Melbourne Metro Rail's ITS: Cyclic Functions Assessment

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***Abstract*—This research will utilize cyclic functions assessment theory to review the Melbourne Metro Rail's Intelligent Transportation Systems (ITS). In doing so, the Melbourne Metro Rail's ITS functionality, simulation and development will be studied. The functionality, simulation and development of this mega rail transportation infrastructure is one of its most difficult and complex tasks. Since Melbourne Metro Rail has a high public service expectation, assessing its on-going system performance is essential. This paper found that explicit systemic KPIs needed to be developed. These KPIs were then carefully compared to ensure alignment with the Melbourne Metro Rail's ITS requirements. These KPIs have a thorough association with the said network's ITS and subsequent functionalities. Applying cyclic functions formula specific functionality were further simulated and developed. Although this process was brief, it indicated intriguing aspects of developed KPIs in setting measures for functionality simulation and development. This method can further assist the rail stakeholders, including academics and professionals to develop a better strategy when planning for system enhancements of mega rail transportation infrastructure.**

***Index Terms*—cyclic functions assessment, Intelligent Transportation Systems (ITS), Melbourne Metro rail**

I. Introduction

The public's demand for high-quality and convenient transportation that provides higher speeds, increased capacity and safety along with improved efficiency is ever increasing in this new high technological era [1]-[5]. Utilization of Intelligent Transport Systems (ITS) is one example of such a technological tool. An ITS is the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency.

In particular, functionality simulation and development of ITS can assist in the development of contemporary transport engineering requirements [5]-[10]. System development in this regard evaluates set system performance measures. Further, functionality simulation and development of ITS are aided by the utilization of various robust technologies together with innovative tools. [11] reviewed ITS as Artificial Intelligence (AI) which holds potential to drive improved transportation system functionality and subsequent enhanced simulation and development. System enhancements produced by these technologies would lead, in turn, to better real-life applications [12], [13].

Importantly, enhanced real-life system applications can be used for various transportation classification and forecasting problems which lead to more flexible computational tools and models. The successful implementation of these practices will encourage transportation authorities to further adopt new technologies leading to measurably efficient transportation networks.

ITS usage would particularly enhance functionality, simulation and development of transportation networks such as rail systems. Accordingly, the present research aims to review the Melbourne Metro Rail's ITS, the functionality, simulation and development.

II. Literature Review

Generally, the rail industry is migrating from an operation mode based on mechanical and electronic systems to one based on telematics were information technology has become a core element of advanced transportation management and control systems. Intelligent Transport Systems (ITS) managed via a traffic management centre and based on telematics facilitates improved travel safety, mobility and efficiency to ground transportation via the application of sensing, analysis, transport management and dispatch control systems and mobile communications technologies and can be defined as innovative technologies for the purpose of improving transportation systems and the development of a so-called smart railway [1], [14]-[20]. Fig. 1 below shows the indicative ITS that can be utilized in the Melbourne Metro.

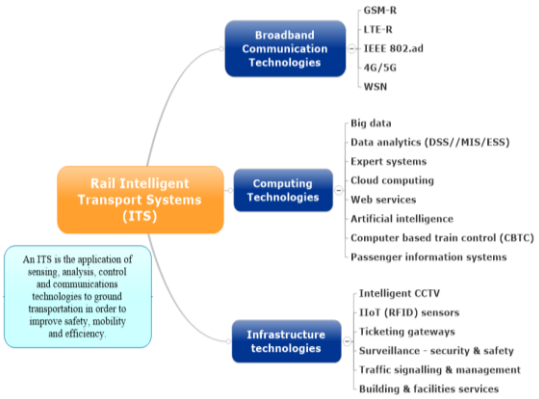

Figure 1. Indicative ITS technologies.

Manuscript received February 21, 2020; revised July 2, 2020.

doi: 10.12720/jait.11.3.166-171

A smart railway ITS are based on telematics and leverage state of the art information technology such as Industrial Internet of Things (IIoT), big data, cloud computing, broadband services and includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology incorporating both wireless and wire line communications.

The IIoT is the network of physical objects (such as devices like smart ticketing gateways, cameras, signals, vehicles, buildings facilities, and other items) embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data for industrial applications.

The IIoT creates opportunities for interconnecting the physical railway transport system to the telematic computer-based systems enabling objects to be sensed and controlled remotely via smart devices across the existing network infrastructure. The smart devices can provide on-board equipment monitoring, remote inspection of and maintenance of rail infrastructure and associated equipment, sensing and monitoring of the environment, and management of transportation patronage services [21]-[23]. Embedding IIoT devices into the railway operations will enable train operations to be adjusted on an as-needs basis to improve the efficiency and punctuality of the rail network and the security and safety of passengers.

The Global System for Mobile Communications Railways (GSM-R)is the dominant communications platform employed in railway networks, the inclusion into the Melbourne Metro railway network of the latest high speed broadband communications technologies (e.g., LTE-R, 4G/5G, WIFI-IEEE 802.11ad) and Wireless Sensor Networks (WSNs) can provide an enabling platform for the deployment of the IIoT devices [19] and high-speed video and other informational services. High-speed broadband communication facilitates the develop of smart rail services by the provision of train to infrastructure, inter-car, intra-car, inside the station, and infrastructure to infrastructure communications.

The development of a smart railway network through the leveraging of IIoT devices and the latest communications technologies to provide real-time information and operating status will enable the introduction of new and improved services such as integrated security, environmental monitoring, asset management, train health management, travel information and predictive maintenance which are expected to improve timely decision-making for issues like safety, scheduling, system capacity and passenger comfort and safety.

The inclusion of IIoT devices and broadband communication technologies will enable complex maintenance decisions to move from being reactive to proactive as data describing the precise location of the train, its speed, weight and other factors can be obtained in real-time and provided to a Decision Support System (DSS) and Expert Systems for data analysis. The move to predictive maintenance can increase the safety and efficiency of the rail traffic while providing an economic benefit through simplified processes and better decision making.

IIoT sensors can also be applied to the management and monitoring of the rail assets such as trains, carriages, signals, etc. generating alerts when the assets need critical attention or maintenance [24], [25]. Intelligent Close Circuit Television (CCTV) systems can provide high resolution images and videos from within the train carriages, along the tracks and in the stations to provide surveillance and a record of events in the case of an incident while enabling real-time alerts and early intervention responses potentially reducing service outages.

The efficiency and convenience of a smart railway system is highly influenced by the effectiveness of the Passenger Information System's (PIS) ability to provide crucial information to passengers via digital signage and audible information in real time and a user-friendly manner. Emerging metro PIS train video communication networks are Wireless Local Area Network (WLAN) based due to the easy availability of commercial-off-the-shelf WLAN equipment. A PIS also includes real-time train tracking information to inform passengers of train arrival and departure times, ticketing price information, the status of train operations and it also enables passengers to communicate with railway staff and provides public service announcements [26].

The introduction of bidirectional GSM-R voice and data communications networks were the keystone for the introduction of the Communication Based Train Control (CBTC) system which is the nerve centre of the smart railway network. The provision of data collected from a variety of sensors to the CBTC via a high-speed communications network can facilitate Melbourne Metro's ability to increase the speed, safety, and density of the train traffic. The CBTC railway signaling system makes use of the communications between the train and track equipment for the traffic management and infrastructure control [19], [27].

In addition to employing the high-speed communication services for managing the trains' services and providing passenger information, the high-speed (broadband) connection means that passengers can benefit from an "always connected internet" service via an on-board Wi-Fi (wireless fidelity) hotspot service similar to that provided in hotels and airports [28].

ITS also cooperates with many sub-systems that individually improve the overall system performance. One key aspect of this improvement is overall system functionality. This can be achieved through better simulation and development methods such as Cyclic functions assessment. While ITS sub-systems typically deal with the macro environment and structure, system functionality relates to specific tasks. Tasks themselves are further classified into elements on the basis of sub-categorization [29]-[32]. While core concepts of ITS could be straight forward, since it deals with soft and hard methodology, the elements are where the essential design questions will be considered. Importantly, on the basis of functionality simulation and development, a careful system inclusive of these elements needs to be evaluated and developed.

One of the most logical computation methods to evaluate system elements is cyclic functions assessment calculation. This mechanism is ideal for complex systems since it identifies required Key Performance Indicators (KPI). To evaluate system elements, specific KPIs are established to enhances the overall functionality. [33], [34] argued that generally for ITS primarily functionality includes case specific KPIs. For rail transportation infrastructure, primary KPIs include:

- KPI 1: Effective system failure detection and monitoring measures. Generally, the main causes of deterioration in transportation systems include wear and tear [35], [36]. Nonetheless, there are instances where normal wear and tear surpass the norm. Reasons for such abnormal or extreme wear and tear include extreme weather conditions such as excessive heat. In addition, erosion such as corrosion, abrasion comprising scratches and cuts could also increase the probable deterioration rates. For tropical and arctic cities additional conditions including temperature changes, humidity, and freezing would also increase the deterioration rates.
- KPI 2: Enhance system performance. The deterioration of rail transportation infrastructure can also be seen in terms of increasing congestion and travel times, which may have different deterioration rates to those of pavements. Furthermore, transportation infrastructures are expected to provide reliable services for long periods of time [37]. This period could be challenging due to dramatic environmental changes, improved technologies and extreme usage. As [38], argued, the traditional damage detection strategies consist of visual inspection and localized non-destructive evaluation techniques. For rail transportation, such as techniques include the ENCOSE which is a well-established measurement of system performance.
- KPI 3: Effective system integration measures. Particularly for rail infrastructure, key system integration measures include successful combination of traffic and transit management, traffic signal systems, real-time traveler information among others [39]. Such system measures employ key techniques including signal processing and statistical classification to convert mega data for appropriate simulation. Such simulation processes will thus detect, localize, and quantify possible system concerns [40]. The possible outcome will include revolutionary mobility improvements achieved through wireless communication with and between trains.
- KPI 4: Improve system reliability measures via reducing down-time via limiting system dynamics. While dynamics can be referred to as interaction, interdependence and causality of system components, too much complexity can further hinder the overall reliability performance [41]. To reduce such dilemmas, system dynamics need to be kept to simple yet the most effective measures.

Although there may be other KPI's, the above are those which hold a strong relationship with that of overall ITS functionality enhancements. Nonetheless, for rail systems ITS functionality simulation and development are also a fundamental outlook.

A. *ITS Computation: Functionality, Simulation and Development*

Commonly, cyclic functions denote the iterates of specific system operations. The aim is to continue iterating until specific measure is identified. Cyclic function is expressed as:

$$f^{n}(x) = x \tag{1}$$

where f^{n} denotes the nth iteration of f. Importantly, the number of iteration can be simulated using a matrix process i.e., $\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} Cos\,\theta & -\sin\theta \\ Cos\,\theta & \sin\theta \end{pmatrix}$.

Generally, for rail transportation, ITS are simulated and developed through the integration of the key KPI's, which is represented in Fig. 2.

Figure 2. ITS functionality simulation and development.

The inclusion of four specific KPIs is based on the primary functions of:

- System failure detection and monitoring measures, to fault diagnosis faults and thus identifying the state of a process.
- Systems performance to identify certain functions under specific conditions.
- System integration measures to correctly align by efficiently setting all the hardware and software.
- System reliability measures to ensure systems can run before any failure. For rail systems this typically involves measuring the differentiation of Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR).

Particularly, rail ITS functionality simulation and development is further enhanced by the integration effective and exactitude system communication. This integration can be mathematically represented by a simple cyclic function's formula:

$$x^{n}, f(f(\ldots f(x))) = x \tag{2}$$

where, f function occurring n times (based on 4 iterations), and x is the output. The summation of this equation is then applied for the actual simulation and development processes. Importantly, the x can be maximized for a specific ITS output condition. This in turn ensures an optimized process control and system performance.

Further, this process can be repeated continuously as a part of system evaluation methods. Subsequently, this on-going iteration can then be used to modify systems, calculate the upper and lower limits, separate each specific function into various related tasks, and outline long-term strategies for probable system degradation of their subsequent outcomes.

III. Research Methodology

As the basis of the research methodology, system logbooks together with network design schematics and reports were accessed and carefully scrutinized. In addition, key industry-based reports were accessed to further appraise the Melbourne Metro Rail's ITS. The authors retained approval of access to all these data. Finally, since this study is a quantitative investigation, a cyclic functions calculation was used as the basis of mathematically system evaluation.

IV. Melbourne Metro Rail's ITS

The Melbourne Metro Rail project as referred to as Metro Tunnel, is scheduled to be operational by end of 2025. This mega rail project is intended to use some of the latest innovative technological systems. This is designed to increase Melbourne's overall rail network efficiency.

A. *Melbourne Metro Rail's Functionality, Simulation and Development*

Melbourne Metro Rail's ITS has extensive communication functionality, particularly data mining prediction and classification. As a part of such system development, specific simulation and development techniques is used. These include specialized control devices to provide a robust prototyping which simulate process control and system performance predictions.

Studies carried out by [42] demonstrated that for rail's ITS, a multi-layered system which cooperates specific inputs are required. Further, for Melbourne's rail network, such input would ultimately lead to specific output that meet the desired function goals, and in-turn increase the systems performance and efficiencies. To achieve this, Melbourne Metro Rail utilizes specific tasks such as, up to date timetabling and so on, which are built into function segmentation. Furthermore, the overall system performance and efficiencies are constantly developed and maintained to assist with the total development of network's ITS priorities, particularly for simulation and development purposes.

B. *Melbourne Metro Rail's Cyclic Functions Assessment*

Melbourne Metro Rail's ITS, in particular the communication apparatus, needs to deal with the city's harsh environmental effects on its network assets. Although a life expectation of such assets varies from area to area, a typical expectation of a decade or two of service can be expected with rehabilitation services performed.

With Melbourne's environmental conditions gradually worsening, any proposed ITS functionality simulation and development need to be reflective of such progression. Accordingly, the functionality simulation and development need to reflect that. Such successful adaptation in system damage detection and monitoring techniques would further reduce the need for the major rehabilitation of the transportation network.

To further clarify the benefit of the proposed Melbourne's ITS functionality simulation and development, Table I provides a further clarification.

TABLE I. Melbourne's ITS Functionality Simulation and Development

System KPI's	Communication effects	System notations	Function outcome
Enhance system performance	Rapid emergency response time, in case of accidents	y^1	*(1_x)* Streamlined inputs
Improve system reliability measures	Faster relaying of information	y^2	*(2_x)* Simpler yet more rapid system processes
Effective system failure detection and monitoring measures	Less communication down-time	y^3	*(3_x)* Explicit optimization processes
Effective system integration measures	Multi-platform for information sharing	y^4	*(4_x)* Better defined outputs

$$x^{(y1-y4)},\ f(f(\ldots f(x)\ldots)) = 1^x \ldots 4^x \tag{3}$$

where, ^{y1} is KPI1, ^{y2} is KPI2, ^{y3} is KPI3 and, ^{y4} is KPI4. In addition, the subsequent *1x* to *4x* is also representative of each function output. For the Melbourne Metro Rail, the four outputs can be built into its ITS systems for further performance optimization, with the inclusion of the output as the basis of parameters. These ITS parameters can also be altered to represent the future functionality simulation and development more intimately. Nonetheless, to further underscore the benefits of the proposed Melbourne's ITS functionality simulation and development, an example is provided in Table II.

TABLE II. Example of Periodic KPI's Functionality Simulation and Development

Input (y^1) Enhance system performance	Process (q^{y1}) Rapid emergency response time	Output (x^{1x}) Streamlined inputs
System initial rating (Iy^A)	System first phase preparation (q^A)	Operation rubric setting (Ox^A)
System restructuring (Iy^B)	System midpoint evaluation (q^B)	Realignment of input variable/s (Ox^B)
Final KPI1 input reformation (Iy^C)	System midpoint evaluation (q^C)	KPI1 proposition (Ox^C)

As it can be observed, the proposed development is not only robust but also specific to rail transportation ITS. The parameters can then be can be mathematically expressed as:

$$x^y 1,\ f^n(f^q(Iy^A f(q^A)Ox^A)) = 1_x \tag{4}$$

Although in this example while there are only three steps, more can be generated based on data and system constraints. With more analysis and purpose a comprehensive functionality simulation and development can be created for the Melbourne Metro Rail. Due to its great size and complexity, however, Melbourne Metro Rail needs to continuously monitor its ITS performance. This can be achieved via incessant simulation and development of the KPI's functionality. For multi-face systems such as Melbourne Metro Rail's ITS, this is necessary to maintain high-quality and convenient transportation network.

V. Conclusion

This paper aimed to review Melbourne Metro Rail's ITS functionality simulation and development. In doing so, it was found that functionality simulation and development of such systems are extremely complex and compounded. To further alleviate such byzantine tasks, specific rail transportation system's KPI's were investigated. These KPI's had strong association with that of effective ITS and their functionalities. Nonetheless, using cyclic functions formula, simple yet specific functionality simulation and development processes were initiated for the Melbourne Metro Rail's ITS. In addition, a simple example of such process was also drawn-up. It was noted that, such processes need to be robust to allow for the Melbourne Metro Rail's ITS demanding nature. As was shown in this paper, that overall benefit of such a process must be supported by on-going simulation and development of the KPI's functionality to further maintain high-quality and convenient transportation network.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

Conflict of Interest

We, the authors, declare that we have no conflict of interest.

Author Contributions

Gharehbaghi conducted the research; Gharehbaghi, Farnes and Paterno analyzed the data and wrote the paper. All authors have approved the final version.

References

[1] D. Bullock, M, Martchouk, F, Mannering, "Analysis of freeway travel time variability using bluetooth detection," *Journal of Transportation Engineering*, vol. 137, no. 10, pp. 697-704, 2011.

[2] K. Gharehbaghi and K. Farnes, "Buried transportation structures: Fuzzy-markov computation case study," in *Proc. the 10th International Structural Engineering and Construction Conference: Interdependence between Structural Engineering & Construction Management*, Chicago, Illinois, United States, 2019, pp. 1-6.

[3] S. Adli, S. Chowdhury, and Y. Shiftan, "Justice in public transport systems: A comparative study of Auckland, Brisbane, Perth and Vancouver," *Cities*, vol. 90, pp. 88-99, 2019.

[4] R. Arora and H. Garg, "A robust correlation coefficient measure of dual hesitant fuzzy soft sets and their application in decision making," *Engineering Applications of Artificial Intelligence*, vol. 72, pp. 80-92, 2018.

[5] A. Bhaskar and E. Chung, "Fundamental understanding on the use of Bluetooth scanner as a complementary transport data," *Transportation Research Part C: Emerging Technologies*, vol. 37, pp. 42-72, 2013.

[6] Y. Shu and Y. Wu, "Travel mode identification using bluetooth technology," *Journal of Intelligent Transportation Systems*, 2013.

[7] K. Gharehbaghi and M. Georgy, "Utilization of Infrastructure Gateway System (IGS) as a transportation infrastructure optimization tool," *International Journal of Traffic and Transportation Engineering*, vol. 4, no. 1, pp. 8-15, 2015.

[8] M. Asudegi and A. Haghani, "Optimal number and location of node-based sensors for collection of travel time data in networks," *Transportation Research Record: Journal of Transportation Research Board*, vol. 2338, no. 1, pp. 35-43, 2013.

[9] C. Bachmann, M. J. Roorda, B. Abdulhai, and B. Moshiri, "Fusing a Bluetooth traffic monitoring system with loop detector data for improved freeway traffic speed estimation," *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, vol. 17, no. 2, pp. 152-164, 2013.

[10] J. Black, A. Paez, and P. Suthanaya, "Sustainable urban transportation: Performance indicators and some analytical approaches," *Journal of Urban Planning and Development*, vol. 128, no. 4, 2002.

[11] K. Gharehbaghi and K. Farnes, "Process automation in Intelligent Transportation System (ITS)," *International Journal of Machine Learning and Computing*, vol. 8, no. 3, pp. 294-297, 2018.

[12] J. Wasson, G. Boruff, A. Hainen, S. Remias, E. Hulme, G. Farnsworth, and D. Bullock, "Evaluation of spatial and temporal speed limit compliance in highway work zones," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2258, no. 1, pp. 1-15, 2011.

[13] A. May, "Urban transport and sustainability: The key challenges," *International Journal of Sustainable Transportation*, vol. 7, no. 3, pp. 170-185, 2012.

[14] T. Kim, *Integrated Urban Systems Modeling: Theory and Applications*, Springer, 2011, pp. 191-199.

[15] F. Corman, A. D'Ariano, A. Marra, D. Pacciarelli, and M. Sama, "Integrating train scheduling and delay management in real-time railway traffic control," *Transportation Research Part E: Logistics and Transportation Review*, vol. 105, pp. 213-239, 2017.

[16] E. Boschmann and M. Kwan, "Toward socially sustainable urban transportation: Progress and potentials," *International Journal of Sustainable Transportation*, vol. 2, no. 3, pp. 138-157, 2008.

[17] R. Buehler and J. Pucher, "Sustainable transport in freiburg: lessons from Germany's environmental capital," *International Journal of Sustainable Transportation*, vol. 5, no. 1, pp. 43-70, 2011.

[18] K. Gharehbaghi and F. Rahmani, "Deterioration of transportation infrastructures: Corrosion of reinforcements in concrete structures," *Materials and Technologies in Engineering*, vol. 940, pp. 160-166, 2018.

[19] P. Fraga-Lamas, T. Fernandez-Carames, and L. Castedo, "Towards the internet of smart trains: A review on industrial IoT-connected railways," *Sensors*, vol. 17, no. 6, p. 1457, 2017.

[20] Q. Li, Z. Zhong, Z. Liang, and Y. Liang, "Rail inspection meets big data: methods and trends," in *Proc. 18th International Conference on Network-Based Information Systems*, 2015, pp. 302-308.

[21] A. Zarembski, "Some examples of big data in railroad engineering," in *Proc. IEEE International Conference on Big Data*, 2014, pp. 96-102.

[22] Ç. Aytekin, Y. Rezaeitabar, S. Dogru, and I. Ulusoy, "Railway fastener inspection by real-time machine vision," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 45, no. 7, pp. 1101-1107, 2015.

[23] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Computer Networks*, vol. 54, no. 15, pp. 2787-2805, 2010.
[24] C. Turner, A. Tiwari, A. Starr, and K. Blacktop, "A review of key planning and scheduling in the rail industry in Europe and UK," *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, vol. 230, no. 3, pp. 984-998, 2016.
[25] C. Turner, P. Ravi, A. Tiwari, A. Starr, and K. Blacktop, "A software architecture for autonomous maintenance scheduling: Scenarios for UK and European rail," *International Journal of Transport Development and Integration*, vol. 1, no. 3, p. 371, 2017.
[26] L. Zhu, F. Yu, B. Ning, and T. Tang, "Cross-layer design for video transmissions in metro passenger information systems," *IEEE Transactions on Vehicular Technology*, vol. 60, no. 3, pp. 1171-1181, 2011.
[27] Q. Li, Z. Zhong, M. Liu, and W. Fang, "smart railway based on the internet of things," in *Big Data Analytics for Sensor-Network Collected Intelligence*, Academic Press, 2017, pp. 280-297.
[28] W. V. Brussel, "Bringing ICT services to trains technical and economical challenges," in *Proc. 9th Conference of Telecommunication, Media and Internet*, 2010, pp. 1-7.
[29] G. Mitsuo, K. Kuinam, H. Xiaoxia, and H. Yabe, *Industrial Engineering, Management Science and Applications*, Springer, 2015.
[30] K. Gharehbaghi, K. McManus, and K. Robson, "Minimizing the environmental impacts of mega infrastructure projects: Australian public transport perspective," *Journal of Engineering, Design and Technology*, vol. 17, no. 4, pp. 736-746, 2019.
[31] D. Finn, "DIY urbanism: Implications for cities," *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, pp. 381-398, 2014.
[32] P. Jin, J. Ji, and R. Gu, "Identifying comparative customer requirements from product online reviews for competitor analysis," *Engineering Applications of Artificial Intelligence*, vol. 49, pp. 61-73, 2016.
[33] P. Centobelli, R. Cerchione, and E. Esposito, "Environmental sustainability in the service industry of transportation and logistics service providers: Systematic literature review and research direction," *Transportation Research Part D: Transport and Environment*, vol. 53, pp. 454-470, 2017.
[34] C. Kahraman and S. C. Onar, *Intelligent Techniques in Engineering Management Theory and Application*, Springer, 2015, pp. 123-135.
[35] H. Gudmundsson, R. Hall, G. Marsden, and J. Zietsman, *Sustainable Transportation: Indicators, Frameworks, And Performance Management*, Springer, 2016, pp. 65-77.
[36] K. Gharehbaghi, K. McManus, K. Robson, C. Eves, and M. Myers, "Fuzzy Markov development for buried transportation bridges: Review of analysis and modeling technique," *International Journal of Structural Integrity*, vol. 11, no. 2, pp. 338-353, 2020.
[37] J. Mathey, S. Rößler, J. Banse, and I. Lehmann, "Brownfields as an element of green infrastructure for implementing ecosystem services into urban areas," *Journal of Urban Planning and Development*, vol. 141, no. 3, 2015.
[38] K. Gharehbaghi and K. McManus, "TIS condition monitoring using ANN integration: An overview," *Journal of Engineering, Design and Technology*, vol. 17, no. 1, pp. 204-217, 2019.
[39] K. Gharehbaghi and M. Myers, "Intelligent system intricacies: Safety, security and risk management apprehensions of ITS," in *Proc. the 8th International Conference on Industrial Technology and Management*, Cambridge, United Kingdom, 2019, pp. 37-40.
[40] T. Krasemann, "Computational decision-support for railway traffic management and associated configuration challenges: An experimental study," *Journal of Rail Transport Planning and Management*, vol. 5, no. 3, pp. 95-109, 2015.
[41] R. Kummitha and N. Crutzen, "How do we understand smart cities? An evolutionary perspective," *Cities*, vol. 67, pp. 43-52, 2017.
[42] K. Gharehbaghi, K. McManus, K. Robson, D. Paterno, and M. Myers, "High speed rail transportation: Key factors for the Australian eastern states," *World Review of Intermodal Transportation Research*, vol. 9, no. 2, pp. 174-197, 2020.

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