Enhancing Sustainable Public Transport Through Business Intelligence

Ilias Kalathas * and Michail Papoutsidakis *

Posted Date: 21 October 2025

doi: 10.20944/preprints202510.1472.v1

Keywords: business intelligence; public urban transportation; sustainable development; WEKA; KNIME

 doi:10.20944/preprints202510.1472.v1

Article

Enhancing Sustainable Public Transport Through Business Intelligence

Ilias Kalathas * and Michail Papoutsidakis

Department of Industrial Design and Production Engineering, University of West Attica, 15354 Athens, Greece

* Correspondence: i.kalathas@uniwa.gr; Tel.: +30-697-473-1434

Abstract

The successful implementation of Business Intelligence (BI) technologies in public transport relies primarily on the Internet for connectivity to facilitate real-time data transfer and communication within the vehicle or system. This contributes to service quality, and due to a positive influence on the environment, it is a sustainable solution. Beyond chatbots and digital assistants, Business Intelligence (BI) technologies can change the face of urban transportation. Equipped with BI and advanced analytics, transport networks will be able to offer better, timely, more personalized services that will enable better decision-making, reduce operational costs, and enhance sustainability. The aim of the paper is to describe the application of Business Intelligence tools in process enhancement at public transport companies with a focus on urban transportation. Integration of such technologies allows new decision-support strategies to be created that will add to sustainable solutions with a positive environmental footprint. More specifically, it investigates how data mining and machine learning, supported by low-cost, open-source tools like Weka and KNIME, can upgrade the processes of transport service providers. The study also investigates the incentives and benefits for companies in charge of providing safe urban transportation through the adoption of these technologies. These tools will help the companies increase their efficiency by reducing operational costs and hence improve the quality of the services. Finally, the results and incentives of transport organizations are presented in order to create applications that can be the main tool for improving decision-making by company management and developing supportive strategies that will lead to sustainable development and efficient urban transport systems.

Keywords: business intelligence; public urban transportation; sustainable development; WEKA; KNIME

1. Introduction

As urban settlements expand, with increased density, strain in terms of environment, and high consumption of energy, efficient, environmentally friendly, and social access networks of transport in smart settlements' direction through optimized mobility have a growing demand [1]. Through smart interventions in terms of information and communications technology (data and smart infrastructure), smart settlements try to develop efficient, environmentally friendly, and social access networks of transport [2]. Greenhouse gas emissions and congestion in terms of traffic and improvement in living standards in urban life, and alternative use of transportation, become its most important objectives [3].

Public transport occupies a backbone in urban life in an environmentally friendly manner. In smart settlements, smart interventions such as passengers' real-time information, contactless payments, and smart scheduling integrate with public transport for its improvement in operations [4]. With such development, passengers have real-time information and make efficient trip planning, and commuting through public transport can become a convenient and preferred manner of commuting. Analysis of real-time information plays a key role in regulating urban networks of transportation in smart urban environments. High-tech administration of traffic, smart lights, pricing

 doi:10.20944/preprints202510.1472.v1

for congestion, and routing algorithms for optimized routes ease driving and make driving less congested, and in consequence, make transportation efficient and effective [5,6].

Utilization of technology such as Business Intelligence (BI), assists in optimizing operations in public transportation networks. With such technology, transportation providers can evaluate big datasets in real-time, and with it, operational efficiency and asset management can be increased [7]. With BI in public transportation networks can maximize operational efficiency, minimize impact, and effectively utilize a model for sustainable transportation. Integration of technology is a key in developing a cleaner, efficient, and smarter urban driving environment, in enhancing service quality, and in minimizing the footprint of public driving networks [8].

Business Intelligence technology and tools present tools and technology for effective collection, storing, processing, and analysis of information in terms of business processes [9]. Business Intelligence tools, such as cheap and free tools such as WEKA software for machine learning and KNIME software for mining, allow one to implement improvements and modifications, and respond to specific requirements for a specific use. With existing technology, these two tools allow one to implement any improvement one wants and adapt them according to individual requirements.

The following part of the article presents relevant studies of the use of software for machine learning, i.e., WEKA, and software for mining, i.e., KNIME, and it is a starting point for developing a smart tool for supporting innovative processes. With its purpose, the tool will contribute to attaining a Business Intelligence system for supporting companies in taking correct and well-informed decisions.

In an attempt to develop a new Business Intelligence system for managing complexity in transportation, such as forecasting demand for tickets and scheduling coaches and trains, and for scheduling workers' shifts, the paper [10] is a relevant contribution.The paper [10] optimizes reading and use of a prototype in terms of construction and proposes new methodologies in data mining. It utilizes data in WEKA in an Advanced Manufacturing Analytics platform in revealing hidden trends in terms of construction processes, with increased productivity and efficiency in work in construction. Study [11] takes into consideration analysis of information through techniques in machine learning with use of WEKA, with an objective of finding faults in availability of an aircraft fleet. It estimates the availability of spare tools and formulates an intelligent system for minimizing spare tool expense, with increased efficiency and use of resources. The paper [12] formulates a systemic model for forecasting maintenance expense for highway construction equipment, with discussion of processes involved in information collection, analysis, model development, and information testing. It takes into consideration development and improvement in variety of types of models, with a comparison of seven algorithms through use of software for mining in WEKA. In paper [13], a data mining algorithm for changing maintenance processes in Greek rails is proposed. Algorithms are utilized in a platform in KNIME, in which future faults can be uncovered and grouped effectively, and accuracy in forecasting is assured. Furthermore, article [14] compares the performance of an industrial project for integration of KNIME data mining tools in Enterprise Service Bus (ESB) platform. It concludes that the web service and data mining engine of KNIME can integrate with present information systems and adapt to Industry 4.0, and companies can use information for improvement in processes of a business. Paper [15] addresses the development and use of predictive maintenance technology for farm machines, using analysis of past information for prediction of future failure in machines. Promotion of technology was conducted using free software, i.e., software of KNIME. The article [16] addresses models for improvement in processing documents. In proposed model, information retrieval and extraction of excerpts have been conducted using machine learning techniques. Implementation of model utilized software, i.e., software for KNIME, for processing documents.

Subsequently, the computer programs WEKA and KNIME have become key tools for comparative analysis and supporting sustained development. Article [17] proposes a new model for solid waste management that involves methodologies using P-graph and machine learning approaches supported through WEKA. In this investigation, 160 scenarios emerged, with a conclusion that the best model is that of the J48 algorithm, characterized by its efficiency, less

 doi:10.20944/preprints202510.1472.v1

consumption of time, and its adaptability in many sectors. Sustained development in future studies is expected to include consideration of both economic and environmental factors. Article [18], entitled promotes a single, open-source platform for simulations in smart cities with a rich variety of tools for machine learning to drive urban sustainability. In addition, article [19], entitled proposes a model for big data integration through the use of KNIME for supporting sustained development.

The next part of this paper will discuss the scientific bases of Business Intelligence by analyzing the characteristics of data mining and machine learning. At the same time, it outlines the key features of sustainable development along with overcoming the environmental issues of public transport, emphasizing innovative machine learning and data mining technology options with open-source software.

2. Research Context

2.1. Business Intelligence: Overview and Implications

Business Intelligence is the advanced computer technology used to support the discovery of data relevant to businesses, which could include revenues, products sold, costs incurred, sales revenues [20]. Organizations (specialized transportation project production) companies hope BI can be used in the provision of actionable information for better strategic and operational performance [21]. While its core functionality has BI delivering systematic conclusions based upon structured data, this procedure does entail several limitations. The use of structured data very often limits analysis to only one type of "closed" trajectory and not the complete range of dynamic business requirements [22,23]. Sometimes, there will be much time and labor involved in obtaining an overall view, especially in complex and multilevel scenarios. At the initial stage, the raw historic data are located and at the final is the making of the final decisions as shown in Figure 1.

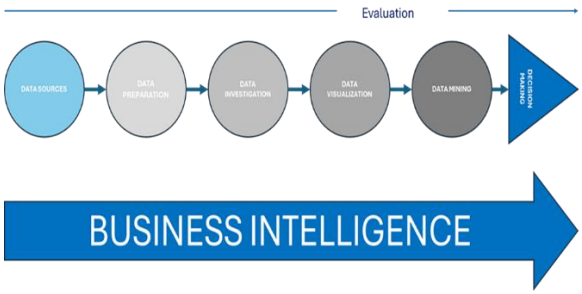

Figure 1. A traditional process of business intelligence data to make better decisions.

Despite these challenges, BI offers significant advantages. Its most notable strength is its ability to grant near-instant access to data insights that would otherwise demand extensive manual research [24]. This positioning makes BI an indispensable tool for tracking and response towards emerging trends and market transportation projects [25]. The speed and efficiency of BI allows businesses to adapt to decision-making processes, facilitate competitiveness, and adaptability within an increasingly changing marketplace [26,27]. In conclusion, although Business Intelligence has its limitations, its ability to streamline data analysis and deliver timely insights renders it a critical asset for modern organizations seeking to harness the power of data in their strategic pursuit.

2.2. Smart Tools Business Intelligence

2.2.1. Machine Learning Tool – WEKA

WEKA is an open-source software platform for machine learning, developed at the University of Waikato in New Zealand, and is under terms of the GNU General Public License. The software contains a variety of algorithms for use in machine learning for use with structured datasets, and these can be loaded in through files and generated through simple queries in a database. The algorithms enable one to build decision trees, and in this manner, streamline decision processes

 doi:10.20944/preprints202510.1472.v1

through predefined default values. In addition, WEKA enables flexible processing workflows for processing personalized information, and when paired with graphical representations of algorithms, proves efficient for predictive maintenance processes [28,29].

2.2.2. Data Mining Tool – KNIME

KNIME was developed in 2004 through a consortium of software developers at the University of Konstanz in Germany. The software is open-source, analytic in purpose, and is placed under the terms of use of the GNU General Public License. As a tool for business intelligence, KNIME possesses a full-fledged development environment and an extendable plugin infrastructure. With the use of the platform offered through KNIME, rapid and efficient processing, transformation, analysis, and visualization of information can be accomplished through its rich feature suite. It can work with big datasets with no restriction in terms of the number of data rows and computation during analysis. KNIME can run under all significant operating platforms, including Linux, Windows, and macOS, through its Java platform base. User-friendly graphical interfaces make it accessible to people with no background in programming. Frameworks for development and architecture in KNIME enable integration with disparate sources of information and allow for creating full workflows, with high-quality output in analysis [30,31].

2.3. Sustainability

Sustainability embodies the concept of satisfying present generations' requirements in such a manner that future generations can satisfy their requirements in a similar manner [32]. Despite its widespread use and sometimes its simplification to a buzzword, sustainability is an important basis for dealing with worldwide concerns in terms of environment, economy, and society [33].

2.3.1. Definition of Sustainability

The 1987 Bruntland Report brings a broadly acknowledged definition of sustainable development:

"Meeting present and future generations' needs, not at the expense of future generations' capacity for satisfying their own needs." [34].

To a considerable extent, sustainability involves a thorough grasp of interdependence between humanity, the planet, and life-support processes and systems. According to the report, economies' and society's welfare depend a lot on living organism and planet processes' vigor [35,36]

2.3.2. Principles of Sustainability

The key fundamentals, which form the basis of sustainability and must become a part of any system designed to tackle concerns and develop and implement practices for sustainable development, include:

- Environmental integrity: It is about prudent conservation and use of planet processes and natural assets in a manner allowing future generations to access them.
- Economic Balance: It involves developing economies satisfying humans' wants and requirements in a manner that does not exhaust planet assets.
- Social Equity: It involves providing fair access for groups and people to basic assets and opportunities, therefore allowing them to contribute at a full and effective level in a fair and equitable society [37–39].

As shown in Figure 2, all three pillars are equally important and interdependent on each other to achieve sustainable development at a holistic level.

 doi:10.20944/preprints202510.1472.v1

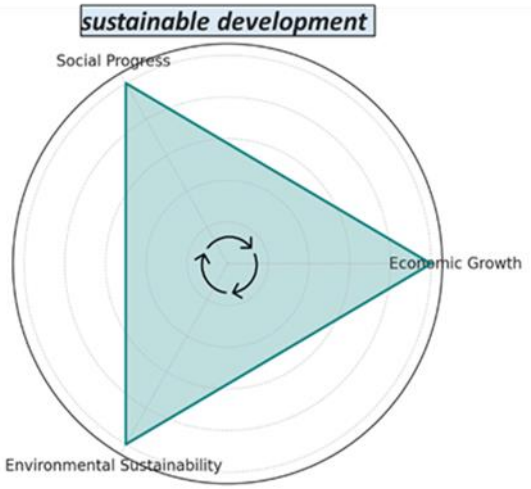

Figure 2. Sustainable development model cycle.

2.3.2.1. Unsustainable Practices and Consequences

Existing consumption trends seen in humanity at present times are actually unsustainable in the current form. In case these trends continue, degradation and exhaustion of planet processes, emerging as a consequence, will become irreparable. In such a case, it will mean:

- Food Insecurity: Degraded lands will not produce enough food provisions.
- Climate Displacement: Climate change will displace millions and destroy livelihoods.
- Resource Conflicts: Inadequacies in such key requirements, including water and arable lands, can ignite discord.
- Biodiversity Loss: Ecosystem degradation can cause extinction of many species, compromising with delicate harmony of overall environmental balance at a global level [40,41].

2.3.2.2. Sustainability in Action

The principle of sustainability must, therefore, be wholistic in its application, using cutting-edge problem-solving approaches and mandating a long-term outlook. Transition to renewable sources of energy, creation of circular economies, conservation of habitats, and establishment of social structures with a view towards equity and resilience are important [48]. Sustainability involves not only environmental factors but is in fact closely tied to humanity's survival and welfare [43]. By embracing such principles of sustainability, it is then feasible to have a planet in which humans and environment harmoniously coexist and co-thrive together [44].

2.4. Smart Public Transport: Sustainable and Ecological Cities

Public transportation forms an integral part of city planning for smart and sustainable cities, offering a pragmatic and environmentally friendly alternative to private car use, such as bus, trams, and similar ones [45]. Despite numerous challenges, urban mobility programs work towards resolving them, and in consequence, provide equitable and accessible options for everyone, including factors such as overcrowded roads, pollution, and greenhouse emissions [46]. Public transportation's positive impact towards urban sustainability comes in terms of reduced use of private forms of conveyances. Eliminating such use reduces jams, curtails pollution, and promotes connectivity, and in consequence, enables urban economy growth in a city in question. With ongoing improvement in public transportation, its effectiveness will serve in supporting environment objectives, such as reduced consumption of energy and increased use of renewable sources [47,48]. The anticipated path of public transportation will witness considerable change through integration with cutting-edge technology and environmentally friendly operational processes. Greater operational efficiency, with reduced emissions, will be attained through the use of electric-powered buses, development of smart transportation infrastructure, and real-time analysis of information [49]. Progress in such direction

 doi:10.20944/preprints202510.1472.v1

will require coordination between government departments, urban planning departments, and transportation departments through public-private partnerships for strengthening infrastructure and operations of public transportation [50].

Public transportation forms a critical part of a future city with a sustainable urban ecosystem, resolving key social and environment-related concerns. Successful examples of efficient bus networks, such as in Singapore and TransMilenio in Bogotá, illustrate that careful planning and technological advancement form key requirements for developing efficient and ecologically friendly transportation networks [51,52]. Thus, investment in public transportation infrastructure is about to become a key driving force for creating a sustainable, accessible, and resilient urban environment.

3. Problems and Solutions for Urban Transportation Using Smart Tools BI

Public transportation providers experience significant hurdles when attempting to make their business models profitable. These hurdles originate from the environment, the economy, society, and the field of technology. This chapter discusses these hurdles and illustrates how solution providers can assist through the use of Data Intelligence (BI), WEKA, and KNIME. Both tools can be downloaded for free and utilized for free. This is beneficial for providers, particularly those with limited capital. These solution providers can streamline their processes, reduce their carbon footprint, and make passengers happier, resulting in superior and sustainable mobility. This chapter illustrates through real-life scenarios the benefits data analysis has for urban mobility.

3.1. Problems Facing the Public Transport Organizations

Public transportation providers experience various issues that influence their improvement over the years. These issues influence their efficiency, the environment, and the public. One significant challenge for the environment is the high emission from the majority of the publicly available motor vehicles using fuels from fossils emitting carbon gas [53–56]. Energy consumption is also an issue since we need to incorporate cleaner energy and energy efficiency like the use of electricity and alternative fuels [57–59]. Increased traffic increases the consumption of fuels and emission levels and also decreases the efficiency level of transportation [60,61]. Proper waste handling is also essential, whereby the cars and the infrastructure require structures for handling waste like tires, lubricants, and batteries [62,63]. Economic problems also involve high investment costs for switching over to clean technologies [64]. Switchovers from traditional cars to clean cars are very costly [65]. Having the support and financing for clean growth is essential, but the funds are not necessarily available [66]. Even the operation and upkeep of clean technologies can also involve high expenses and specialized skills [67]. Social barriers comprise the acceptance by the populace of the adoption of new forms of mobility, such as interoperability of public transport [68–70]. Accessible public transport is essential for sustainability, where everyone can travel, and the costs remain affordable [71]. Transforming the habits of individuals is also one of the greatest challenges, where rewards and transparent communication need to assist them in adopting the adoption of new mobility [72].

Effective management, study, and implementation of sophisticated Business Intelligence tools have the potential to significantly contribute towards improving the transportation industry, while also encouraging the maximum usage of resources. The following sections describe ways through which intelligent and economical business intelligence tools need to be used for making digital and non-digital changes within the organizations dealing with the provision of transport services.

3.2. Using KNIME and WEKA for Environment Friendly Transportation Solutions for the City

The use of Business Intelligence (BI) tools such as the WEKA machine learning tool and the KNIME data mining tool can significantly help public transport systems and transport companies by solving various issues. Using the WEKA software tool, route control, passenger needs analysis and road analysis can be carried out. This improves the routing process and reduces fuel consumption. The new system will be able to provide better routes to save energy and reduce emissions.

 doi:10.20944/preprints202510.1472.v1

KNIME helps collect and analyze data from various sources such as GPS sensors, databases, and real-time road and weather data. This increases the efficiency of the transportation and also decreases the costs.

In capacity forecasting and forecasting demands, WEKA applies machine learning for forecasting the passengers by day, by time, and by season. This assists the fleets and helps avoid the waste of resources. KNIME, however, analyzes high levels of data from ticket machines, sensors, and portable devices for providing data for optimizing the mode of transport. For energy conservation and emission of less carbon, classification and regression by WEKA determine the cars and routes using the highest levels of fuel, optimizing the mode of transport. KNIME also optimizes sensor data for the consumption of fuel and its environment impact for the support of greener options and emission reduction of CO_2.

WEKA offers predictive abilities for when maintenance is required and for reducing the expenses. These models analyze the deterioration and failures of the parts over the past and recommend the prevention of the failures, thus the cost of the repairs is reduced. Analyzing the work previously performed, including the failures, can avoid sudden breakdowns of the cars, and this is simplified using KNIME. The supply of useful information, via the datamining process, leads to making the right decisions so as to optimize the maintenance as shown in Figure 3 and the goals set case by case.

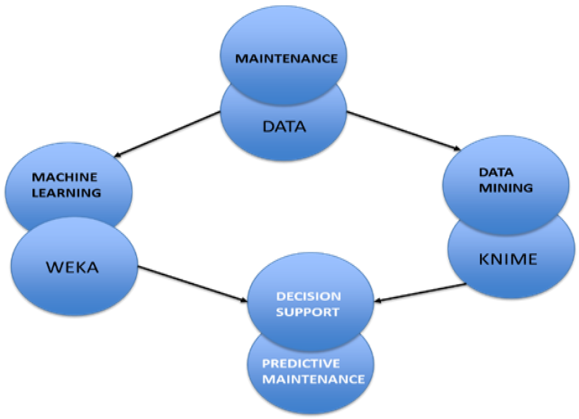

Figure 3. Flow chart diagram for predictive maintenance with WEKA and KNIME.

Analyzing data from passengers, their movements, and their feedback assists the improvement of the passengers' experience and motivates passengers to travel using public mode. Data from the online networks, online reservations, and the cell phones are merged and analyzed using KNIME, thus providing customized services for the passengers.

In decision-making and policymaking, WEKA facilitates the building of models for forecasting the impact the use of environmentally friendly innovations, such as cars and interoperability of public transport, has on the economy and the returns from them. KNIME analyzes various economic indicators, environment-focused study, and regulations for sustainability to enable informed data-driven decisions. Both KNIME and WEKA make the handling of vast data by the transport sector easier, informed decision-making, and transition towards sustainable development, as shown in the flowchart in Figure 4. These entities can make their processes faster, minimize their carbon print, save resources, and improve the satisfaction of passengers using data mining and machine learning.

 doi:10.20944/preprints202510.1472.v1

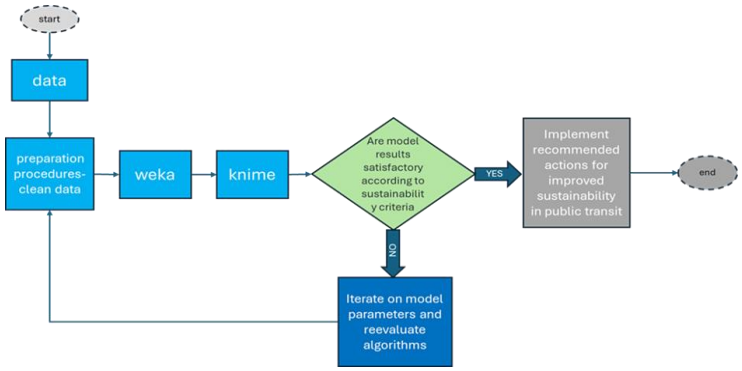

Figure 4. Flow chart diagram for sustainability in public transit with business intelligence methods.

4. Analysis and Potential Directions

4.1. Discourse

The application of Business Intelligence (BI) in public transportation is emerging as a key factor in advancing sustainability, improving efficiency, and optimizing urban mobility. The ability to collect, analyze, and utilize vast amounts of data enables transportation organizations to enhance service quality while simultaneously reducing environmental impacts. The integration of advanced analytical tools, including machine learning and artificial data mining, allows transport companies to make better-informed decisions, optimize resource management, and achieve higher levels of operational efficiency. Table 1 below illustrates concrete examples of the impact of business intelligence on public transport.

Table 1. The Impact of Business Intelligence on Public Transportation.

The Impact of Business Intelligence on Public Transportation	
Sphere of influence	Description
Optimization & Traffic Management	GPS & traffic data analysis for efficient routes, fuel & emissions reduction
Energy Consumption Reduction	Identifying efficient vehicles, transitioning to electric transport & consumption analysis.
Demand Management During Peak Hours	Demand forecasting, schedule adjustments, congestion reduction & fuel savings.
Predictive Maintenance	Vehicle data analysis to predict failures, reduce costs & enhance reliability.
Waste Minimization & Recycling	Tracking & managing transport waste, promoting reuse & recycling.
Enhancing Public Transport	Passenger pattern analysis, service improvement, reduced private car dependency & emissions.

 doi:10.20944/preprints202510.1472.v1

The adoption of open-source tools such as WEKA and KNIME further enhances the potential of BI in the public transportation sector. These platforms provide transport companies with powerful data analysis capabilities without requiring significant financial investments. By utilizing these tools, organizations can analyze historical and real-time data, predict future demand trends, and implement data-driven strategies to improve operational efficiency. Open-source solutions are particularly beneficial for public transport authorities and organizations with limited financial resources, as they offer a cost-effective approach to implementing BI solutions. Table 2 presents the economic advantages of using open-source software provided free of charge such as WEKA and KNIME.

Table 2. Economic benefits of using WEKA and KNIME.

Economic benefits	
Component	Description
Economically Viable Solutions	Open-source BI tools (KNIME, WEKA) enable cost-effective transport operations.
Data Analysis Capability	Allows analysis of large datasets without high financial investment.
Adherence to Aims	Supports goals by reducing reliance on expensive proprietary software.
Enhanced Decision-Making	Improve decision-making while keeping operating costs low
Economic & Monetary Benefits	Simplifies financial incentives for business and investment.

Additionally, both KNIME and WEKA also promote the cause for environmental sustainability by helping the operators of transport reduce energy consumption and emissions. Organizations can improve the efficiency of fuels, find opportunities for using less energy-consuming forms of transport, and transition towards using environment-friendlier forms of tech like hybrids and electric cars by applying data mining and machine learning processes. Ultimately, the adoption of business intelligence data into the formulation of policies and operating strategies helps ensure that sustainability remains the core emphasis for the improvement of urban mobility solutions.

4.2. Future Directions

To further improve effectiveness, public transport can be made more efficient with the aid of Business Intelligence by following various strategies that are oriented towards the future directions as shown in Table 3. These directions can guide the principles to shape the applications of the sector into the future.

Table 3. Economic benefits of using WEKA and KNIME.

Future Technological Strategies [73–79]	
Key Technological Strategy	Description

 doi:10.20944/preprints202510.1472.v1

Phygital Experience Platform	IoT-enabled platform for real-time passenger engagement.
Data and AI Hub	Central AI hub to optimize data architecture and AI-driven processes.
Process Optimization	Uses BPM & RPA to enhance efficiency and streamline operations.
Standardization of Enterprise Systems	Replace outdated systems with cloud solutions for efficiency and sustainability.
Operational Resilience	Strengthens cybersecurity, disaster recovery, and business continuity.
Talent Development	Upskilling programs to support digital innovation and adaptability.

It is clear that deployment of transport with the incorporation of next-generation technologies like AI, IoT, big data, and cloud computing will provide wiser and prudent decision-making capabilities, improve passengers' travel experiences, and automate major functions to the best levels of performance.

5. Conclusions

The integration of Business Intelligence (BI), Machine Learning (ML), and Data Mining technologies into public transportation systems represents a transformative approach to addressing urban mobility challenges, sustainability, and operational efficiency. By leveraging low-cost open-source tools such as WEKA and KNIME, public transport providers can optimize routes, reduce energy consumption, predict passenger demand, and enhance service quality while minimizing environmental impacts. These technologies enable real-time data analysis, predictive maintenance, and dynamic decision-making, which are critical for developing smarter, more sustainable urban transport networks. Application of platforms such as WEKA and KNIME, operated through an open-source platform, will bestow high-tech analysis capabilities in operators with little financial resources, and in the process, will enable even small operators to access the value that BI can produce.

The future direction of public transportation in future years will be characterized through continued integration of digital technology, such as artificial intelligence, Internet of Things (IoT), and big data analysis, with a view towards increased operational efficiency and comfort for passengers.

In summary, effective use of Business Intelligence, Machine Learning, and Data Mining in public transportation networks creates a path towards smarter, environmentally friendly, and efficient urban mobility platforms. By leveraging such technology metropolitan areas can tackle urbanization-related problems, promote environment-friendliness, and maximize resource efficiency, enhancing

 doi:10.20944/preprints202510.1472.v1

citizens' living standards and supporting development towards a cleaner and environmentally friendly.

Author Contributions: Conceptualization, I.K.; methodology, I.K.; software, I.K.; validation, M.P.; formal analysis, I.K.; investigation, M.P.; resources, I.K.; data curation, I.K.; writing—original draft preparation I.K.; writing—review and editing, M.P.; supervision, M.P.; project administration, I.K. and M.P. All authors have read and agreed to the published version of the manuscript

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to specific technical characteristics.

Acknowledgments: All authors would like to thank the University of West Attica for the financial support provided to them to undertake this research project.

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

References

1. Ali, N. (2021). Evaluating sustainable urban transport systems: A Review study for the identification of smart mobility indicators. Transactions on Transport Sciences, 12(2), 16-23. doi: 10.5507/tots.2021.008
2. Mavlutova, I., Atstaja, D., Grasis, J., Kuzmina, J., Uvarova, I., & Roga, D. (2023). Urban Transportation Concept and Sustainable Urban Mobility in Smart Cities: A Review. Energies, 16(8), 3585. https://doi.org/10.3390/en16083585
3. Trindade, E. P., Hinnig, M. P. F., Costa, E. M., Marques, J. S., Bastos, R. C., & Yigitcanlar, T. (2017). Sustainable development of smart cities: A systematic review of the literature. Journal of Open Innovation: Technology, Market, and Complexity, 3(1), 11. https://doi.org/10.1186/s40852-017-0063-21
4. Yong-Hong Kuo, Janny M.Y. Leung, Yimo Yan a (2023), Public transport for smart cities: Recent innovations and future challenges European Journal of Operational Research, Volume 306, Issue 3, 1 May 2023, Pages 1001-1026 https://doi.org/10.1016/j.ejor.2022.06.057
5. Zhang, L., & Zhang, J. (2020). Smart public transportation systems: A review of the literature. Transportation Research Part C: Emerging Technologies, 120, 102824. https://doi.org/10.1016/j.trc.2020.1028242.
6. Bibri, S. E., & Krogstie, J. (2019). Generating a vision for smart sustainable cities of the future: A scholarly backcasting approach. European Journal of Futures Research, 7(1), 5. https://doi.org/10.1186/s40309-019-0157-0
7. Chen, H., Chiang, R. H. L., & Storey, V. C. (2012). Business Intelligence and Analytics: From Big Data to Big Impact. MIS Quarterly, 36(4), 1165-1188. https://doi.org/10.2307/41703503
8. Allam, Z., & Dhunny, Z. A. (2019). On big data, artificial intelligence and smart cities. Cities, 89, 80-91. https://doi.org/10.1016/j.cities.2019.01.032
9. Wang, Y., Kung, L., & Byrd, T. A. (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. Technological Forecasting and Social Change, 126, 3-13. https://doi.org/10.1016/j.techfore.2015.12.019
10. Gröger, C., Niedermann, F. and Mitschang, B. (2012) Data Mining-driven Manufacturing Process Optimization. Proceedings of the World Congress on Engineering, London, 4-6 July 2012, Corpus ID: 14461305
11. Rahim, A., Hamizah, F., Noor, N.M., Abdullah, H. and Annanurov, B. (2020) Cost Minimization of Aircraft Critical Components for Planning and Maintenance Requirements. International Journal of Integrated Engineering, 12, 40-53. https://doi.org/10.30880/ijie.2020.12.07.005

 doi:10.20944/preprints202510.1472.v1

12. Bayzid, S.M., Mohamed, Y. and Al-Hussein, M. (2016) Prediction of Maintenance Cost for Road Construction Equipment: A Case Study. Canadian Journal of Civil Engineering, 43, 480-492. https://doi.org/10.1139/cjce-2014-0500
13. Kalathas, Ilias & Papoutsidakis, Michail & Drosos, Christos. (2021). Business Intelligence and Machine Learning Methods for Predictive Maintenance in Greek railways. Open Journal of Applied Sciences. 11. 20-35. 10.4236/ojapps.2021.111A003
14. Massaro, A., Maritati, V., Galiano, A., Birardi, V. and Pellicani, L. (2018) ESB Platform Integrating Knime Data Mining Tool Oriented on Industry 4.0 Based on Artificial Neural Network Predictive Maintenance. International Journal of Artificial Intelligence & Applications, 9, 1-17. https://doi.org/10.5121/ijaia.2018.9301
15. Lüttenberg, H., Bartelheimer, C. and Beverungen, D. (2018) Designing Predictive Maintenance for Agricultural Machines. 26th European Conference on Information Systems (ECIS 2018), Portsmouth, Research Papers 153. https://aisel.aisnet.org/ecis2018_rp/153
16. Rahmaoui, O., Souali, K. and Ouzzif, M. (2020) Towards a Documents Processing Tool usIng Traceability Information Retrieval and Content Recognition through\ Machine Learning in a Big Data Context. Advances in Science, Technology and Engineering Systems Journal, 5, 1267-1277. https://doi.org/10.25046/aj0506151
17. Ali, R. A., Nik Ibrahim, N. N. L., Wan Abdul Karim Ghani, W. A., Sani, N. S., & Hon, L. L. (2022). A hybrid P-graph and WEKA approach in decision-making: Waste conversion technologies selection. Tamkang University Press. https://doi.org/10.6180/jase.202302_26(2).0012
18. Shulajkovska, M., Smerkol, M., Noveski, G., & Gams, M. (2024). Enhancing Urban Sustainability: Developing an Open-Source AI Framework for Smart Cities. Smart Cities, 7(5), 2670-2701. https://doi.org/10.3390/smartcities7050104
19. Taques, Fernando & Chasco, Coro & Taques, Flávio. (2024). Integrating big data with KNIME as an alternative without programming code: an application to the PATSTAT patent database. Journal of Geographical Systems. 1-31. https://doi.org/10.1007/s10109-024-00445-0.
20. Mary, S.S.C., Arun, C.J. (2024). Data Mining and Business Intelligence Trends. In: Poulose, J., Sharma, V., Maheshkar, C. (eds) Data-Driven Decision Making. Palgrave Macmillan, Singapore. https://doi.org/10.1007/978-981-97-2902-9_5
21. Du, Juan & Wang, Wenxin & Gao, Ray & hu, Min & Jiang, Haili. (2023). Sustainable Operations: A Systematic Operational Performance Evaluation Framework for Public–Private Partnership Transportation Infrastructure Projects. Sustainability. 15. 7951. https://doi.org/10.3390/su15107951.
22. Kabir, Syed Muhammad. (2016). METHODS OF DATA COLLECTION. in book: Basic Guidelines for Research: An Introductory Approach for All Disciplines (pp.201-275) Edition: FirstChapter: 9Publisher: Book Zone Publication, Chittagong-4203, Bangladesh
23. Gad-Elrab, A.A. (2021). Modern business intelligence: Big data analytics and artificial intelligence for creating the data-driven value. E-Business-Higher Education and Intelligence Applications, 135. https://doi.org/10.5772/INTECHOPEN.97374.
24. Farayola, Oluwatoyin & Olatoye, Funmilola & Chinwe, Nnabugwu & Daraojimba, Chibuike. (2023). BUSINESS INTELLIGENCE TRANSFORMATION THROUGH AI AND DATA ANALYTICS. Engineering Science & Technology Journal. 4. 285-307. 10.51594/estj.v4i5.616 https://doi.org/10.51594/estj.v4i5.616
25. Sharma, K., Shetty, A., Jain, A., & Dhanare, R.K. (2021). A Comparative Analysis on Various Business Intelligence (BI), Data Science and Data Analytics Tools. In 2021 International Conference on Computer Communication and Informatics (ICCCI) (pp. 1- 11). IEEE. DOI: 10.1109/ICCCI50826.2021.9402226. Available at: https://dx.doi.org/10.1109/ICCCI50826.2021.9402226.
26. Olszak, C.M., Zurada, J., & Cetindamar, D. (2021). Business intelligence & big data for innovative and sustainable development of organizations. Information Systems Management, 38(4), .268-269. [online] Available at: https://dx.doi.org/10.1080/10580530.2021.1971021
27. Ilieva, R., Ivanova, M., Peycheva, T., & Nikolov, Y. (2021). Modelling in support of decision making in business intelligence. In Integration Challenges for Analytics, Business Intelligence, and Data Mining (pp. 115-144). IGI Global. [online] 2021, pp. 61-76. Available at: https://dx.doi.org/10.4018/978-1-7998-5781-5.ch006

28. Asha Kiranmai, S. and Jaya Laxmi, A. (2018) Data Mining for Classification of Power Quality Problems Using WEKA and the Effect of Attributes on Classification Accuracy. Protection and Control of Modern Power Systems, 3, Article No. 29. https://doi.org/10.1186/s41601-018-0103-3
29. Kulkarni, E.G. and Kulkarni, R.B. (2016) Article: Weka Powerful Tool in Data Mining. IJCA Proceedings on National Seminar on Recent Trends in Data RTDM, 2, 10-15
30. Feltrin, L. (2015) KNIME an Open Source Solution for Predictive Analytics in the Geosciences [Software and Data Sets]. IEEE Geoscience and Remote Sensing Magazine, 3, 28-38. https://doi.org/10.1109/MGRS.2015.2496160
31. Jagla, B., Wiswedel, B. and Coppée, J.-Y. (2011) Extending KNIME for Next-Generation Sequencing Data Analysis. Bioinformatics, 27, 2907-2909. https://doi.org/10.1093/bioinformatics/btr478
32. Kuhlman, T., & Farrington, J. (2010). What is Sustainability? Sustainability, 2(11), 3436-3448. https://doi.org/10.3390/su2113436
33. Srivastava, Meetika, (2012). A Study on Sustainability and Sustainable Development: Detailed Explanation of the Terms and Its Evolution, Concept and Meaning Including Discussion on How to Enable Sustainable Development. Available at SSRN: https://ssrn.com/abstract=3652024 or http://dx.doi.org/10.2139/ssrn.3652024
34. European Union https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:sustainable_development
35. Cairns,Jr, John. (2001). Ethics in environmental politics and sustainable use of the planet. Ethics in Science and Environmental Politics. 1. 10.3354/esep001038. https://doi.org/10.3354/esep001038
36. Timo Busch, Carolin Weber, and Theresa Sophie Rötzel, (2024) Sustainability Transformation or Utopia? The Role of Organizational Practices for Resolving Tensions. Proceedings, https://doi.org/10.5465/AMPROC.2024.259bp
37. Diaz-Barrera, M.E., Alfaro-Aucca, C., Pacheco-Mendoza, J. et al. (2025). Bibliometric analysis of prominent topics in global scientific production on sustainable development goals in Scopus (2013–2022). Discov Sustain 6, 74 (2025). https://doi.org/10.1007/s43621-024-00700-w
38. Mishra, M., Desul, S., Santos, C.A.G. et al. (2024). A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities. Environ Dev Sustain 26, 11101–11143 https://doi.org/10.1007/s10668-023-03225-w
39. Schirone, M. (2024). The formation of a field: sustainability science and its leading journals. Scientometrics 129, 401–429 https://doi.org/10.1007/s11192-023-04877-1
40. Alfirević, N., Malešević Perović, L., & Mihaljević Kosor, M. (2023). Productivity and Impact of Sustainable Development Goals (SDGs)-Related Academic Research: A Bibliometric Analysis. Sustainability, 15(9), 7434. https://doi.org/10.3390/su15097434
41. Rani, S., Jining, D., Shoukat, K., Shoukat, M. U., & Nawaz, S. A. (2024). A Human–Machine Interaction Mechanism: Additive Manufacturing for Industry 5.0—Design and Management. Sustainability, 16(10), 4158. https://doi.org/10.3390/su16104158
42. Mishra, M., Desul, S., Santos, C.A.G. et al. (2024). A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities. Environ Dev Sustain 26, 11101–11143 https://doi.org/10.1007/s10668-023-03225-w
43. Schirone, M. (2024). The formation of a field: sustainability science and its leading journals. Scientometrics 129, 401–429 https://doi.org/10.1007/s11192-023-04877-1
44. Hao, Z., Rallings, A. M., Espinoza, V., Luo, P., Duan, W., Peng, Q., Gao, Y., & Viers, J. H. (2021). Flowing from East to West: A bibliometric analysis of recent advances in environmental flow science in China. Ecological Indicators. https://doi.org/10.1016/j.ecolind.2021.107358
45. Ashraf, Aayesha & Idrisi, Dr. M. (2024). Smart and Sustainable Public Transportation - A Need of Developing Countries. International Journal of Networked and Distributed Computing. 12. https://doi.org/10.1007/s44227-024-00023-2
46. Wasif, Mumtaz & Sano, Nadeem. (2025). Smart City Development and AI: Revolutionizing Urban Infrastructure Optimization for Efficient Transportation Planning. https://doi.org/1010.13140/RG.2.2.26625.77920.

 doi:10.20944/preprints202510.1472.v1

47. E, IKUGBE & T., HASSAN & MATHEW, ANIH. (2025). AN APPRAISAL OF THE IMPACTS OF SCIENCE AND TECHNOLOGY ON SUSTAINABLE URBAN DEVELOPMENT. International Journal of African Innovation and Multidisciplinary Research. https://doi.org/10.70382/mejaimr.v7i2.025.
48. Sezer, Nurettin & Batur, Irfan & Arı, Ibrahim. (2016). Green Mobility Application (GMAP). https://doi.org/10.5339/qfarc.2016.EESP3063.
49. Torre-Bastida, A.I., Del Ser, J., Laña, I., Ilardia, M., Bilbao, M.N. and Campos-Cordobés, S. (2018), Big Data for transportation and mobility: recent advances, trends and challenges. IET Intell. Transp. Syst., 12: 742-755. https://doi.org/10.1049/iet-its.2018.5188
50. Irwandi, & Pratomo, Soni & Febri, Cynthia & Indarti, Sri & ., Taufiqurrachman & Sari, Avid. (2024). PUBLIC-PRIVATE PARTNERSHIPS FOR SUSTAINABLE URBAN DEVELOPMENT: LESSONS FROM INDONESIAN CITIES. VISIONER Jurnal Pemerintahan Daerah di Indonesia. 16. 71-81. https://doi.org/10.54783/jv.v16i1.1047.
51. Echeverry, Juan & Ibañez, Ana & Moya, Andres & Hillón, Luis. (2004). The Economics of TransMilenio, a Mass Transit System for Bogota. Journal of LACEA Economia. 5. https://doi.org/10.1353/eco.2005.0014.
52. Chin, Hoong & Foong, Kok. (2006). Issues in transportation planning - the Singapore Experience. https://doi.org/10.2495/978-1-85312-799-1/07.
53. Hou, L., Wang, Y., Zheng, Y., & Zhang, A. (2022). The Impact of Vehicle Ownership on Carbon Emissions in the Transportation Sector. Sustainability, 14(19), 12657. https://doi.org/10.3390/su141912657
54. Pang, K., Zhang, Q., Ma, C. Y., Zhu, L. Q., Chen, H. R., Kong, X. R., Pan, F., and Yang, H. (2022). "Forecasting of Emission Co-reduction of Greenhouse Gases and Pollutants for the Road Transport Sector in Lanzhou Based on the LEAP Model." Huan Jing Ke Xue 43 (7): 3386-3395. https://doi.org/10.13227/j.hjkx.202109119.
55. Wang, Bo & Sun, Yefei & Chen, Qingxiang & Wang, Zhaohua, (2018) "Determinants analysis of carbon dioxide emissions in passenger and freight transportation sectors in China," Structural Change and Economic Dynamics, Elsevier, vol. 47(C), pages 127-132. https://doi.org/10.1016/j.strueco.2018.08.003
56. Fameli, K.M. & Assimakopoulos, V.D.. (2014). Development of a road transport emission inventory for Greece and the Greater Athens Area: Effects of important parameters. The Science of the total environment. 505C. 770-786. https://doi.org/10.1016/j.scitotenv.2014.10.015
57. Gajdzik, B., Wolniak, R., Nagaj, R., Žuromskaitė-Nagaj, B., & Grebski, W. W. (2024). The Influence of the Global Energy Crisis on Energy Efficiency: A Comprehensive Analysis. Energies, 17(4), 947. https://doi.org/10.3390/en17040947
58. Farghali, M., Osman, A.I., Chen, Z. et al. (2023) Social, environmental, and economic consequences of integrating renewable energies in the electricity sector: a review. Environ Chem Lett 21, 1381–1418 https://doi.org/10.1007/s10311-023-01587-1
59. Yuksel, Tugce, and Jeremy J. Michalek. (2015)"Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States." Environmental Science & Technology 49 (6): 3974-3980. https://doi.org/10.1021/es505621s
60. Yao, Zhihong, Yi Wang, Bo Liu, Bin Zhao, and Yangsheng Jiang. (2021) "Fuel Consumption and Transportation Emissions Evaluation of Mixed Traffic Flow with Connected Automated Vehicles and Human-Driven Vehicles on Expressway." Energy 230: 120766. https://doi.org/10.1016/j.energy.2021.120766.
61. Xie, R., Fang, J., & Liu, C. (2017). The effects of transportation infrastructure on urban carbon emissions. Applied Energy, 196, 199-207. https://doi.org/10.1016/j.apenergy.2017.01.020
62. Wang, Y., Zhou, Y., Zhu, L., Zhang, F., & Zhang, Y. (2018). Influencing Factors and Decoupling Elasticity of China's Transportation Carbon Emissions. Energies, 11(5), 1157. https://doi.org/10.3390/en11051157
63. Shamsuddoha, M., Kashem, M. A., & Nasir, T. (2025). A Review of Transportation 5.0: Advancing Sustainable Mobility Through Intelligent Technology and Renewable Energy. Future Transportation, 5(1), 8. https://doi.org/10.3390/futuretransp5010008
64. Adão, B., Narajabad, B., & Temzelides, T. (2024). Renewable technology adoption costs and economic growth. Energy Economics, 129, 107255. https://doi.org/10.1016/j.eneco.2023.107255
65. Demartini, M., Ferrari, M., Govindan, K., & Tonelli, F. (2023). The transition to electric vehicles and a net zero economy: A model based on circular economy, stakeholder theory, and system thinking approach. Journal of Cleaner Production, 410, 137031. https://doi.org/10.1016/j.jclepro.2023.137031

 doi:10.20944/preprints202510.1472.v1

66. Clark, R., Reed, J., & Sunderland, T. (2018). Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. Land Use Policy, 71, 335-346. https://doi.org/10.1016/j.landusepol.2017.12.013
67. Martínez-Peláez, R., Ochoa-Brust, A., Rivera, S., Félix, V. G., Ostos, R., Brito, H., Félix, R. A., & Mena, L. J. (2023). Role of Digital Transformation for Achieving Sustainability: Mediated Role of Stakeholders, Key Capabilities, and Technology. Sustainability, 15(14), 11221. https://doi.org/10.3390/su151411221
68. Kayikci, Y., & Kabadurmus, O. (2022). Barriers to the adoption of the mobility-as-a-service concept: The case of Istanbul, a large emerging metropolis. Transport Policy, 129, 219-236. https://doi.org/10.1016/j.tranpol.2022.10.015
69. Delaere, H., Basu, S., Macharis, C., et al. (2024). Barriers and opportunities for developing, implementing, and operating inclusive digital mobility services. European Transport Research Review, 16, 67. https://doi.org/10.1186/s12544-024-00684-8
70. Nikiforiadis, A., Tsavdari, D., Mizaras, V., & Ayfantopoulou, G. (2023). Identifying Barriers and Expectations in MaaS: Users' and Stakeholders' Perspective. Future Transportation, 3(4), 1240-1252. https://doi.org/10.3390/futuretransp3040068
71. Jelti, F., Allouhi, A., & Tabet Aoul, K. A. (2023). Transition Paths towards a Sustainable Transportation System: A Literature Review. Sustainability, 15(21), 15457. https://doi.org/10.3390/su152115457
72. Bıyık, C., Abareshi, A., Paz, A., Arce Ruiz, R., Battarra, R., Rogers, C. D. F., & Lizarraga, C. (2021). Smart mobility adoption: A review of the literature. Journal of Open Innovation: Technology, Market, and Complexity, 7(2), 146. https://doi.org/10.3390/joitmc7020146
73. Pathuri, Naveena. (2024). IoT-Enabled Cross-Platform Applications for Real-Time Logistics Monitoring. International Journal of Scientific Research in Computer Science, Engineering and Information Technology. 10. 1179-1185. https://doi.org/10.32628/CSEIT241061159
74. Khan, M.W.; Saad, S.; Ammad, S.; Rasheed, K.; Jamal, Q. Smart Infrastructure and AI. In AI in Material Science; CRC Press: Boca Raton, FL, USA, 2024; pp. 193–215
75. Gopalakrishnan, Karthika. (2023). Robotic Process Automation: Streamlining Operations and Revolutionizing Traditional Banking Processes. Journal of Artificial Intelligence & Cloud Computing. 1-4. https://doi.org/10.47363/JAICC/2023(2)332.
76. Bejinaru, Ruxandra & Marian-Vladut, Toma. (2024). Enhancing Business Operations Through Microlearning, BPM and RPA. Proceedings of the International Conference on Business Excellence. 18. 1831-1847. https://doi.org/10.2478/picbe-2024-0154.
77. Gholamhosseinian, Ashkan & Khalifeh, Ahmad. (2012). Cloud Computing and Sustainability: Energy Efficiency Aspects. https://doi.org/10.13140/RG.2.2.14030.33606.
78. Panda, A. and Bower, A. (2020), "Cyber security and the disaster resilience framework", International Journal of Disaster Resilience in the Built Environment, Vol. 11 No. 4, pp. 507-518. https://doi.org/10.1108/IJDRBE-07-2019-0046
79. Li, L. (2024) Reskilling and Upskilling the Future-ready Workforce for Industry 4.0 and Beyond. Inf Syst Front 26, 1697–1712 https://doi.org/10.1007/s10796-022-10308-y