci et al., 2024). However, fragmented regulations across different countries present a major barrier to widespread AV adoption, as each nation has its own legal framework for the operation of autonomous trucks, creating complexities for cross-border logistics (Automotive Logistics, 2024).

Key Trends and Players Driving AV Adoption in Logistics

Various key trends are driving the adoption of AVs within logistics. Of many, one of the more prominent is indeed the push toward transportation solutions that are more sustainable and cost-effective. AVs are meanwhile seen to reduce fuel consumption and improve route optimization, particularly in industries where timely deliveries have become critical, such as the food and beverage sector (Marcucci et al., 2024). Additionally, many research studies highlight how AVs can contribute to decreasing the carbon footprint of supply chains thanks to route optimization and a general reduction of unnecessary vehicles in operations (DHL, 2024; Marcucci et al., 2024).

The increasing speed of AVs' implementation, above all for last-mile logistics, is enhancing time efficiency in e-commerce and is increasing service reliability. Nowadays, more companies rely on AVs for handling high-demand delivery schedules, especially in congested city centers where traffic congestion and labor shortages may bring everything to a stop (Supply Chain World, 2024). The report also highlights the potential use of AVs in enhancing supply chain resilience by reducing dependence on human labor, mainly during crises such as the COVID-19 pandemic. Large logistics players like Amazon and DHL have been among the early adopters that tested AV technology with serious investments in autonomous systems to gain efficiency and reduce costs. These companies have focused on the integration of AVs with other advanced technologies, such as Artificial Intelligence (AI) and the Internet of Things (IoT), for enhancing the intelligence of supply chain networks based on big data. Indeed, these will further inspire developments in AV technology, hence very important in logistics operations in the future (DHL, 2024).

Methodology

This comprehensive literature review examines the economic impacts that AVs may have on food and beverage supply chains in Europe. We synthesize findings, look for trends, and identify gaps in the extant literature as to how AVs improve supply chain efficiency, cost, and resilience.

The literature review includes peer-reviewed studies, industry reports, and pertinent research collected, analyzed, and synthesized. In this analysis, we examine how AV technology solves logistical problems in European food and beverage supply chains and the economic impacts they have.

The literature study relies on academic databases and industry reports. These resources were used:

- The SCOPUS Database was searched for peer-reviewed journals, conference papers, and reviews. Keywords were "Autonomous Vehicles," "Supply Chain Resilience," "European Food and Beverage Supply Chains," "Logistics Efficiency," and "Economic Impact."
- Research and industry reports were analyzed to understand the deployment of AV technology in European transportation and logistics.

By utilizing Boolean operators and wildcards, we extended our search to capture as many relevant publications as possible. The data extraction in this review covered the years from 2015 to 2024. The following search formula, which utilized keywords, yielded 1,879 papers:

> TITLE-ABS-KEY ("self-driving trucks" OR "autonomous vehicles" OR "automated freight transport" OR "logistics") AND TITLE-ABS-KEY ("supply chain efficiency" OR "fuel consumption" OR "economic impact") AND PUBYYEAR > 2015 AND PUBYYEAR < 2024.

Discussion

Our study focuses on the research landscape related to AVs in the food and beverage supply chain in Europe. The results are based on an analysis of 1,879 documents. Several factors are considered, including the number of publications, citations, and the strength of the links between countries, to understand the extent of research productivity, influence, and collaboration. Study results indicate the importance of countries like the United Kingdom, Germany, and Italy in advancing AV research. The analysis of these metrics also reveals how some nations have become hubs for cross-border innovation and research through the strength of their inter-country collaborations. This discussion interprets these data points, pointing to their implications for the adoption of AVs in supply chains. It also highlights emerging trends and potential areas for future research. Its purpose is to provide a detailed examination of the research contributions across Europe, illustrating the role of AVs in improving food and beverage logistics and efficiency.

Table 1: Research Collaboration and Impact on Autonomous Vehicles in European Food and Beverage Supply Chains

Country	Documents	Citations	Total link strength
United Kingdom	117	2784	147
Germany	79	1004	71
France	63	1253	61
Spain	72	1156	59
Sweden	46	945	58
Italy	83	1485	57
Netherland	39	1075	44
Norway	27	421	40
Turkey	50	692	35
Belgium	19	189	28

Table 1 shows the several contributions and collaborations that different European countries have made to the research output in AVs and their impacts on the supply chain of food and beverages. The table represents 117 documents, 2784 citations, and 147 total links, which shows the leading position of the UK in terms of research output and international collaboration. Similarly, in Germany and Italy, both the

number of publications and link strengths were conspicuous, with substantial citation counts supporting them. In countries like France and Spain, although the number of publications are relatively low, citation counts are high with regards to the number of documents, thereby indicating the impact of research from those countries. Despite the number of publications in Belgium and Norway are lower, they still indicate recent growth of interest in research relating to the AVs in development of supply chains networks. The total link strength metric represents the collaboration between countries. It therefore means that the UK, Germany, and Italy, which have higher values, are producing more research and, thus, collaborating with other countries on active levels to develop a wider AV and supply chain ecosystem in Europe.

Figure 1 illustrates international collaborations in particular, European countries. The two countries are acting like central hubs with a high number of linkages to countries like France, Spain, and the UK. For the last few years, Italy and Germany have been contributing a great deal to collaborative research. Along with the USA, UK, France, and Spain, these countries also have strong research collaborations. By contrast, the thin, lighter-colored line extending from Ukraine suggests more isolation with fewer connections. Even when Ukraine did participate in international research collaborations, it did so less frequently than central European countries. Generally, Figure 1 suggests well-developed and solid collaboration networks in Europe, dominated by Italy and Germany and their immediate neighbors.

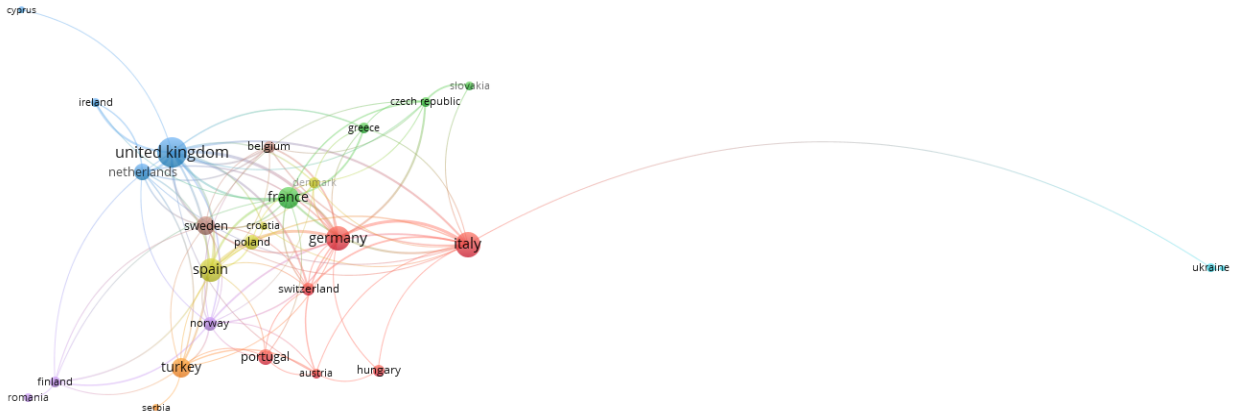

Figure 1: Network Visualization of Collaborative Research on Autonomous Vehicles in European Food and Beverage Supply Chains

This network diagram provides insight into the shifting pattern of collaboration in European research on AV in supply chains. Thicker and darker lines can indicate older collaborations, dating back to around 2016, that were crucial in building leading countries such as the United Kingdom, Germany, and France into strong and well-connected networks. The newer members in the network, like Poland, the Czech Republic, and Ukraine, have lighter lines from right to left, showing the emerging collaborations between 2020 and 2024. The continued presence of Italy and Germany as linchpins allows for further collaboration between established and emerging research teams. Newcomers, such as Slovakia and Ukraine, have joined more established countries like the USA and Italy in contributing to the rising participation of researchers in this field. The timeline for this growing collaboration is shown by the gradient color spectrum, indicating an increase because every day AV technology becomes more significant.

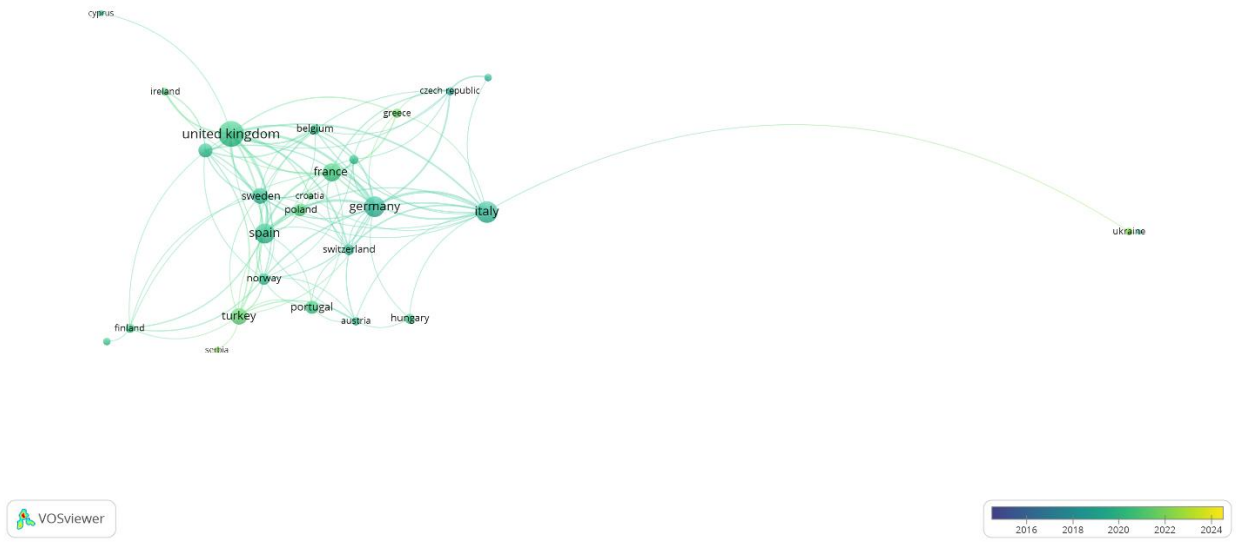

Figure 2: European Research Temporal Collaboration Dynamics on Autonomous Vehicles in Food and Beverage Supply Chains.

Density Map Showing Intensity of Research Collaboration between Various Countries in Europe Concerning AV and Their Impact on Food and Beverages Supply Chains. The gradient of color through green and into yellow describes the level of research activity and collaboration, with brighter areas going to yellow being higher in research concentration and darker areas going to blue/green representing low levels of involvement. Of all the brightest yellow hotspots on this map, Italy is very much a player in this research area, high in its output contribution and collaboration with other countries. Italy's prominence is a result of high involvement in both the academic and practical aspects of AVs in supply chains, particularly to optimize logistics and efficiency. The UK also comes out as an important research hub, showing a dense yellow area. This would therefore imply that the UK is one of the biggest contributors and collaborators in research on AVs, probably impelled by technological capabilities, strong academic institutions, and economic interest in the betterment of supply chains through automation.

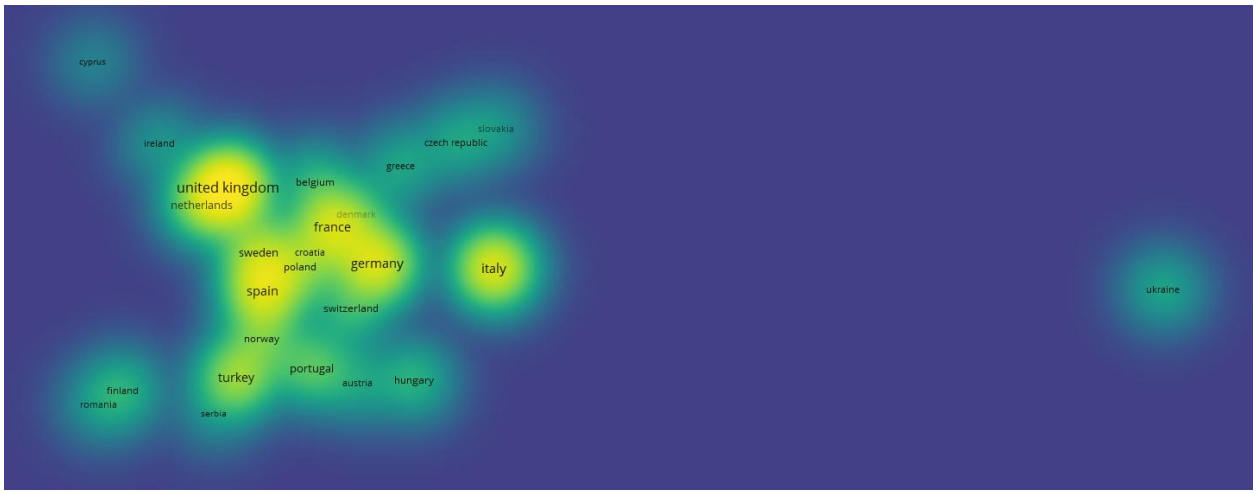

Figure 3: Geographic Heatmap of Global Research Collaboration on Autonomous Vehicles in Supply Chains

The countries are being mapped to represent their networks of cooperation and volume of research regarding the case of AVs or supply chains. A cluster may be thought of as countries that have stronger intra-cluster collaborations compared to another (but not the strongest inter-cluster) collaboration.

- **Cluster 1** (Germany, Italy, Austria, Switzerland, and others) well-anchored partnerships largely over Western and Central Europe. These countries are key players for AV tech development and supply chain logistics.
- **Cluster 2** with France, Greece, Slovakia, and other countries, indicating large amount of cooperation in southern and eastern Europe, with AV studies being increasingly popular in these regions.
- **Cluster 3** includes the UK, Netherlands, Ireland, and Cyprus and emphasizes the strong research in Western Europe that is prevalent, with the UK leading many of the collaborative initiatives.
- **Cluster 4** includes countries like Denmark, Spain, and Croatia. These countries are on a medium level in the research network, collaborating often both with Eastern and Western Europe. Their involvement is significant, though not as marked since it links different regions.
- **Cluster 5** consists of Nordic countries such as Finland, Norway, and Romania; the latter, however, is not generally considered Nordic but shows trends like Nordic countries. These countries have shown growing interest in AV and supply chain research over recent years. Again, this trend should be welcomed because it shows that countries are increasingly committed to such important issues.
- **Cluster 6** consists of Ukraine and Latvia and incorporates the emergent players in the field. These will provide an insight into areas of possible growth for collaborative research-in-effect, which countries should be involved in extended initiatives. Though still at a developmental stage, these countries are a promising choice.
- **Cluster 7** also comprises several countries, such as Turkey and Serbia, which are showing regional cooperation within this area of AV research. Their participation is not so deep compared to the other clusters, but they are relevant for stability and development in the region.
- **Cluster 8** consists of Belgium and Sweden and reflects strong collaboration across northern Europe, which also reflects their advanced engagement of these countries in AV technologies. The contributions are geographically concentrated, but the effects spread out due to the advanced technological capability.

Figure 4: Collaboration Networks Among Countries

The Importance of AVS in Supply Chain

Although full implementation or widespread adoption of AV technologies has not occurred, their potential impacts have been speculated by various researchers. The theoretical studies predict that the integration of AVs, particularly in logistics, can significantly enhance economic outcomes at all levels by reducing labor costs, improving fuel economy, and reducing accident-related costs to construct overall resilience (Kim et al, 2022).

Most of the food and beverage industries have a major problem while transporting perishable products. With AVs, there is real-time monitoring of the systems to ensure that goods are moved under optimum conditions, hence reducing cases of spoilage and generally improving efficiency and reliability in supply chains (DHL, 2024). Moreover, in urban cities, where there are often congestions and labor shortages, AVs help smooth the last-mile deliveries. Companies like DB Schenker and DHL already adapt to such technologies that solve such logistics bottlenecks, enhancing operational efficiency and resulting in more sustainable practices with less emission (Automotive Logistics, 2024; Marcucci et al., 2024). The application of AVs has become more critical in the food and beverage supply chain across Europe due to the continuous increase in demand for efficiently managed logistics. Major sectors in food and beverage are time-sensitive concerning delivery timings of especially perishable goods; therefore, this sector will greatly benefit from AV technology (Marcucci et al., 2024). The following assessment is organized into two parts that are organized to include: the first one, looking at the economic impacts of automated cars on supply chains; and the second one, which looks at the case of the impact of automation on the food and beverage supply chain.

Part 1: Economic Impact of AVs on Supply Chains

- Labor costs: The drivers are eliminated due to the introduction of the AV technology, thus reducing labor costs significantly. Various studies, such as Makahleh et al. (2024), investigate how investment in AVs reduces labor costs, especially in long-haul transportation. These can support continuous operation without mandatory rest breaks, result in reducing human labor input and increasing efficiency. The reduction in labor expenses by eliminating the need for drivers on long-haul routes, is particularly helpful in countries facing worker shortages. Since AVs don't require rest breaks, they allow for higher vehicle utilization, further lowering operational costs. According to Heutger and Kuechelhaus (2019), autonomous technology, allows for continuous operation, reducing downtime and maximizing the efficiency of logistics operations. On a related note, Nagurney (2021) also determined that automating the delivery process reduces the costs related to operations since one would not need to consider using human drivers on very long routes, thereby increasing efficiency in delivery. Since the AVs will work without breaks, this entails an increase in maximum vehicle utilization and reduction of delays due to labor shortages (Khalafi et al., 2024). In this aspect, Chen et al. (2024) cite that the application of AVs in the trucking industry could reduce costs through cooperative systems by minimizing labor and operational costs. A detailed study by Engholm et al. (2020) highlights the significant cost efficiencies that autonomous trucks can bring to freight transport. The authors claims autonomous trucks are projected to reduce total costs by up to 45%. The study by Kang et al. (2019) illustrates that although the upfront costs are higher, with greater market shares, connected autonomous trucks have the potential for billion dollars in savings; their case study of a busy Illinois corridor yielded impressive net savings, especially when 50 percent or more market shares were realized.
- Impact on fuel and operations costs: Multiple studies show that AV technology enables more accurate route planning and utilize efficient technologies such as platooning to further optimize operational costs by minimizing downtime and fuel consumption (Engholm et al., 2020; Makahleh et al., 2024; Marcucci et al., 2024). Davis (2023) claims by optimizing route planning, AVs may reduce fuel costs by up to 15-20% in some cases. Moreover, Kang et al. (2019) have conducted an economic and environmental efficiency analysis of truck platooning using connected autonomous vehicle technologies. That results in improved fuel efficiency, a reduction in aerodynamic drag, increase in pavement life, and reduction in truck crashes. Research by Tsugawa et al. (2016) discusses truck platooning, where all trucks are automated driving systems that enable them to travel closely behind each other with very minimal gaps. The automation of this kind reduces fuel consumption through minimal aerodynamic drag and

improves efficiency due to cooperative driving. Besides, Le et al. (2024) discussed the application of advanced technologies like artificial intelligence and machine learning in predicting and optimizing fuel consumption. In this respect, the implementation of AI into maritime operations will enhance decision-making, reduce fuel consumption accordingly, and advance sustainability toward more efficient logistics and transportation systems.

- Accident-related costs: Perhaps one of the most important economic benefits attributed to AVs is being able to reduce the costs associated with traffic-related accidents. Wang et al. (2020) discuss that the human element accounts for 94 percent of crashes, and their research study shows this technology. Collision warning systems and lane departure warning systems are just some of the technologies that could reduce casualties and fatalities by as much as 33%. As more AVs hit the roads, significant enhancements in road safety will result in marked reductions in accident costs. On the other hand, Ye et al. (2021) have provided a more conservative estimation. According to the analysis of 133 crash reports involving AVs, their findings indicate that while there have been advances, it also means that the AVs haven't shown a clear reduction in traffic injuries as compared to traditional vehicles. This would, therefore, mean that though AV technology shows promise, up until today, they have not shown any substantial reduction in traffic injuries when compared to conventional vehicles.
- Resilience in supply chain: Multiple valuable studies have been conducted with the aim of conceptualizing the benefits arising from applying AV concepts in supply chains, particularly focusing on improvements in reliability. The enhancement in reliability is due to reduced human errors and AI-powered route optimization, hence keeping delays at a minimum and boosting customer satisfaction. Heutger and Kuechelhaus (2019) emphasize that integrating digital technologies like AI and digital twins greatly improves logistics by allowing for real-time monitoring and optimization, which in turn enhances the performance of autonomous vehicle operations. Simlarly, Perussi et al. (2019) explain how AVs and automated equipment add up to the development of a more resilient supply chain. It focuses on automated vehicles, autonomous trucks, drones, and industrial conveyors, which are all part of industry and are major contributors to supply chains. Additionally, AVs have the potential to help in the management of traffic flow, reduce accidents, and further optimization of transport, thereby contributing to general supply chain resilience through minimizing disturbances and ensuring timely deliveries.

Part 2: Impact of Automation on Transporting the Foods and Beverages

- Efficiency in transporting perishable goods: The food and beverage industries rely heavily on the timely transportation of perishable products. Automation, especially using autonomous vehicles, enhances the speed, improves predictability and reliability to sustain fewer spoils and associated costs. These are some of the very important aspects in the transportation industry of beverages and food. This is very critical for temperature-sensitive supply chains. Amongst the key benefits of automated delivery systems is that they can work for extended hours without any need to take breaks, which aids in reducing the time of delivery at such a time when the demand is high. In this respect, Marcucci et al. (2024) noted that AVs can cut in 10-15% of the delivery times, which is highly relevant to maintaining the freshness of perishable commodities. Pettigrew et al. (2023) discuss how autonomous food deliveries will impact the Australian context. Indeed, businesses are increasingly using AVs to reduce labor costs, increase service capacity, and expedite deliveries. This would especially imply that for consumables, the delivery would be fresher upon arrival due to enhanced transportation and the reduction of delays caused by human elements such as driver fatigue. Long-distance shipment transportation costs can also be reduced using AV technology. Gružauskas et al. (2018) even claim cost-saving effects for autonomous trucks in supply chains, at a rate of about

5% in saving transport costs. The authors, however, still note that with such huge cost savings, the initial costs to establish technology, coupled with regulatory hurdles, have first to be met before the full benefit of autonomous trucks can be realized.

- Environmental impact: With the automation of trucks within the food and beverage supply chains, carbon emissions might further be reduced, which will be very important for companies aiming to implement sustainability goals. Efficiently, as underlined by Gružauskas et al. (2018), increase supply chains, especially when truck convoys are in operation, or freight is consolidated within logistic clusters. The authors estimate that up to 22% of CO2 can be saved by autonomous trucks with optimized driving and convoy strategies that lower fuel consumption.
- Cost efficiency: By automating transport, AVs mitigate human error and challenges associated with driver shortages that have worsened in recent years. Since these AVs can operate at any time, labor constraints have minimal effects, while route optimizations in the meantime become crucial for cost-efficient and timely delivery (Nagurney, 2021). Figliozzi (2020) gives an overview of the cost-effectiveness of using AVs for food and beverage delivery. The paper focuses on the extent to which AVs, both in the form of drones and ground robots, have the potential to significantly reduce energy use and carbon emissions compared to the conventional mode of delivery, hence operational cost savings. The findings of the study have been that drones are more economical in rural, small deliveries, whereas AVs for the ground can do well in higher urban delivery densities. There will be no need to bear the cost of human labor; hence, AVs can be considered very efficient in last-mile deliveries. Their efficiency is dependent on the size of the area served and the number of customers availing of the service since different systems give better results with respect to different amounts. On a similar vein, Jennings and Figliozzi (2020) discuss how autonomous delivery robots can increase the level of cost efficiency, especially in urban areas. According to the authors, for timely delivery of perishable commodities such as food and drinks, delivery robots are helpful since they reduce labor costs and increase the speed of delivery.
- Supply chain resilience: Various studies indicate that autonomous trucks enhance supply chain resiliency to a great degree, given their ability to operate without necessarily depending on human labor to create continuity of operations. The effect of such technologies within supply chains often minimizes delays resulting from workforce shortages or disruptions. The use of such trucks would involve advanced technologies such as AI and IoT to route and manage risk in real-time, hence furthering the cause of agility in responding to shocks unpredictably faced by the supply chains. Cost savings through reduced fuel consumption and more efficient driving patterns contribute to long-term resilience. The autonomous trucks would contribute toward sustainability by lowering the carbon emissions, meeting regulatory requirements, and mitigating environmental risks. This, in turn, makes supply chains more flexible, affordable, and resistant to any disruptions. Such factors make supply chains more flexible, cost-effective, and resilient against disruptions (Karanam et al., 2024; Liu et al., 2024; Tuli et al., 2024).

Indeed, AVs are capable of revolutionizing supply chain performance, as the adoption of such vehicles minimizes labor costs by improving fuel efficiency and reducing accident costs, which contributes to resilient and cost-effective logistics networks. Whereas autonomous trucks boast of major operation savings, the literature warns that they may also yield increased urban congestion, possibly limiting their cost benefits. Despite these challenges, strong environmental advantages for automation and increased supply chain resilience exist. Further development of AV technology will be expected to contribute much to higher levels of operation efficiency and sustainability in the food and beverage transportation industry, even though the impact this is to make on urban logistics and congestion will need to be managed with much care.

Implications for Policy

General Safety Regulation EU 2019/2144 of the European Union stipulates that cars are equipped with improved safety technologies in order to reduce road accidents and injuries (Galassi, 2022). In recent literature, it has also been pointed out that these regulations will be important in ensuring that AV technology is safe. Joint Research Centre (JRC) reports on the current testing and certification processes that are being carried out about autonomous vehicles, while indicating that strict standards on safety would be required (Baldini, 2020). The research (EUR-Lex - 32019R2144 - EN - EUR-Lex, 2019) indicates that the regulation makes provision for the amendment of the minimum performance requirements of motor vehicles in the EU through making the fitting of various advanced driver assistance systems (ADAS) compulsory.

Intelligent Speed Assistance (ISA) is a vehicular safety mechanism intended to assist drivers in adhering to speed regulations, hence improving road safety. An ISA may only inform the driver of the prevailing speed limit or may take active control of the vehicle's speed to keep it at or below the limit. The ISA rule of the European Union which calls for ISA installation in new cars, began implementation in July 2022 (McKinsey & Company, 2023). ISA is the system that has been proven beyond reasonable doubt to reduce road accidents and consequently associated deaths. Tests carried out in several European countries revealed that ISA had a potential to reduce hospital admissions by 15% and at the precise death rates of 21% (Juliussen, 2022).

Policymakers can create a clear and enabling regulatory environment that encourages autonomous vehicle use in logistics. This will include proposing standards that ensure safety, setting guidelines on operations, and eventual adherence to the current transportation laws. The U.S. Federal Policy Framework calls for the provision of a federal policy directed toward the deployment and commercialization of technology for AVs (Autonomous Vehicle Industry Association, 2023). It is also most likely that governments provide various financial motivations, such as tax cuts, grants, and subsidies for those businesses ready to invest in autonomous vehicle technology. All this can lower the financial barriers to entry and, therefore, will provide motivation for businesses to take part in the deployment of AVs in their logistical activities. Also, funding for research and development may quicken technological advancements and pave the way to offering AV solutions to the market quickly (Nwankwo & Etukudoh, 2023).

Conclusion

This paper mainly explores visions of AVs in changing the face of European food and beverage supply chains. It also brings significant economic benefits by reducing route inefficiency, minimizing labor costs, and saving fuel consumption. Due to such advantages, not only the perishable goods sector, but also other sectors that have a high reliance on credible, timely delivery systems can highly benefit from these technologies. AVs can further solve labor shortages, eliminate human errors and support the environmental objectives of the European Union.

With more and more AVs on the road, it is certain that jobs in logistics and transportation will change due to the lack of driver employment. On a larger scale, the widespread use of AVs might likely influence the labor markets, infrastructure investments, and regulatory frameworks. But this adoption of automated vehicles does not come without challenges. In the absence of a uniform legal framework in European nations, there are diverse legal frameworks that make full utilization of the benefits of this technology difficult. Most importantly, the regulatory framework needs to shift in a direction that allows cross-border circulation of AVs, particularly in Europe, where the divergent legal frameworks currently pose an obstacle to the intricate implementation of AVs (Cichosz et al., 2020; Automotive Logistics, 2024).

Supply chains will be significantly impacted because of AVs, with this presenting a promising outlook for the future of European industry. Therefore, more research into AVs will be needed to determine their broader social and economic impacts, mainly on the labor markets and legislation. Industry and governments will need to cooperate to meet these challenges and ensure that the application of AV technology is carried out in a smooth way for the economy, society, and prosperity of the countries.

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