First and Last Mile Connectivity and Ridership Performance in Urban Rail Systems

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ABSTRACT

Railway transportation offers an environmentally friendly solution, sustainability, easy to access and preferable transportation choices. However, issues regarding first and last mile (FMLM) connectivity with ridership performance is underexplored in urban rail system. Despite the extensive research literature on railway development and broader adoption of public transit throughout years, the significant gaps linking between first/last mile (FMLM) or also known as an ingress and egress connectivity to ridership performance still lacking and under research. This paper using a bibliometric analysis to extract raw data from two major databases; Scopus and WoS, emphasizing frequent keywords, trends and gap in literature collection throughout years of research. The analysis went under two comprehensive techniques such as performance analysis and science mapping. The combined dataset included 632 research papers after PRISMA filtration carried out to ensure a highly impartial analysis and discover structural network within research topic. An awakening interest found in 2007 when publication citations skyrocketed which indicated the awareness starting to growing among researchers. These key themes have dominating the research FMLM field such as strengthen railway system performance, focusing on social and behavioural demographic, convenient and user-centric transportation management, implementation strategic transit-oriented development (TOD) consistently and the interest on potential of supporting green FMLM travel. This scenario serves as significant opportunities among local and international companies to invest and develop innovative mobility solutions tailored to specific users' demand and characteristics. Future research should alert more on spatially nuanced strategies among policymaker approaches, continuously linking railway system with different climate adaptations and harmonious improvement relationship between urban railway system and environmental sustainability.

Keywords: First and Last Mile; Connectivity; Ridership Performance; Urban Rail; PRISMA

INTRODUCTION

Rapid growth of civilization and economic expansion has led to the developing transportation systems. As the cities experiencing demand for effective daily transportation, people still reliance to private vehicles which contribute to massive traffic congestion, environmental degradation and maximize energy consumption (Chonsalasin et al. 2025; Lieu & Akar, 2025). Public transport seems to be promising to overcome these issues considered by daily demand, practicality and general availability throughout the countries including urban and suburban. However, its usage quite limited, particularly with restricted access between public transport and final destinations (Sogbe et al., 2025). In recent years, railway have become major transit nodes and intermodal facilities providing streamlined, low-carbon and mass-transit alternatives for congested metropolitan areas most part of the world (Pulido et al., 2018). The implementation of urban rail systems has fortified urban resilience and optimized subterranean development. These efforts do not only streamline passenger movement but also leverage underground infrastructure to sustain vital city operations, ultimately driving economic prosperity (Patil & Gaur, 2026). Beyond improving mobility, these practises also to enhance the mobility transportation to all passenger including people with disabilities for ensuring efficiency and equitable access, promoting more inclusive and sustainable cities (Lieu & Akar, 2025; Almeida et al., 2026). Urban rail systems fundamentally alter urban public transport dynamics by enhancing the efficiency of mass-scale passenger movement. The positive implication has contributed to far-reaching economic, social, and public health improvement as well as encouraging population density (Kumar et al., 2026).

Despite the extensive research literature on railway development and broader adoption of public transit throughout years, the significant gaps linking between first/last mile (FMLM) or also known as an ingress and egress connectivity to ridership performance still lacking and under research. FMLM exclusively refer to the distance from house to the railway station or public transportation and the distance to the final destination (Kåresdotter et al., 2022; Yadav et al., 2025). To address the most efficient urban mobility design lies in vital aspect of urban transportation planning which influenced by FMLM connectivity to the primary mass transit system (Hussin et al. 2021; Puspitasari et al. 2025). The problem arises by FMLM connectivity highlights the structural impediments encountered by commuters during the ingress and egress stages of transit nodes. These constraints are intensified in continuous rail networks characterized by wide station distance, even in high-density urban environments (Krygsman et al., 2004). In order to optimize the utilization of ridership performance on railway system, a number of initiatives need to be comprehended for successful execution of multi-faceted strategic plan (Torabi et al., 2022). These complexity issues are rooted from broad spectrum of domains namely as ranging from socio-demographic traits, urban planning, trip characteristics and micro-mobility services to FMLM policy frameworks (Chakraborty et al., 2025; Chatterjee & Paul, 2025; Puspitasari et al., 2025).

In an effort to identify FMLM connectivity and ridership performance on railway system, a bibliometric approach obligates to map the various vital knowledge gaps research, contribution factors and recent trends regarding to railway is necessary. The priority lies to primarily investigate several factors namely as socio-demographic traits, urban planning infrastructure, development of mobility hubs as well as policy intervention and execution. Ridership performance seems to be associated with FMLM connectivity significantly correlated (Peng et al., 2023). This factor is essential which can influence user preferences during FMLM travel on urban railway system. Demographic parameters such as age range, monthly income, gender, vehicle ownership and education level acts as pivotal characteristics that influence users' final trip destination as well as FMLM distance range with the intent to increase ridership performance on urban railway system significantly (Zuo et al. 2020; Chakraborty et al. 2025; Almeida et al. 2026). To ensure the long-term viability and growth of urban railway usage among travellers, the governing authorities must prioritize public needs and finding most efficient problem solving to existing barriers (Saiyad et al., 2022). Some researchers have shown lower income traveller were prefer walking to/from the railway station went to their destinations. This was due to the limited access to private vehicles (Meng et al. 2016; Lieu & Akar, 2025). However, preference on how deciding travel time differ between individual which contribute to their modes of transportation for FMLM travel (Mo et al., 2018). However, travellers' preference opted for private vehicles as the trip distances extend (Lieu & Akar,

2025). This situation decreased the ridership performance among travellers significantly and need to be alarming as existed crisis in railway system.

The effectiveness of ridership performance on railway directly correlated to excellent FMLM connectivity that cater the needs of the travellers (Rahman et al., 2022). Operational efficiency of FMLM connectivity to maximize ridership performance driven by strategic location which often found in residential areas or office clusters that are opting for rail-based travel over alternative modes (Sari et al., 2025). Location of railway station are crucially important as various of transit mode varies as walking, e-scooter, cycling, ride-hailing and bus services widely available (Liu et al., 2022). According to Sari et al. (2025), walking is the most popular modes during FMLM as it is easily practical, cheap alternative and refreshing. In addition, established a significant series of sheltered pedestrian sidewalks close to the transit stations could contribute to the gradually increasing number of railway ridership (Jehle et al., 2022). Data compiled by Ahadi et al. (2021) directly correlated to previous viewpoints which accommodating significant amenities to the pedestrian sidewalks such as planting shaded trees and roofs encouraged people to choose walking instead of using motorized private vehicles. Therefore, higher chance of public transport being used rather than private vehicles. Such initiatives are delivers environmental sustainability and promoting green development around minimize private vehicle usage. According to Norazlan et al. (2021), circulating awareness among citizen who frequently used private vehicles about carpooling and vanpooling program and their advantages to the environment can reduce a significant air pollution level in future. In future, sustainable urban environments could be expanded globally through improving FMLM connectivity by integrating environmentally friendly mobility (Salleh et al., 2022). This approach is one of the exercises to achieve sustainable development goals (Kåresdotter et al., 2022). Failing to sustain the effectiveness of infrastructure connection during FMLM could reduce the ridership performance significantly and thus drastically affect deficiency in using public transport (Chatterjee & Paul, 2025).

One of the concerns among travellers during FMLM is distance which significant to dictate the choice of modes. Shorter distance encouraged travellers to choose active mobility or non-motorised transport such as walking and cycling (Goel & Tiwari, 2016; Rahman et al., 2022). According to Bergman et al. (2011), a survey conducted in Portland has shown walking is the most preferred modes for distances within a one-mile radius while feeder services such as bus and e-haling transport being opted as the FMLM travel distance increases. However, the traveller priorities shift as the total distance increased especially involving inter-urban travel. This pattern among travellers is known as threshold effect whereas extended FMLM travel time considered as tolerable duration which represent a smaller fraction in overall journey to the final destination (Rahman et al., 2022). In addition, travelling using a comprehensive railway system that providing travellers' requirement increasing utilization of public transit for the whole trip (Krygsman et al., 2004). There a quite a number of new research trend on micro-mobility has been circulated to increased FMLM travel which can accelerate ridership performance using public transport. In general, proposition of using micro-mobility more reliable to initiate in the urban area. However, due to high population density and diverse employment landscape mostly in urban areas, development on railway system are facing several issues such as accessibility, environmental pollution, sustainability and social injustice (Xanthopoulos et al., 2024). To tackle these issues, mobility infrastructure should be main concern from policymakers and governing bodies to improve ridership performance particularly on public transport efficiency. One alternative that have gained popularity recently to revoke traditional access is known as urban mobility hubs (Liao et al., 2024; Yuliyanto et al., 2026). Integration transport modes from shared, public and private has stimulate the impact of lingering challenges to ensure that solutions are both strategic and efficient. According to Stam et al. (2021), the mobility hubs were proved to enhanced FMLM accessibility to increase ridership potential that promotes using public transport mode during journey. Planning as such strategic location for urban mobility hubs is crucial as it originally to aim multimodal transport services at strategic urban nodes (Weustenenk & Mingardo, 2023). This plan required in both demand and supply system in order to work. A flexible transit modes and services could act as supply which depend extensively on government policy and commercial business model. On the other hand, on-demand part particularly depends on ridership of travellers including their socio demographic level, trip characteristic and journey distance (Meng et al., 2020). It was identified that on-demand context crucially critical for addressing FMLM connectivity with ridership performance. By synchronizing both of the system,

FMLM hurdles would be easily eliminated and optimizing the efficiency of the railway system to facilitate traveller experience an enjoyable trip (Sun & Meng, 2026).

METHODOLOGY

An approach on bibliometric methodology was employed to indicate the previous literature regarding FMLM connectivity aspect linking to the ridership performance in urban railway. This research conducted a comprehensive literature review and bibliometric analysis to identify the connectivity between FMLM and ridership performance in urban rail system. This technique has been widely used to evaluate the research outputs, yearly trends, and research implication towards public transport generally. A diverse variety of academically publication which consists of indexed journals, peer-reviewed journal articles, conference proceedings, book chapters and related reports was carefully selected. Data were collected from two major databases namely as Thomson Reuters' Web of Science (WoS) and Elsevier's Scopus-indexed to ensure the authenticity and precision literature selection. The search terms including first mile, last mile, ridership, public transport, urban mobility and any associated terms to narrow down the search parameters. However, databases such as Google Scholar were an exception due to inconsistencies data and deficient references which emphasized the poor data quality make it incompetent as a bibliometric tool (Farooq, 2023). Selection of journals from databases going through in-depth process using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) framework to determine, select and eliminate the unrelated sources (Page et al., 2021; Puspitasari et al., 2025). Afterwards, bibliometric science mapping using VosViewer was executed to reveal the research patterns and visualising bibliometric networks based on keywords of co-occurrence, citation, and co-authorship relationships (van Eck & Waltman, 2010; Puspitasari et al., 2025; Kumar et al., 2026). Those keywords were employed to investigate the frequency that appear together throughout any types of publications in order to identify thematic proximity and dominant research clusters. This illustrated the structure of research field over the years and how it conveys for future development particularly in public transport. Simultaneously, this approach promotes potential direction for broader and successful future research as to preserve a comprehensive reference and enhance significant advancement regarding FMLM connectivity obstacles (Puspitasari et al., 2025; Kumar et al., 2026).

2.1 Data Selection and Characteristics

Journals were selected from two databases, Scopus and WoS by applying several filters to ensure a better concise and insightful review analysis. Through combination between two impactful journal databases, a data sufficiency that comprehensively understands the FMLM connectivity on ridership performance could be achieved to ensure the validity for research evaluation. There were particular steps that need to be completed during collecting the multiple types of publication in order to establish the authenticity criteria to ensure a systematic and reliable approach in this bibliometric analysis. Firstly, a collection of data was retrieved from databases. Then, the data were coordinated accordingly using PRISMA guidelines which promotes a reliable and structured methodology for next crucial steps such as identifying, screening and designating relevant research based on the specific inclusion and exclusion criteria (Puspitasari et al., 2025). This crucial step was programmed to minimize the bias, remove any duplications to verify all the data criteria were aligned with the research objectives. The literary period was chosen as "all years", while documentation types was selected as "all types" to ensure variation of different viewpoint writing with a language restriction to English. On the other hand, some words were excluded while choosing the data namely as logistics, delivery, freight transportation, supply chain that were related to FMLM keywords. In the data search strategy, Boolean operator was applied which includes operators namely as "AND", "OR", and "NOT" in order to find the relevant literature for each data (Sun et al., 2026). In the both databases, trial searches were carried out to refine selected keywords namely as "first mile", "last mile", "ridership performance", "urban rail" and any synonym or similar terms to minimize the unnecessary data in this research. The particular term in Boolean operator indicated certain interpretation. For example, the term "AND" was applied to ensure all the specific keywords included in the data while "OR" term was used to capture any similar or synonym specific keywords

that can be found in the data. However, to avoid any irrelevant data during data selection, term “NOT” was employed to remove any non-related keywords which can disrupt the originality of chosen data. Therefore, a comprehensive structured search query was conducted on May 3, 2026, across two major selected databases which is Scopus and Web of Science (Core Collection). The search aimed to capture relevant literature of intersection of first and last mile connectivity correlates with ridership performance as well as the related concepts. To enhance the searching transparency and quality, the search included every types of documents including books, journal papers, review paper as well as conference papers. All those books and papers were published in English in year between 1993 and 2026 which indicated that the topics have sustained strong research interest over the years. To uphold standards of reproducibility of this research, the complete, exact search strings, including database-specific field codes and Boolean operators, are provided in Table 1.

Table 1. Scopus and Web of Science databases search queries

Scopus search query	**Web of Science search query**
TITLE-ABS-KEY("railway" OR "subway" OR "transit" OR "metro" AND "ridership" OR "passenger" AND "the first" AND "last mile" NOT "freight" NOT "delivery" NOT "logistic") AND PUBYEAR > 1993 AND PUBYEAR < 2026 AND DOCTYPE(ar OR re OR ch OR cp OR bk)	TS=("railway" OR "subway" OR "transit" OR "metro" AND "ridership" OR "passenger" AND "the first" AND "last mile" NOT "freight" NOT "delivery" NOT "logistic") AND PY=(1993-2026) AND DT=("Article" OR "Review" OR "Book Chapter" OR "Proceeding Paper")

Upon after filtering data, the search has retrieved 374 articles from Scopus and 292 articles from WoS respectively. Nevertheless, there was possibility that articles could be duplicated in two large databases. To convince the data accuracy, both data collection was exported into Bibliometrix, an R-based bibliometric tool with different bibliographic data format. This process has identified 29 articles were duplicated resulting the final 632 articles of literature collection proceed to further analysis as illustrated in Figure 1.

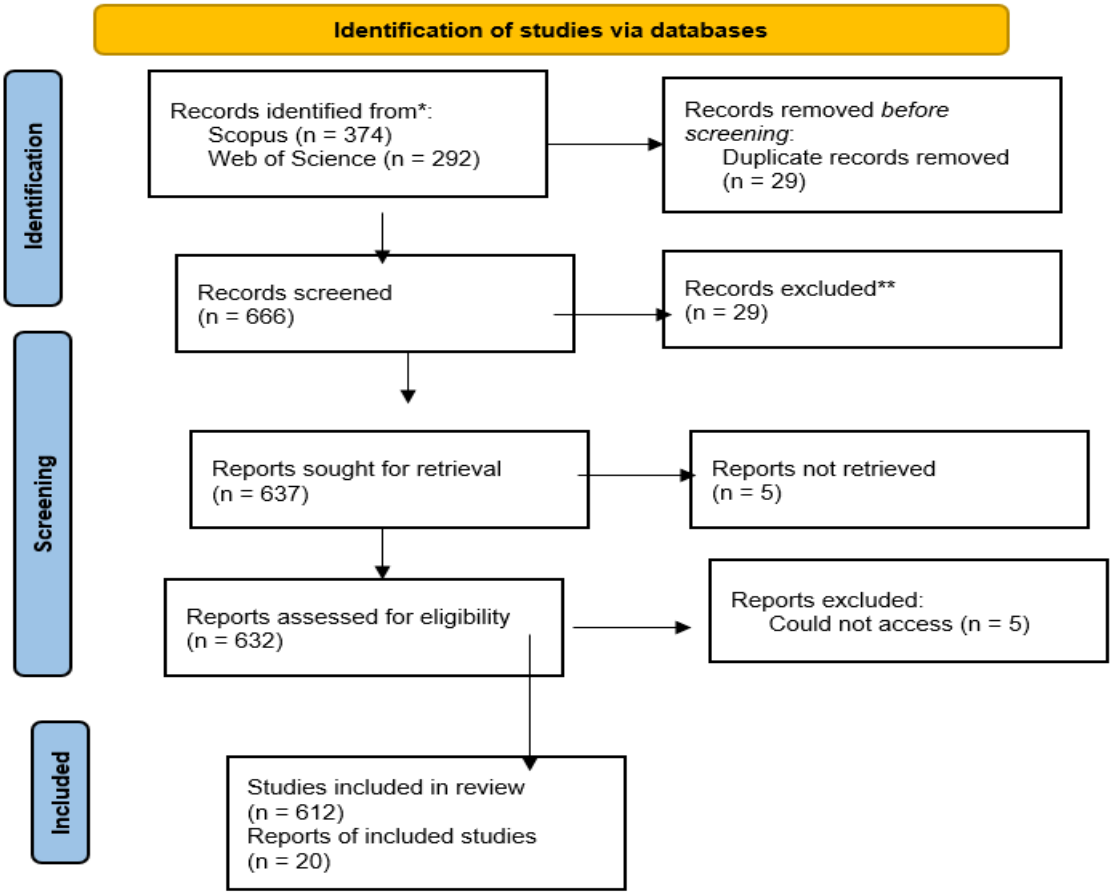


Figure 1: A diagram of the PRISMA

2.2 Bibliometric Analysis

Generally, bibliometric analysis was conducted to summarize a large collection of bibliometric data with the attention of demonstrating the literature data and possible topic or field research trends all years of publications. Hence, the association between social and structural literature data were possible to interpret via research criteria such as authors, countries, institution and topics. These methods applied to carried out bibliometric analysis includes two crucial identification namely as performance analysis and science mapping. Performance analysis is a standard exercise in literature review to present the possible trends from research criteria as mentioned above. Through this practise, the most pronounced result is the number of publications and citations per year or per research criteria. The publications imply productivity of the research fields or topics throughout years while citations indicate the impact or influence of particular topic (Donthu, et al., 2021). Domain visualization using Bibliometrix was comprehensive strategy due to its offer of efficiency and approachable mapping analysis tool that support bibliometric analysis process. Collection of data imported to the Bibliometrix in R programming language to ensure its running smoothly during analysis. Then, it provides several options for in-depth analysis which allows versatile matrices that provides a number of details mapping. Hence, various analysis performance can be identified including network analysis, multiple correspondence analysis, and other data visualization (Arruda et al., 2022). This approach represents a comprehensive and informative bibliometric analysis with ability to display publication correlation and pattern throughout years. Science mapping extensively focuses on the relationship between research criteria which evaluates the literature data connection according to the research topic. It provides graphical user interface-based analysis from VOSviewer. It strategically chosen for the particular analysis due to its offering to investigate deeper relationships such as co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation in three various visualization namely as network, overlay or density visualization (Arruda et al., 2022). These techniques practically competent to visualize a multifaceted relation between publications (Puspitasari et al., 2025).

FINDING

3.1 Performance analysis

The first part of analysis described the result of research contribution mainly focus on flexibility relationship between various research constituents and collaboration patterns including authors, journals, publications and trend topics in the selected collection data. It would emphasize the compelling factors that have affected and influenced the FMLM studies throughout the years of research. Figure 2 has shown the total number of publications from 1993 until early 2026 grouped by publication types namely as articles, books, conference/proceeding papers, review papers and editorial paper. The stacked bar graph has shown positive growth for various publications throughout years of research. Although, articles were dominated most of the publication types, researchers started to introduce the topics in books as early as 1993. The trend keep continues in 2026 despite the number of publications less frequently than articles. Starting in 2008, researchers increasingly published the research topic in the articles and the growing interest has a possible breakthrough due to escalate publication in conference/proceeding papers, review papers and editorial papers as well. The data for 2022 and 2023 might suggest that research activities are expected to continue but at a moderate pace since it has not shown drastic different number of publications. Even granting that, in 2024, the publications skyrocketed and peaked in 2025 which indicate the research topic has gaining popularity and trending issues among the research community. While for conference/proceeding papers, it actively progress started in 2016 which might suggest there was an active researcher community that dedicated to impart their knowledge and pilot finding about the research topic and promotes two-way of professional discussions. Intersecting lines over the stacked bar graph is called for the annual total citation referring the academic research contribution of various publications. The citation skyrocketed in 2007 from the books and possibly would be one of the research masterpieces regarding relevant topic. It indicates that a number of possible researches could be highly generated and continues fluctuates over time. The orange line with black dot indicated the annual total citations shown that the academic impact of these publications which happen overlaying the stacked bar chart. It started slow to non-existence citation from beginning until 2005. Then, it skyrocketed in 2007 but began to decline afterward. However, the line has shown citations occur continuously in every year with visible rises and falls over time. Despite these fluctuations, the production of publication was growing in every year which indicates that the studies on FMLM has gained a tremendous interest among researchers in recent years. A sudden decrease in citation number and publication between 2025 and 2026 likely due to this analysis being implied in early 2026. This visualization is expected to increase by the end of 2026 by looking at the publication trend throughout the years of research. It would emphasize the awareness and perceptions among researchers has highlight the important and influential impact of FMLM studies over time.

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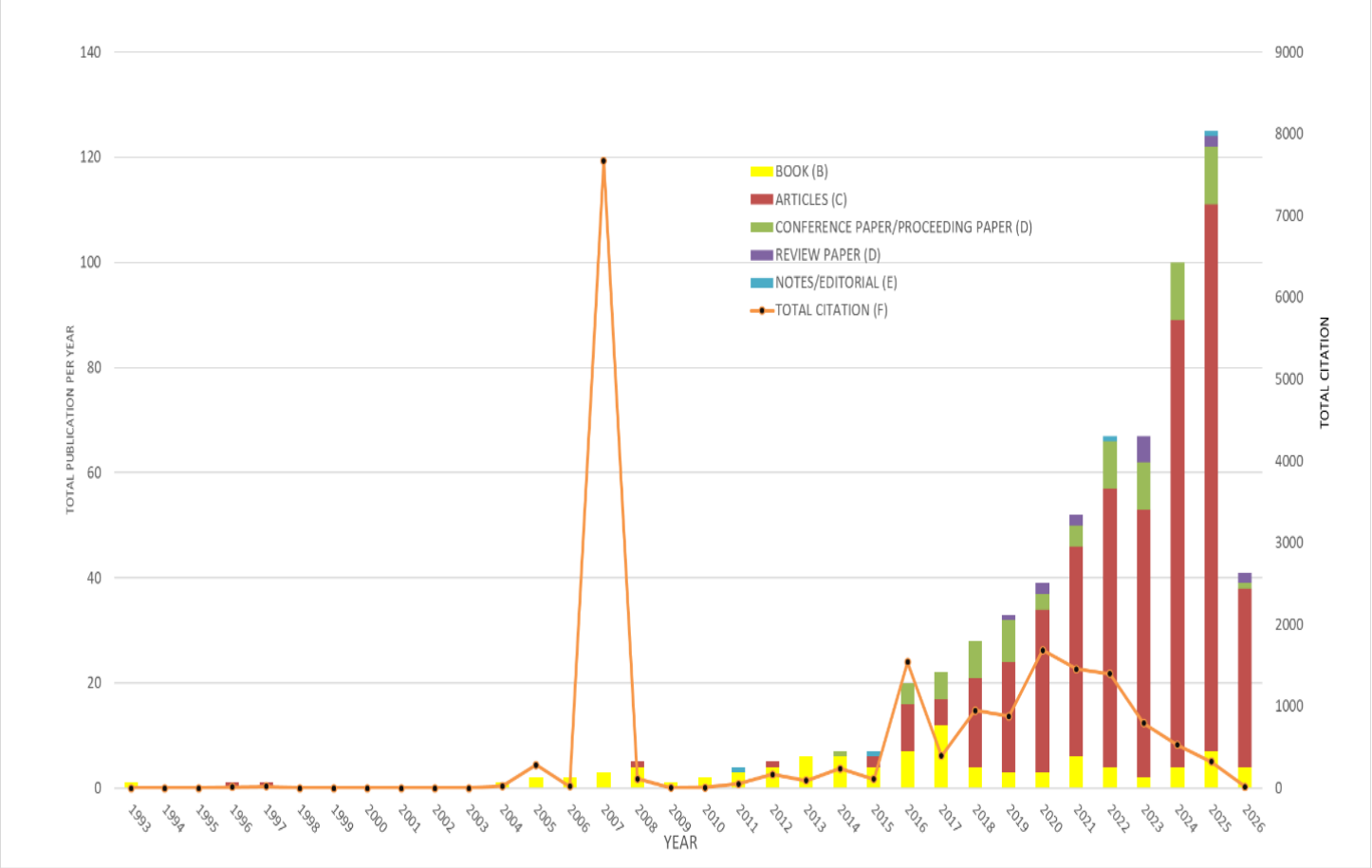


Figure 2: Scholarly Publications on FMLM of Public Transport with The Number of Citation

3.2 Science Mapping

This finding is important to emphasize the relationship between various publications in FMLM connectivity and ridership performance by using co-occurrence, citation, co-citation analysis, and collaboration networks. By means of these analyses, the pattern of development literature and trend on this topic would be easily simplified. In addition, vital informative keywords would highlight in the literature which deepen our understanding on FMLM topic simultaneously spark into various new research explorations. For example, in Figure 3 was used co-occurrence of word pairs in collected literature which identify the research trends with various perspectives within FMLM connectivity and ridership performance studies. The higher frequency of keyword that appear in the literature can be retrieve through in VOSviewer to identify thematic proximity and dominant research clusters. In research field, different style writing can be same meaning of keywords. The bibliometric data were further visualized using VOSviewer software (version 1.6.20). In order to achieve an optimum performance result from dataset, the association strength normalization method was applied which recommended approach in VOSviewer software. This normalization minimizes the frequency bias, ensuring that ubiquitous generic terms do not overshadow the network structure, and allowing for the accurate identification of thematically specific clusters. An initial extraction of the dataset yielded a total of 1421 unique author keywords. To ensure the map focused on the most prominent and relevant concepts, a threshold setting of a minimum of 5 occurrences per keyword was established. The final step of filtered the dataset resulting 211 keywords met this inclusion criterion. Therefore, a thesaurus file created through the database to ensure all keywords included for analysing performance (McAllister et al., 2022). This will highlight the important the synonym keywords to certify no overlapped keyword during research studies to avoid bias. Figure 3 has illustrated five clusters of FMLM connectivity and ridership performance studies with different colours and interconnected topics based on research field. The first cluster (red) accentuate efficient railway system model which includes keywords namely as “model”, “demand” and “design” monopolize in occurrence and link strength. This situation highlights the important of competent railway system or framework to ensure

higher ridership performance and decreased the use of private vehicles. The second cluster (green) revolved around social and behavioural demographic with keywords such as “travel behaviour”, “services” and “impact”. The third cluster (blue) represent public transport with the keywords of “service quality”, “transit” and “policy”. The next fourth cluster (olive) illustrated that ridership consists of keywords such as “accessibility”, “land-use” and “transit ridership”. This cluster has dominated the keywords which indicating the most frequent keyword appeared in the collection databases. In network map, this cluster also transcending across various research clusters indicates the flexibility or demanding of keywords in FMLM studies. For example, with keyword like “autonomous vehicle” might hint towards advanced transportation technologies for future public transport studies. The last cluster (purple) highlight keywords such as “bicycle”, “bike-sharing” and “built environment” which emphasize sustainable mobility through environmentally friendly vehicle during FMLM research

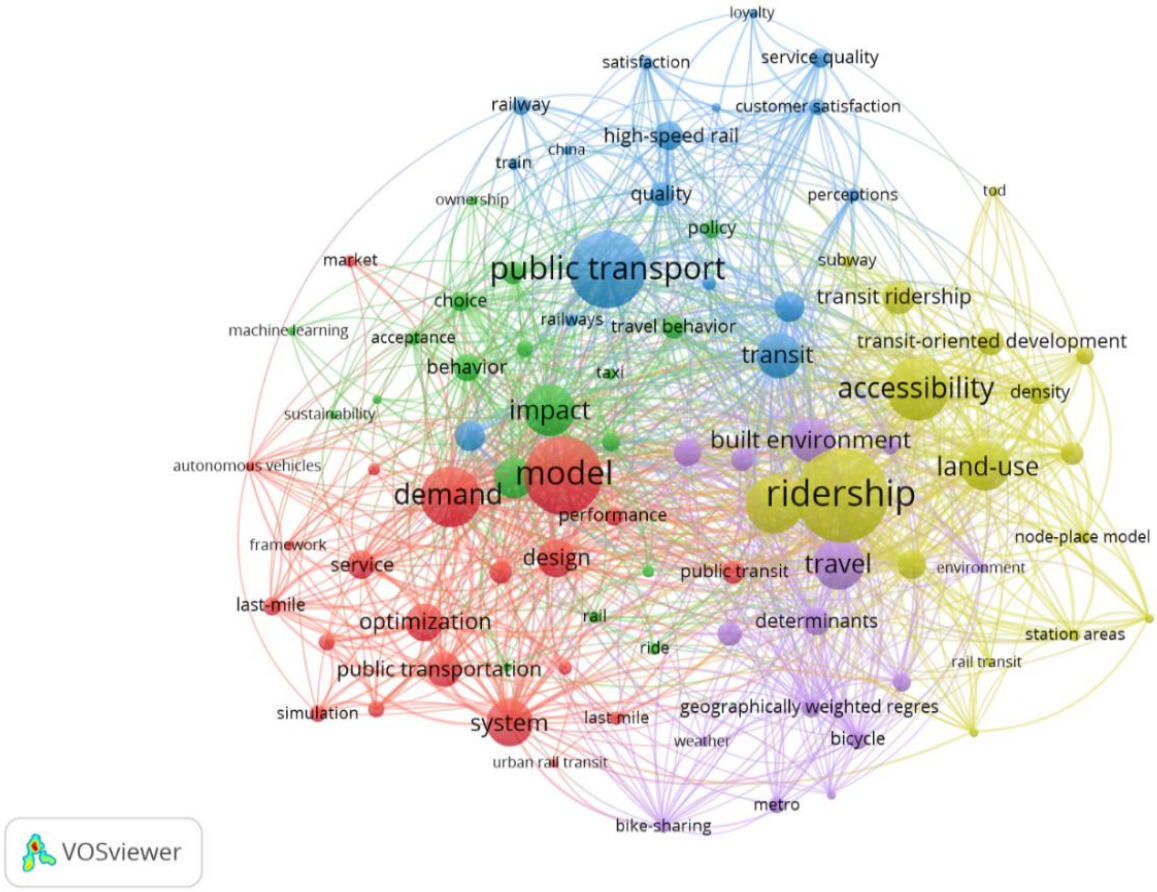


Figure 3: Co-Occurrence of FMLM Connectivity and Ridership Performance

In Figure 4, thermal visualization was used to emphasize a better understanding on the keywords frequency via percentage rate. The most pronounced percentage rate among cluster is Cluster 1 (24%). This highlight the efficiency of railway system model as key research to increase the ridership performance. This cluster involved other keywords such as optimization railway service, performance improvement, establishment framework and sustainability design approach. While, Cluster 2 (21%) more focusing on social and behavioural demographic which directly influence their choice to utilize the public transport especially rail transit during their journey to preferred destinations. Following Cluster 3 and Cluster 4 which have the same percentage rate 19%, respectively. Both clusters have the proportional focus on transportation management and transit-oriented development (TOD) of FMLM research studies. Cluster 3 highlighted on transportation management which prioritize on users’ satisfactory condition whereas the various approach has been used to improve the railway system. These includes high speed train development to cater traveller needs and preference during their journey to destination. In support for transportation management, Cluster 4 emphasized how transit-oriented

development (TOD) is vital for making FMLM problems to achieve an optimum performance result. The strategic planning and systematic development could boost public interest in rail travel as one of the most used modes of transport. The sustainable mobility approach in Cluster 5 (17%) indicates the interest in their potential to support green FMLM travel.

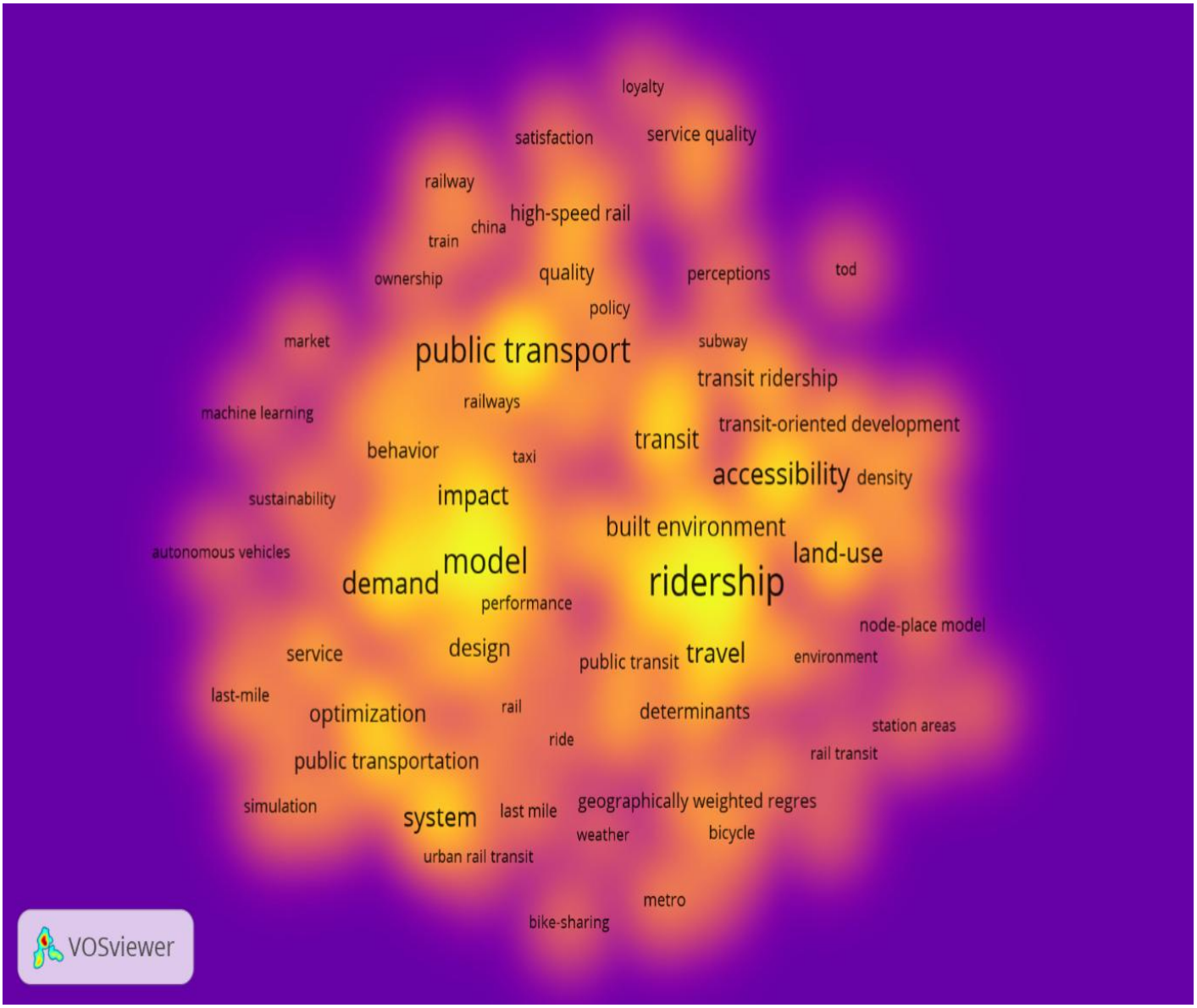


Figure 4: Thermal Visualization on Co-Occurrence of FMLM Connectivity and Ridership Performance

Limitation

Through the finding using bibliometric analysis, several results have been drawn such as thematic clusters, co-occurrence keywords among researchers, research term trend and researchers' publications. Nonetheless, there were limitations that need to be consider which might be affect the reliability of result and conclusions drawn. This analysis particularly relies on the choice of keywords. It has potential of misinterpreting specific research synonym simultaneously exclude the related research. Therefore, the limited relevant studies decreased the accuracy of this recent collection database. For example, the term such as first mile and last mile widely applied in public transport, however, some of the researchers used the term access and egress in their studies that might overlooked during filtering method. This is due to broader varied keywords making it quite difficult to extract title and abstract. Second limitation involving the biases collection data extracted from preferred databases. There are possibilities the review may not reflect a full complete situation of the recent knowledge regarding FMLM issues (Sobczuk & Borucka, 2024). There are various databases namely as Scopus, WoS,

Science Direct, Taylor and Francis, PubMed and many more academic literatures. Although this study using Scopus and WoS as collection database, the result might contain some duplications and certainly should filter thoroughly. Each of database has their own format and filtering system, therefore, some information could be missing although the particular context still acceptable. Language barrier also become one of the limitations whereas the non-English writing excluded purposely to ensure the analysis run smoothly. This situation might highlight some missing important data or contributions that being discussed in their research. Other limitation such as potential misinformation of self-reported data and context-specific analyses could be related between stated and actual behaviour data. Some of preferred hypothetical method may not accurately reflect the real-world challenges which highlight the need of more robust and specific studies to deepen understanding on FMLM issues (Almeida et al., 2026; Kumar et al., 2026).

DISCUSSIONS

This research promotes the unbiased map of the literature collection by selecting Web of Science and Scopus as a dual-database bibliometric framework. During finding data, the search syntax was purposely referring to the specific logical operators and searching tags. Standard procedure of inclusion and exclusion criteria was deployed to ensure high quality collection data. The raw bibliographic data was extracted from two major databases; WoS in plain text format while Scopus in BibTex format. Then, considering different indexing system these databases, a data harmonization was carried out using the open-source bibliometric package bibliometrix (R studio). The combination of raw collection data underwent de-duplication process to ensure there is no biased data obtained. The merged data collection was examined further by using dual-dimensional bibliometric evaluation involving performance analysis and science mapping. Performance analysis was implemented in order to evaluate the proportionally trajectory of the domain indicators. On the other hand, science mapping was utilized to visualize the conceptual and current framework of research field.

To date, this study particularly focuses on ridership performance which correlating with FMLM issues and challenges. This research has offers various issues such as strengthen railway system performance, focusing on social and behavioural demographic, convenient and user-centric transportation management, implementation strategic transit-oriented development (TOD) consistently and the interest on potential of supporting green FMLM travel. It also includes the recommendations to enhance the current implementation workflow in FMLM, policy development and future research to improve the lacking or gap within FMLM issues and challenges. Improving railway system constantly become priority to ensure the rate of ridership steadily increased over time (Hamdan et al., 2019). Improving railway system constantly become priority to ensure the rate of ridership steadily increased over time (Hamdan et al., 2019). Efficient resource utilization and technological advancement are important considerations in improving operational performance. Both of first mile and last mile connectivity are equally important to overcome ridership issue. Both of first mile and last mile connectivity are equally important to overcome ridership issue. An expansion of railway network systematically focus in urban area is a priority to enhance ridership. This method has been analysed by Yoo et al. (2025) which substantial growth identified in Tokyo at the new railway stations expansions. It emphasizes that higher ridership performance notably at the densely populated urban area whereas more concentrated and frequently used railway located. Furthermore, it coherently noticeable increases in ridership when railway system upgraded simultaneously leading to significant pollution minimization. Reliability on services satisfaction and utilization of subway is also one of the vital indicators to upgrade existing railway system (Fahmy-Abdullah et al., 2019). The finding as reviewed by Sogbe et al. (2025) and van Lierop et al. (2018), indicated that convenience and user-friendly approach are equally important to ensure the efficiency and inclusivity of railway system leading to the most critical attributes for commuters' satisfaction. Additionally, social and behavioural demographic aspect need to be considered as it initiates to encourage people to use the railway transport. According to Lieu & Akar (2025), majority of larger households and lower income group preferred more to the sustainable modes such as railway for their daily transportation whether its first mile or/and last mile. Any affordable fare discounts are well received across all income levels leading as critical factor to increased ridership performance. Prioritization on certain marginalized group consists of senior citizens, people with disabilities, and suburban community with limited private vehicles access need to be investigate deeper to ensure all their rights are protected.

The first and last mile are both equally critical when it comes to ridership performance in urban railway system (Peng et al., 2023). Extra effort should be center on transport efficiency and accessibility for creating a system that has potential of mass transit over time. Convenient access to the public transport particularly subway station not only subject to strategic first or last mile location along with the availability of feeder services to reach the facilities. According to Rayaprolu & Levinson (2024), sufficient access to subway station is a vital factor influencing ridership performance as higher availability access simultaneously boost higher number of ridership. It supported by Sogbe et al. (2025) stated that limited accessibility to the subway station terribly affected commuters due to time consuming during their planning journey. Therefore, it influencing the difficulties to increase ridership over time. Some suggestions of using micromobility system such as shared e-scooter, autonomous vehicles, and bike-sharing during FMLM travel chains has increased tremendously among researchers (Peng et al., 2023). It has claimed that provides cohesive alternative service compared to the traditional method (Tennøy, 2022). Therefore, these micromobility system usage has encouraged policymaker and official authority to provide a seamless framework to ensure effective implementations. However, Rich (2026) agreed to the disadvantages of overusing micromobility such as lower health benefits and increased unnecessary cost whereas simply encouraged walking to the destination. Due to these drawbacks, Chen et al. (2020) and Van Kuijk et al. (2025) suggested that an adequate distance is required for commuters using the micromobility networks to ensure a balanced healthy lifestyle along with beneficial for environment. One complementary method that need to discover is strategic and optimal locations for urban mobility hubs to ensure transport efficiency. Development of hub enhances first and last mile accessibility, optimize intermodal efficiency and revitalize community spaces (Stam et al., 2021; Yuliyanto et al., 2026). Tactical and calculated planning demand both in theoretical and practical execution are important to centralize multimodal transport connectivity in urban area particularly (Weustenenk & Mingardo, 2023).

Rapid urbanization, influenced by exponential demographic growth and an increasing trend in private vehicle ownership, has overwhelmed urban area infrastructures, leading to urban traffic congestion. An outline of strategic plan such as transit-oriented development (TOD) making it convenient and appealing for community as surrounding area equipped with an abundance of comprehensive infrastructure and facilities (Al Asmi et al., 2024). As stated by Orso et al. (2025), TOD is characterized as centralized place whereas residentials, office, public transport stations and open space are located. It is also supported by Mohamad et al. (2021) who clearly agreed that accessibility with various modes of transport, best utilized land use as well as great system integration are essential to improve development of TOD. Planning with significant policy implications along with a fresh perspective on the operational TOD framework are essential for creating a comprehensive feedback and user-centered FMLM system (Mun Chye et al., 2022). Furthermore, TOD goals are aligned with smart cities approach according to Pajilani et al. (2022) who stated that integrating significant facilities that cater to the needs of public are crucial to increase the quality of life including effectiveness of public transport services. The policymaker and official authorities are responsible to outline a dynamic policy that are prioritizing current demand of FMLM issues encompassing both new and regular commuters (Golbabaei et al., 2024). Additionally, the implementation of TOD policies must comprehensively encapsulate environmental sustainability frameworks to ensure equitable urban expansion. Significant exploration on environmental impact has gained attention in recent years emphasized various advantages sich as reducing air pollution, mitigating traffic congestion, well-constructed land use as well as enhanced urban vitality. For example, Zhang et al. (2023) actively reviewed on shared transport implementation in megacities in China which leading to improvement of urban air quality. Similarly, Benoliel et al. (2021) who conducting a survey found that integrating green infrastructure strategically in city developments leading to the improvement public well-being. However, some limitations remain as under-researched seasonal climate countries, uneven or limited location coverage and insufficient data on urban sustainability policies (Kumar et al., 2026).

CONCLUSION

The challenges of FMLM connectivity and ridership performance are still underexplored deeply over time. This research particularly addressing the gap between commuters starting or final point along with transit

demand and usage reliability. Various of issues has discovered during examined this particular research such as improve railway system credibility, social travel and behavioural, policy framework development, strategic transit-oriented development (TOD) and the potential of green FMLM travel. This paper strengthens the conceptual and theoretical link between FMLM issues and ridership performance from two major databases; Scopus and WoS. By employing bibliometric analysis, several substantive frameworks have been produced by identifying key themes, dominant research pattern and potential limitations. It definitely offers potential key finding for further future investigation regarding of his topic. Two comparatives techniques including performance analysis and science mapping were utilized to evaluate the raw data into descriptive analysis and conceptual network between data. In general, both of first mile and last mile connectivity are carrying equally significant in terms of increasing ridership performance in railway system. One of the key insights in the analysis is enhancing railway system as expanding them strategically leading to the higher users' preferences over time. Meeting commuters' demand and expectations including service quality and efficiency is essential to attract and encourage frequent railway usage, which subsequently mitigates private car usage thus minimize air pollution as well (Kumar et al., 2026). Emphasizing on the transport efficiency and accessibility to the public transport particularly subway stations has indicated that availability of feeder services such as shared e-scooter, autonomous vehicles, and bike-sharing contributed to boost higher number of ridership. This programme aligned with operational TOD framework which convenient for community as targeted areas equipped with extensive amenities for public accessibility. This given context has encouraged policymaker and official authorities to prioritize investment based on current demand on FMLM challenges. Their focus can diverge into several sections such as urban planning concept, smart mobility transportation and redundancy optimization strategy. This scenario serves as significant opportunities among local and international companies to invest and develop innovative mobility solutions tailored to specific users' demand and characteristics. Therefore, future research should alert more on spatially nuanced strategies among policymaker approaches, continuously linking railway system with different climate adaptations and harmonious improvement relationship between urban railway system and environmental sustainability.

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