




Enhancing Efficiency in Food and Beverage Supply Chains [†]

Stefan Ugrinov, Dragan Čočkalović , Edit Terek Stojanović , Sanja Stanisavljev, Mihalj Bakator 
and Verica Gluvakov

Technical Faculty “Mihajlo Pupin”, University of Novi Sad, 23101 Zrenjanin, Serbia; stefan.ugrinov@tfzr.rs (S.U.); dragan.cockalo@tfzr.rs (D.Č.); sanja.stanisavljev@tfzr.rs (S.S.); mihalj.bakator@tfzr.rs (M.B.); verica.gluvakov@tfzr.rs (V.G.)

* Correspondence: edit.terek@tfzr.rs; Tel.: +381-631-124486

[†] Presented at the Sustainable Mobility and Transportation Symposium 2024, Győr, Hungary, 14–16 October 2024.

Abstract: This paper aims to explore how to optimise the efficiency of food and beverage supply chains by focusing on transportation and mobility. This paper highlights the role of advanced technologies such as blockchain, artificial intelligence (AI), and Internet of Things (IoT) in traceability, demand prediction, and real-time equipment monitoring. It also points out that sustainable practises such as eco-friendly packaging, optimised logistics, and collaborative planning can reduce environmental footprints and operating costs. Moreover, it stresses challenges such as time variability, perishability, and regulatory compliance, and the need for adapting to consumer trends. This paper holds value as a possible introductory text for the extensive realm of sustainable supply chain management and it could assist practitioners in gaining a comprehensive understanding of the extensive academic literature.

Keywords: supply chain; transportation; mobility; efficiency; optimisation; logistics; technology



Citation: Ugrinov, S.; Čočkalović, D.; Terek Stojanović, E.; Stanisavljev, S.; Bakator, M.; Gluvakov, V. Enhancing Efficiency in Food and Beverage Supply Chains. *Eng. Proc.* **2024**, *79*, 2. <https://doi.org/10.3390/engproc2024079002>

Academic Editors: András Lajos Nagy, Boglárka Eisinger Balassa, László Lendvai and Szabolcs Kocsis-Szürke

Published: 28 October 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Ensuring that foods, beverages, and other similar inputs are available to consumers throughout the world falls squarely under the domain of the global food and beverage industry. With the development of more and more integrated supply chain infrastructures, it is becoming increasingly important for the industry to enhance its capability in efficiently moving food and beverages.

Supply chains need to be responsive to consumer expectations and environmental norms; blockchain technology increases the supply chain traceability and transparency and AI helps to increase the accuracy of demand forecasting and logistics efficiency, and real-time monitoring means that products can be kept at the right temperature throughout the supply chain and the potential for food waste is minimised. For example, Walmart, in collaboration with IBM, uses blockchain technology to track food products from farm to store, enhancing traceability and reducing the time needed to identify contaminated produce from days to seconds.

The smooth operation of supply chains is crucial for the quality of life of all people. They supply the essential inputs for production and ensure their delivery to customers or end users. Any disruption in supply chains can disturb the balance between supply and demand in the market, leading to negative consequences such as product shortages, inflation, black markets, crime, and, in extreme cases, conflicts and wars. The transportation process links all phases of the supply chain, from the delivery of raw materials to production facilities, through storage, and finally to distribution to end users [1].

Over the last decade, technologies like blockchain, AI, and IoT enhance traceability, improve demand forecasting, and enable real-time monitoring, reducing transportation times in the food and beverage supply chain [2]. Nestlé utilises AI-driven tools for demand

forecasting and inventory management, optimising production schedules and logistics to minimise waste and reduce costs.

Today, sustainable practises are at the core of supply chain strategies. Companies using biodegradable packaging and who have optimised logistics to offer reduced carbon footprint are well on their way to building themselves a future. Companies should focus on optimised transportation routes, consolidation of shipments, and the adoption of fuel-efficient vehicles, as all these would contribute to a reduction in their environmental impact, as well as a positive impact on cost efficiency [3].

Supply chain coordination faces challenges such as demand variability, perishability of goods, and regulatory compliance. Collaborative planning with suppliers and retailers, advanced analytics, and agile strategies help mitigate these issues, ensuring efficient storage, transportation, and delivery processes [4].

Consumer trends significantly impact supply chain efficiency. The demand for organic, locally sourced products and the rise in online grocery shopping require changes in sourcing and distribution. Building closer relationships with local suppliers reduces transportation costs and environmental impact. The focus on health and wellness increases the need for fresh, minimally processed foods, necessitating quick and efficient transportation and delivery solutions [5].

2. Methodology

2.1. The Subject and the Problem of Research

The subject of this research is enhancing the efficiency of supply chains in the food and beverage industry, with a focus on improving transportation and mobility. The problem addressed is the inefficiencies in these areas which lead to delays, increased costs, food spoilage, and a higher carbon footprint.

2.2. Research Goal

The goal of this research is to identify guidelines and recommendations to improve transportation and mobility in food and beverage supply chains, thereby enhancing efficiency, reducing environmental impact, and better meeting consumer demands.

2.3. Research Question

How can transportation and mobility within food and beverage supply chains be optimised to enhance efficiency, reduce costs and environmental impact, and meet evolving consumer demands?

2.4. Research Method

Theoretical principles form the basis of this research, and conclusions were drawn after analysing existing studies from the period of 2014–2024. AI tools were used to prepare this manuscript with the main goal of improving readability and fluency.

3. Results and Discussion

Blockchain technology helps in provisioning transportation across the supply chain of the food and beverage sector due to three main reasons: increasing transparency, enhancing traceability, and improving efficiency. In terms of transportation management, more accurate tracking of shipments in transit will lead to reduced delays and losses. Secondly, blockchain technology enhances accountability in transportation as issues in the transportation process can be traced back to its source very readily, and finally, blockchain technology can reduce documentation and compliance costs and speed up transit times as well. Blockchain technology will also enable improved coordination between supply chain partners, thereby improving transportation operations and making them more efficient [6].

These advantages enable AI forecasting to make the food and beverage supply chain more mobile as production and packaging companies can predict accurately consumer demand and plan the routes and schedules, thus minimising the transportation cost.

Furthermore, it determines the most cost-effective and fuel-efficient transport modes to bring the products to the right destination, minimising fuel usage and transit time. When it comes to handling goods in the food and beverage industry, AI will be able to detect any potential disruptions, such as traffic or weather, and update the route and schedule as needed to ensure the mobility of the supply chain, delivering goods in a reliable way, and on time [7].

The IoT helps optimise transportation in the food and beverage supply chain by providing real-time data on temperature, humidity, and other conditions, preventing spoilage and ensuring timely deliveries [8].

IoT-enabled fleet management enhances visibility into vehicle performance and status, making route planning, location tracking, and fuel consumption monitoring more efficient. Automated operations and mapped data feeds help reduce fuel use and transit times, while real-time location tracking and improved maintenance schedules prevent breakdowns and enhance delivery precision. IoT technology also supports adaptive logistics, allowing supply chains to respond dynamically to demand fluctuations, traffic, and climate changes. For example, in unexpected traffic jams, IoT systems automatically reroute vehicles to avoid delays, maintaining efficiency and the timely delivery of goods and services [9]. Companies like Maersk and Danone are already using IoT sensors for real-time monitoring of shipping conditions and fleet management, reducing spoilage, enhancing delivery precision, and improving route optimisation.

A key area of sustainable supply chain management is optimising its logistics aspects by reducing the carbon footprint from the supply chain. Efficient logistics entails the optimisation of the route planning for freight movements, consolidation and grouping of shipments together to maximise load and minimise empty runs, and the implementation of fuel-efficient and alternatively fuelled vehicles as far as possible for transportation. These increase profitability for the companies while reducing their contributions to greenhouse gas emissions. Companies are also increasingly considering the implementation of inter-modal transport, where sea, road, and rail are used for freight moving as far as possible for optimisation of the efficiency in freight movements as well as for minimisation of the carbon footprint. These are often supported by advanced analytics and AI which help in identifying the optimal routes and modes of movements for the freight [10].

Changing consumer trends can also play an important role in optimising supply chain efficiency. A leading example is the growing importance of organic and local products. The modern consumer cares more than ever about how food is produced and in what conditions, which explains the current trend towards organic, GM-free, sustainably sourced products. The shift in consumer demand towards organic products creates significant changes for companies. First, it requires them to source from and ship more local produce to maintain their supply. Shorter supply chains need greater coordination and, in some situations, collaboration; this can reduce transportation costs and the companies' environmental footprint. Second, companies must invest in certificates that show the organic or sustainable characteristics of their products are genuine [11].

The aim of reducing waste in the food and beverages supply chain, especially transportation and mobility, is to improve performance in terms of vehicle-related costs and environmental impact. Different solutions include planning and the consolidation of loads. In fact, the more fully a vehicle from a company is loaded, the smaller the number of vehicles needed to transport goods, resulting in lower fuel consumption and emissions, fewer partial loads prone to spoilage, and increased transportation efficiency. A different solution could lie in the coordination of deliveries to the same area of several different companies, reducing the need for vehicles and improving transportation efficiency while reducing the risk of product waste [12].

Better packaging options can reduce waste. Good and reusable packaging that ensures the integrity of products during transportation reduces the likelihood of damage and spoilage. Other innovative packaging materials designed for temperature resistance or cushioning materials can safeguard the integrity of the product all along the supply chain.

Furthermore, the use of recyclable or biodegradable packaging materials can reduce waste in the environment and support general sustainability efforts [13]. Tesco's collaboration with Loop to offer reusable packaging, Unilever's use of blockchain technology for sustainable sourcing, and PepsiCo's AI-driven logistics optimisation are all real-world examples demonstrating the impact of integrating sustainability into supply chain practises.

Collaborative logistics is another promising approach to reduce waste in transport. Companies could begin to share transport spaces such as trucks and warehouses in order to better optimise loads and the like, which would subsequently reduce the amount of trucks on the road, lower fuel consumption and emissions, and improve the speed and efficiency of deliveries, minimising the time that perishables spend in transit and, consequently, the risk of waste [14].

By setting up regular maintenance checks, vehicles will keep running more efficiently, and breakdowns will be less likely. While breakdowns can often cause delays in completing a shipment when they do occur, they can also increase the risk of spoilage as perishables might be stuck in vehicles for long periods of time. Companies can implement telematics and predictive maintenance technologies to keep their owned and contracted fleets in good working order, thereby reducing unplanned downtime and promoting greater reliability in the chain [15].

We mostly focused on the positive sides of implementing new technologies for the sake of enhancing efficiency in the food and beverage supply chain. We cannot ignore the potential downsides. Relying heavily on technology can make supply chains vulnerable to technical failures, cyber-attacks, and systemic disruptions. While these technologies can optimise supply chains under normal conditions, they may be less effective during extreme, unpredictable events (e.g., natural disasters, geopolitical conflicts) where physical and logistical constraints cannot be easily managed by digital tools alone.

The COVID-19 pandemic highlighted vulnerabilities in food and beverage supply chains, such as disruptions in transportation, labour shortages, and shifts in consumer demand. The resilience of most supply chains was pushed to the limit during this period [16]. Blockchain technology, AI, and IoT became crucial to ensure real-time monitoring, optimise logistics, and maintain the flow of goods.

4. Guidelines and Recommendations

Based on the results from our findings, we present guidelines and recommendations on how to improve transportation and mobility, how to achieve sustainable practises in the supply chain in the food and beverage industry, and how to adopt a consumer-centric approach.

4.1. Improving Transportation and Mobility

- **Route optimisation:** Use ideas of advanced analytics and AI to figure out the delivery fleet's optimal tour for maximum efficiency in terms of miles covered, least fuel usage, and fewer delays in transmission.
- **Real-time monitoring:** Through IoT devices, the location, status, and condition of goods can be monitored. It helps to avoid delays and improve the quality of the products.
- **Cold chain management:** It is a vital process of transporting and storing perishable goods such as meat, eggs, or fresh fish under optimal temperature for as long as possible to avoid spoilage. The key component is real-time monitoring and the control of environmental conditions for the products' safety.
- **Vehicle efficiency:** Utilise fuel-efficient vehicles, electric, or hybrid trucks, and regular maintenance that reduce energy usage and emissions, thus promoting a sustainable transport system.
- **Collaborative Logistics:** Sharing transportation sources and delivery vehicles with manufacturers and retailers with the aim to use trucks more efficiently and to reduce empty runs to lower transportation costs and carbon footprint.

4.2. Sustainable Practices

- **Eco-friendly packaging:** Replace current packaging materials with more environmentally friendly options, such as recyclable, biodegradable, or compostable materials. This will follow consumer trends for environmentally friendly products.
- **Energy-efficient warehousing:** Use of energy-efficient lighting, heating, ventilation, and air-conditioning (HVAC) systems in warehouses, and harness renewable energy (e.g., solar panels) to power the facilities.
- **Sustainable sourcing:** Entering into direct relationships with suppliers and respecting their craft principles; in this way, a reliable supply chain is assured and, especially, local communities are supported.
- **Waste reduction:** Improving inbound inventory management to prevent the generation of unnecessary materials. Making sure that outbound shipments are optimised, as they can cause an overproduction of materials. Instituting and maintaining recycling and composting programmes to lower the quantity of materials to landfill.
- **Intermodal transportation:** Moving cargo by rail, road, and sea to simultaneously take advantage of the energy efficiency of each mode and eliminate dependence on a single one.

4.3. Consumer-Centric Adaptation

- **Demand forecasting:** Using AI technology, businesses can better predict the actual consumer need for products and then scale production and inventory levels accordingly to minimise material and capital waste and ensure that products reach the correct markets and consumers at the right time.
- **Efficient order fulfilment:** Systems that expedite order processing and delivery. Doing this well has become a new priority for online grocery shopping, for example, and also for direct-to-consumer sales.
- **Transparency and communication:** Sharing this information with consumers tends to build trust. More and more people say they know and do care about their food's origins and production methods, and therefore retailers, restaurants, and food companies are responding to consumer demand for more and better information about their food.
- **Health and wellness trends:** Adjusting supply chains to cope with an increasing variety of fresh, minimally processed foods, as well as to ensure that their perishable nature can be transported quickly and efficiently so that they arrive fresh and at the optimal moment to best serve our health needs.
- **Customization and personalization:** Customisation and personalisation provides products tailored to specific consumer tastes and dietary requirements, perhaps by producing small batches and managing flexible supply chains to meet a variety of consumption needs.

5. Conclusions

This literature review concludes that the adoption of innovative technologies like blockchain, AI, and IoT is essential to improve transportation and mobility in FMCG supply chains. Eco-friendly packing, optimising logistics, and the use of fuel-efficient trucks are important sustainability practises which are integral to modern supply chain strategies. Sourcing materials from sources that demonstrate social and environmental responsibility is a way to guarantee the availability of raw materials, as well as contribute to local communities. Companies should adopt an integrated approach, where technological innovation, green practises, and consumer adaptations are involved in order to increase profitability. Companies in FMCG have to improve efficiency, eliminate inefficiencies, and enhance the flexibility of supply chains in order to meet the changing requirements of consumers and regulatory bodies and contribute to the resilience of the food system in the long-term.

Author Contributions: Conceptualization, S.U. and D.Ć.; methodology, E.T.S.; software, M.B.; validation, S.U. and S.S.; formal analysis, V.G.; investigation, S.U.; resources, S.S.; data curation, M.B.; writing—original draft preparation, S.U.; writing—review and editing, E.T.S.; visualization, V.G.; supervision, D.Ć. All authors have read and agreed to the published version of the manuscript.

Funding: This research has not received internal or external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data for this study are available upon request from the corresponding author.

Acknowledgments: During the preparation of this work the author(s) used QUILLBOT text editing in order to increase the fluency of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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

References

1. Drljača, M.; Sesar, V. Supply chain transportation management. *Transp. Res. Procedia* **2023**, *74*, 338–345. [\[CrossRef\]](#)
2. Aithal, A.; Singh, M.K.; Ray, P.; Duraipandian, R. An Integrated Approach to understand Supply Chain Optimization through the Lens of Technology. *Shanlax Int. J. Manag.* **2021**, *8*, 167–178. [\[CrossRef\]](#)
3. Sarkis, J. *Handbook on the Sustainable Supply Chain*; Edward Elgar Publishing: Cheltenham, UK, 2019.
4. Espinosa, R.V.; Soto, M.; Garcia, M.V.; Naranjo, J.E. Challenges of implementing cleaner production strategies in the food and beverage industry: Literature review. In Proceedings of the Advances and Applications in Computer Science, Electronics and Industrial Engineering: CSEI, Ambato, Ecuador, 26–30 October 2020; pp. 121–133.
5. Aliche, K.; Rexhausen, D.; Seyfert, A. Supply Chain 4.0 in consumer goods. *McKinsey Co.* **2017**, *11*, 1–11.
6. Dutta, P.; Choi, T.M.; Somani, S.; Butala, R. Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *142*, 102067. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Toorajipour, R.; Sohrabpour, V.; Nazarpour, A.; Oghazi, P.; Fischl, M. Artificial intelligence in supply chain management: A systematic literature review. *J. Bus. Res.* **2021**, *122*, 502–517. [\[CrossRef\]](#)
8. Manavalan, E.; Jayakrishna, K. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Comput. Ind. Eng.* **2019**, *127*, 925–953. [\[CrossRef\]](#)
9. Ben-Daya, M.; Hassini, E.; Bahrour, Z. Internet of things and supply chain management: A literature review. *Int. J. Prod. Res.* **2019**, *57*, 4719–4742. [\[CrossRef\]](#)
10. He, B.; Liu, Y.; Zeng, L.; Wang, S.; Zhang, D.; Yu, Q. Product carbon footprint across sustainable supply chain. *J. Clean. Prod.* **2019**, *241*, 118320. [\[CrossRef\]](#)
11. Adams, D.; Donovan, J.; Topple, C. Sustainability in large food and beverage companies and their supply chains: An investigation into key drivers and barriers affecting sustainability strategies. *Bus. Strateg. Environ.* **2023**, *32*, 1451–1463. [\[CrossRef\]](#)
12. Read, Q.D.; Brown, S.; Cuéllar, A.D.; Finn, S.M.; Gephart, J.A.; Marston, L.T.; Muth, M.K. Assessing the environmental impacts of halving food loss and waste along the food supply chain. *Sci. Total Environ.* **2020**, *712*, 136–255. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Ali, I.; Aboelmaged, M.G.S. Implementation of supply chain 4.0 in the food and beverage industry: Perceived drivers and barriers. *Int. J. Prod. Perform. Manag.* **2022**, *71*, 1426–1443. [\[CrossRef\]](#)
14. Gichuru, M.; Iravo, M.; Arani, W. Collaborative Supply Chain Practices on Performance of Food and Beverages Companies: A Case Study of Del Monte Kenya Ltd. *Int. J. Acad. Res. Bus. Soc. Sci.* **2015**, *5*, 17–31. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Tichy, T.; Brož, J.; Belinova, Z.; Kouba, P. Predictive diagnostics usage for telematic systems maintenance. In Proceedings of the 2020 Smart City Symposium Prague (SCSP), Prague, Czech Republic, 25 June 2020; IEEE: Piscataway, NJ, USA; pp. 1–6.
16. Aday, S.; Aday, M.S. Impact of COVID-19 on the Food Supply Chain. *Food Qual. Saf.* **2020**, *4*, 167–180. [\[CrossRef\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.