China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1599-1610

SYNCHRONIZED APPROACH: INTEGRATED PLANNING FOR PUBLIC TRANSPORTATION

Ranjit Kumar Valugula[1], Dr. Ajay Swarup[2]

[1]Research Scholar, Dept. of Civil Engineering, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Bhopal-Indore Road, Madhya Pradesh, India.

[1]Professor, Dept. of Civil Engineering, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Bhopal-Indore Road, Madhya Pradesh, India.

Abstract

Integrated Mass Transit Planning is an emerging discipline dedicated to formulating policies, initiatives, and projects that attain transportation goals with minimal societal expenditure. It calls for global cooperation to foster and assess inventive concepts, while addressing the inherent uncertainty in future projections and consistently gauging system efficiency. The principles and methodologies of integrated transportation planning, endorsed by the Puget Sound Regional Council for urban planning entities, are thoroughly examined. This article delineates the blueprint for an Integrated Mass Rapid Transit System (MRTS) tailored for a smart city endeavour in Western India, concurrently serving as an instructive manual for MRTS. Integrated transportation assumes a pivotal role in facilitating intelligent, seamless travel experiences spanning both intercity and regional domains. To ensure the triumph of a smart city's transportation facet, a robust amalgamation of various mass rapid transit modes is imperative. This encompasses data integration, physical infrastructure, network optimization, fare structuring, and more. Conducted via a questionnaire survey, primary data research sought public input to enhance urban transportation services. Respondents provided valuable insights into the factors influencing their inclination towards public transit and potential hurdles to MRTS integration. Employing multiple linear regression analysis, the study endeavours to establish equations quantifying respondent satisfaction and probability of transitioning to public transportation, with a focus on pivotal factors identified in the survey. Notably, time-saving and vehicle comfort ratings emerge as critical determinants for prospective transit users. The integration possibilities of metro rail with BRTS, monorail, or Indian railways yield diverse permutations, each yielding unique rapid transit systems. A universal smart card for accessing all modes of transportation emerges as a pragmatic stride towards MRTS integration, aligning with the overarching objective of seamless, effective public transit.

Keywords: Mass rapid transit systems, rapid transit system, integrated, transportation is moving.

Introduction

There is a growing consensus among policymakers and academics in favour of adopting a comprehensive approach to transportation planning that considers all modes simultaneously. This principle is a fundamental component of nearly every urban and transportation development masterplan worldwide [1,2]. However, actual implementation has faced prolonged delays. Shifting

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1599-1610

focus from the supply side to the demand side represents a crucial paradigm shift in transportation planning. Instead of adhering to the traditional notion of transportation planning solely as a means to facilitate infrastructure for traffic flow, there is a pressing need to reorient perspectives towards individuals and their specific requirements.

A contrasting viewpoint contends that transportation planning primarily serves to ensure the availability of infrastructure necessary for sustaining or improving transportation systems. All parties involved in politics, the economy, urban planning, and civil society must jointly recognize the value of an approach cantered on comprehending individuals' preferences [3-6]. It is widely accepted that there is a gap between theoretical concepts and practical implementation in the real world. This investigation into e-mobility, supported by the German Ministry of the Environment, serves as the central case study in this paper. Throughout the project, the research methodology underwent substantial evolution. Initially, our aim was to determine the requisite charging infrastructure needed to incentivize on-street parkers in urban areas to transition to electric vehicles in the future.

However, the research perspective underwent a substantial shift during the investigation. The conventional "predict and provide" approach, commonly employed in transportation planning to address the supply side, assumed that a transition to electric cars alone would suffice [7-10]. Regrettably, the Ministry of Transportation did not conduct a comprehensive assessment of the specific transportation needs of its citizens, assuming an inherent demand for private electric vehicles. Subsequently, the study's focus evolved towards establishing an optimal charging infrastructure setup. Based on our findings, we advocate sidelining this directive in favor of a demand-driven methodology, which delves into the unmet needs of participants that might otherwise be overlooked. Rather than amassing data to support suggested alterations, our method produced specific empirical findings, revealing a preference among individuals to forego private cars entirely rather than embrace e-mobility vehicles. This change in research methodology laid the foundation for a grassroots planning approach that demonstrated considerably greater benefits for both the environment and society compared to its predecessor.

The burgeoning population of India coupled with the expansion of urban centers are key factors contributing to the country's progressively intricate transportation dilemmas. Swiftly expanding cities tend to experience a rise in varied and intricate travel requirements, frequently resulting in traffic congestion. This rapid urbanization, particularly evident in Delhi, has given rise to a range of transportation-related issues, including congestion, inadequate service levels, imbalanced modal distribution, and pollution. The strain on public transit networks to meet escalating travel demands has compelled commuters towards private modes and paratransit [11,12].

"Paratransit," denoting a supplementary form of public transportation offering personalized, short-distance trips without fixed routes or schedules, has become a critical component. To combat these transportation issues, it is imperative to establish robust public transportation networks and implement eco-friendly solutions.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1599-1610

As of the 2011 census, approximately 97.5 percent of Delhi's population resides in urban areas, solidifying its status as one of India's most urbanized states. Despite consistent and rapid growth in demand, Delhi's public transportation systems have struggled to keep pace. Bus services have experienced a decline in both levels and relative productivity, prompting passengers to turn to individualized modes and paratransit.

Integrated public transportation systems, which combine various modes of transport, play a pivotal role in enhancing public transit operations. These systems offer seamless mobility options, making travel user-friendly, accessible, safe, and cost-effective. Through integration, different modes of transport can complement each other, alleviating the surge in personal vehicle usage on Delhi's roads.

Transport planning involves preparing for future transportation needs in policies, investments, and designs. Integrated transport planning considers objectives, the transport-land use relationship, modes, and operations for an efficient system.

"Sustainable development" means meeting current needs without harming future generations. In transportation, "sustainable transport" means socially, ecologically, and climatically responsible practices. Sustainable cities need transportation networks that reduce environmental impact, with coordinated land use and transportation planning to lower travel demand, enhance energy efficiency, and improve urban life quality [13-15].

Development of an integrated transport-land

The layout of a city unquestionably wields a significant impact on the mobility patterns of its residents. Among the pivotal determinants of these movement patterns is the distribution of activities within the urban landscape. How and where activities are clustered profoundly shapes how people traverse the city. Furthermore, the accessibility and availability of transportation infrastructure significantly sway the decisions made about where to locate various activities. This dynamic interaction, in turn, ripples through the economic, settlement, and social fabric of the city.

Indeed, the symbiotic relationship between land use and the transportation system is abundantly clear. These two facets of urban planning are inextricably linked, their fortunes intertwined. The way in which the city's physical space is allocated for different functions fundamentally informs how individuals navigate their environment. In parallel, the transportation system's efficiency and reach dictate the extent to which people can engage with these activities.

To delve deeper into this interconnectedness, it's imperative to recognize that the urban landscape is far from a static entity. It is an evolving mosaic of residential, commercial, industrial, and recreational zones, each with its own gravitational pull on human activity. As these zones grow, contract, or shift, they act as magnets, exerting a powerful influence on how people distribute themselves across the city. The arrangement of these activities, thus, shapes the ebb and flow of urban movement.

This dance between land use and transportation is not a one-way street. The transportation network, in its various forms, serves as the circulatory system of the city. It breathes life into the urban form, granting access and connectivity to its diverse activities. Be it roads, railways, subways, or pedestrian walkways, the transportation system is the vital conduit through which individuals access their workplaces, homes, shopping centres, recreational spaces, and more.

Consider, for instance, the impact of an efficient, accessible public transit system. It not only enables workers to reach their offices but also empowers them to choose housing that aligns with their lifestyle preferences rather than just proximity to work. This, in turn, can influence the structure of settlements within the city, potentially leading to the development of vibrant, mixed-use neighbourhoods that blend residential, commercial, and recreational spaces.

Conversely, a haphazard or inefficient transportation system can stifle the potential of certain areas, limiting their accessibility and appeal. This, in turn, can impede economic growth and exacerbate issues of social equity. In essence, the transportation system serves as the arteries and veins that nourish the urban organism, influencing its health, vitality, and overall well-being.

The imperative to integrate land use and transportation planning has never been more pressing. With urbanization continuing apace, cities are faced with the urgent task of creating environments that are not only liveable but also sustainable. This calls for a holistic approach that considers how the layout of the city interacts with its transportation infrastructure. By harmonizing these elements, cities can forge a more cohesive, efficient, and environmentally conscious urban fabric, one that serves the needs of its inhabitants today without compromising the prospects of future generations. This imperative for integration is not just a matter of urban planning theory; it is a practical necessity for the cities of tomorrow.

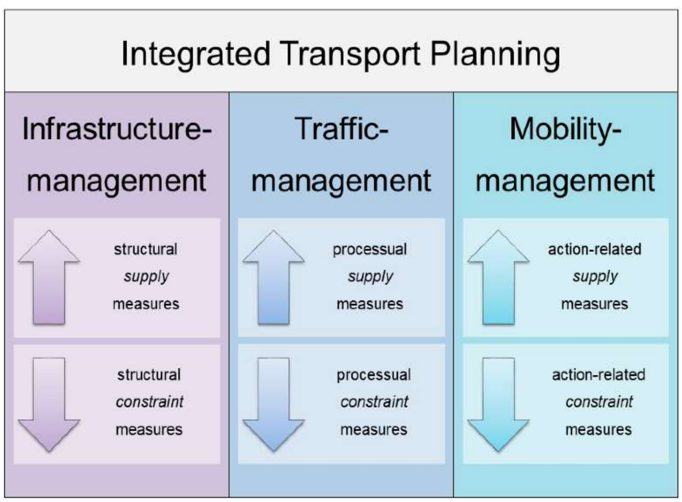

Figure 1: Integrated transport planning

Single land use models typically assume a static future transportation system, while the widely used four-step transportation models expect the spatial distribution of land use to remain unchanged. Oryani and Harris's 1996 research supports the validity of these assumptions.

Since the 1960s, various models have emerged to integrate transportation planning with land use considerations, recognizing their interdependence. Timmermans (2003) categorizes these planning models into three stages, collectively referred to as Land Use–Transport Interaction (LUTI) models:

The first generation consists of aggregate spatial interaction-based models, relying on aggregate data and concepts like gravity and entropy maximization.

The second generation revolves around multinomial logit models, focused on optimizing utility functions.

The third generation employs microdata and incorporates insights into activities and travel patterns.

These progressive stages mark the evolution of models aimed at providing a more comprehensive understanding of the intricate relationship between land use and transportation planning.

Objectives

- The aim of this investigation was to assess the effectiveness of an integrated public transportation system.
- This study focused on the concurrent development of an integrated mass transit planning system.

Methodology

The process of crafting a network design unfolds in two distinct stages, each pivotal in shaping the system as a whole. The initial phase entails the creation of a diverse array of feasible routes, while the subsequent step involves the intricate task of pinpointing the most efficient amalgamation of routes and their corresponding frequencies to comprise the network.

To grapple with this intricate optimization challenge, the Genetic Algorithm emerges as a powerful metaheuristic technique. It stands as a computational approach adept at navigating the vast landscape of potential route combinations. This intricate task is deftly managed by a specialized software known as the Genetic Search Tree, which employs the Genetic Algorithm to uncover the most promising network configurations.

The choice of the Genetic Algorithm as the linchpin of this endeavor is driven by the inherent complexity of the problem at hand. The challenge lies in the nonconvex nature of the task, compounded by the sheer expanse of the search space. These factors coalesce, demanding an approach that can systematically explore an immense array of potential route combinations to arrive at an optimal solution.

In essence, the Genetic Algorithm harnesses principles inspired by biological evolution to hone in on the most efficient network design. It employs a process akin to natural selection, where promising route configurations are systematically refined and cross-bred to generate increasingly effective solutions. Through a cycle of iteration and refinement, the algorithm converges towards an optimal network design that strikes a balance between diverse routes and their corresponding frequencies.

The Genetic Algorithm's strength lies in its ability to grapple with complexity and uncertainty inherent to the task. By leveraging a process of controlled randomness and guided selection, it systematically explores the solution space, gradually honing in on configurations that promise the highest levels of efficiency and effectiveness.

In conclusion, the deployment of the Genetic Algorithm, facilitated by the Genetic Search Tree software, represents a sophisticated and powerful approach to crafting an integrated public transport system. Through a meticulous process of route generation, evaluation, and refinement, this technique navigates the intricate terrain of potential network configurations. It stands as a testament to the capacity of computational methodologies to tackle complex optimization challenges, ultimately paving the way for an integrated public transport system that maximizes efficiency and accessibility.

Generation of Candidate Route Set

The process begins with a candidate route set generating algorithm, forming a pool of potential routes in the initial phase. These routes serve as input for the subsequent stage, where a combination is chosen to create the final network solution. This set of routes forms the foundation for the ensuing phase.

The route creation hinges on crucial input data: terminal node pairs, an OD demand matrix, and a Network file with node and link information. Routes link these chosen terminal node pairs based on the existing demand. These pairs are typically situated in neighbourhoods with a concentration of residential or commercial buildings. The Djikstra approach is employed to create routes that are both direct and shortest between each pair. Routes adhering to maximum length criteria are included for further assessment, while shorter ones are excluded. Alternate routes are also devised by removing specific links from the current shortest route, allowing for the discovery of new paths covering shorter distances, while still adhering to criteria for maximum route length, overlap, detour, and duplication.

Two distinct pathway types emerge. Feeder routes, constituting the feeder system, always initiate or conclude at a major transport hub, acting as the system's starting or ending point. These routes address non-feeder service needs, catering to customers requiring transfer and feeder services. Importantly, travel times on these routes are notably reduced. Thus, establishing an integrated network design to optimize these routes is highly recommended. These feeder routes smoothly integrate into the candidate route set, progressively assuming a pivotal role within the evolving pool of routes.

Optimizing the Route Set

In this phase, the objective is to sift through the array of potential routes and identify the most optimal combination of roads to traverse, known as the Candidate Route Set (CRS). This task is framed as an optimization challenge, seeking to pinpoint a path that minimizes overall costs for both users and operators while adhering to specific constraints like frequency and load factor limits. The overarching aim is to minimize expenses incurred by users and operators, presenting a multifaceted objective function.

The user cost, covering all travel time, constitutes the initial segment of this function, encompassing time in the vehicle, waiting, and transferring. This is calculated by adding the product of demand (d) and total travel time (TT) across chosen routes within the network, as detailed in Equation 1. TT represents the total travel time across the selected routes.

The second component addresses the operational cost of bus operation. It is computed by multiplying the total active time of the bus during a single trip (Tk) by the total number of trips conducted (k). This quantifies the expenses incurred by the bus operator in terms of time spent in operation.

Equation 2 embodies the objective function used to determine both user and operator costs, striking a delicate balance between minimizing user travel expenses and considering operational costs for the bus operator.

$$Min\ Z = C_1\left[\sum_{i,j=1}^{n} d_{ij}TT_{ij}\right] + C_2\left[\sum_{k=R} \lambda_k T_k\right] \quad \text{--- (1)}$$

$$Z = \left((Tt + (D_{un} * Des_{Dur}) + bus\_pty)U_c + bus\_km * O_c\right)/T_{dem} \quad \text{--- (2)}$$

The optimization process hinges on several crucial variables, primarily the objective function (Z), total travel time (Tt), and unsatisfied demand (Dun). Additionally, factors like the required trip duration (DesDur), bus penalty (Bus pty), and total bus kilometres (bus km) play pivotal roles in determining the optimal routes.

The objective function is a comprehensive metric that incorporates both user and operator costs. User cost, represented as Uc, covers all time spent on travel, including time spent within the vehicle, waiting, and transferring. This is computed by summing the product of demand (d) and total travel time (TT) for the selected routes. TT refers to the combined travel time across the chosen routes.

Operator cost, denoted as Oc, solely pertains to the total kilometres travelled by buses, as the distance covered by newly established public transportation lines remains constant. This unchanging variable has no impact on variations in the objective function and can thus be disregarded in its calculation.

The total demand, represented as Tdem, is another crucial variable considered in the optimization process.

Trip assignment is a pivotal step in assessing user expenses and operator charges. Multiple routes are generated for each Origin-Destination (OD) pair, and assignments are made based on frequency sharing criteria for a subset of available routes. Notably, an integrated approach is employed in this study, distinguishing it from the conventional technique used in route creation. In traditional transit route selection, direct routes are favoured over transfer routes. However, for trip assignment, routes involving transfers are considered only when no direct route is available. This approach may suffice when only one mode of transportation is involved but falls short when integrating a mass rapid transit system into the network.

The unique approach adopted in this study involves a comprehensive assessment of direct routes, routes with one transfer, and routes with two transfers for each OD pair. These pathways represent potential components of public transit systems. This is significant as routes involving two transfers, utilizing both metro and buses, may prove significantly faster than routes relying solely on buses without any transfers. This distinction underscores the importance of identifying all routes to select the most suitable one for assignment, prioritizing routes with the fewest transfers.

Routes are then ranked based on travel time, with those approaching or matching the fastest route chosen for demand assignment. Employing frequency share rules enables demand segmentation based on route frequencies, facilitating the final assignment decisions. Routes with more frequent service naturally attract higher volumes of traffic, assuming that passengers are inclined to choose the first available bus when routes are nearly equal in terms of travel time.

Total trip time covers the duration spent in the vehicle, initial waiting time, transfers, and associated penalties. These penalties account for mode switches and the discomfort experienced during these transitions.

To determine the optimal route, the Genetic Algorithm proposed by Holland in 1992 is employed to minimize the objective function. The process starts by randomly establishing a set of frequencies linked to each route. Routes failing to meet the minimum or maximum frequency requirements are excluded. This set of solution routes then undergoes trip assignment, yielding potential routes, including mass transit lines (MTL) with preset frequencies and distinctive features like higher link speeds. MTL's velocity and frequency are determined using available standard data. While MTL consistently appear in the solution route set, they don't influence the evolutionary algorithm's decision on which operators to employ. This precaution ensures that MTL aren't inadvertently removed in subsequent generations.

The evolutionary process involves reproduction, genetic crossover, and mutation operators to generate the next generation of solutions. Given the extensive size of the candidate route set, this computational effort demands significant time and resources, warranting the use of the number of generations as the stopping criterion.

In summary, this optimization process integrates a range of variables and employs sophisticated techniques to identify the most efficient routes for an integrated public transportation system, striking a balance between user and operator costs. The Genetic Algorithm plays a central role in this endeavour, guiding the evolution of route selections over successive generations.

Research Location and Data Compilation

The research focused on Mumbai, India's bustling metropolitan region, chosen for its substantial population and diverse urban landscape. Situated along the west coast, Mumbai experiences significant population growth, particularly in this area. The region currently relies heavily on an extensive network of suburban trains, accommodating an average of 7.6 million passengers daily. To address traffic congestion, proposals for a metro system have been made, with one route already operational and others in various stages of development. Additional modes of transportation include private vehicles, taxis, motorcycles, walking, and intermediate public transportation (IPT).

The network data, encompassing nodes, links, and Origin-Destination (OD) demand statistics, was sourced from the 2008 CTS report by LEA Associates. This report provided the basis for constructing a CUBE model, facilitating data extraction. The established suburban rail line and planned metro line were treated as fixed routes, with details on nodes and frequencies obtained from the report. Transfer OD demand data, especially for the feeder route set (FRS), played a crucial role in establishing routes within the Candidate Route Set (CRS). This essential data was derived from CUBE's trip assignment results. Following public transit assignment, routes for each Origin-Destination (OD) pair, along with pertinent transfer information, were obtained.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1599-1610

This data contributed to the formulation of an OD matrix reflecting transfers to and from the metro system, subsequently integrated into the feeder route creation process.

Results and Discussions

Table 1 outlines crucial input parameters utilized in the research project for both the candidate route set development and subsequent optimization. Projected for 2031, the network and demand statistics are detailed. The proposed route set included feeder and non-feeder routes. Initially, 5,271 distinct routes were formulated, with 7,049 node pairs as terminals. Among them, 596 were feeder routes, advancing to the subsequent optimization phase.

Executing route set optimization is a highly demanding computational task, taking 52 hours on a 16-core Intel Xeon processor to complete 1,000 generations. A population size of 16 was selected to match the available processing cores, expediting results. The graph depicting the progression of the objective function value across generations exhibits a consistent downward trend, signifying the genetic algorithm's convergence toward the global minimum. A noticeable inflection point in the graph represents the algorithm's attempt to navigate out of a local minimum, exploring a previously uncharted area. It also underscores the importance of appropriately calibrating the weights for user and operator costs to strike a balance in the objective function. This equilibrium prevents one from unduly overshadowing the other. Figure 1 illustrates a consistent reduction in both the user's overall travel time and bus kilometres, underscoring the algorithm's effectiveness in devising an efficient network design for the region.

Table 1: Parameters for Optimizing the Route Set Program

Parameter	Value	Parameter	Value
Population Size	16	Bus Link Speed (m/min)	250
Generations	1000	Metro Link Speed (m/min)	450
Crossover Probability	0.5	Suburban Link Speed (m/min)	750
Mutation Probability	0.0006	Bus Capacity (passengers)	80
No. of metro lines	22	Metro Capacity (passengers)	1800
No. of suburban lines	55	Suburban Capacity (passengers)	4500
Weight for user cost	0.155	Weight for operator cost	4.49
Min freq for buses (in min)	60	One transfer penalty (min)	5
Max freq for buses (in min)	12	Two transfer penalty (min)	15
Max no. of 0T routes allowed	50	Size of FRS (no. of routes)	596
Max no. of 1T routes allowed	30	Size of CRS (no. of routes)	4675
Max no. of 2T routes allowed	15	Size of CRG (no. of routes)	5271
Total OD pairs for assignment	20,866	Total Demand for Assignment	5,31,207

Table 2 provides network parameters for the optimal solution achieved after 1000 generations of testing. In the proposed scenario, the technique results in an average per-journey travel time of 94.6 minutes per passenger. Conversely, CUBE Voyager estimates an average In-Vehicle Travel Time (IVTT) of 76.2 minutes per passenger per trip for 2031, using the same demand matrix. This indicates an 18 percent reduction compared to the proposed technique's result.

The significant variation in values can be attributed to the inclusion of Intermediate Public Transport (IPT) routes in the CUBE Voyager model. IPT routes often have shorter travel times during peak hours, resulting in a lower average In-Vehicle Travel Time (IVTT). In regions with limited demand, IPT proves to be a more cost-effective transportation mode than buses, benefiting both users and operators.

In the proposed approach, the IPT network is integrated alongside buses, offering substantial cost advantages. Bus operating agencies in the Mumbai Metropolitan Region (MMR), often government-controlled, may face financial losses due to high operational expenses. MMR bus companies are currently grappling with substantial losses. The proposed approach's objective function considers both user and operator costs, seeking a balanced solution to protect both parties from undue financial burdens.

The existing bus frequencies closely align with the minimum (60 minutes) and maximum (12 minutes) frequencies calculated using the proposed methods (see Table). Meeting 70 percent of total demand is challenging due to the impracticality of operating buses in areas with low demand. In urban settings, IPT typically serves such demand more efficiently, offering greater speed and responsiveness compared to buses on fixed schedules.

Table 2: Characteristics of the Optimal Route Set for the Network

Parameters	**Values**
No. of Bus Routes	1109
Zero Transfer Demand (% of total)	5
One Transfer Demand (% of total)	29
Two Transfer Demand (% of total)	36
Waiting Time (min/pax)	20.6
In vehicle travel time (min/pax)	94.6
Total travel time (min/pax)	135.93
Bus kms	2,29,918
Fleet size required	4,933
Avg route length (km)	18.73
Avg_route frequency (min)	20
Number of routes chosen from FRS	134
Number of routes chosen from CRS	975

Conclusion

The study's main aim was to develop an integrated land use and transport model, providing a vital tool for local authorities to advance urban sustainability. This entails shifting from private to mass transit. The method focuses on reallocating activity volumes to optimize public transportation capacity. Through Visum's macro-simulation program, various models, including the existing transportation system (version V0), were generated and assessed. This process yielded a comprehensive set of parameters and metrics crucial for evaluating established criteria. These measures were then employed in:

1. Conducting a computational experiment using the Electre III/IV method, resulting in the final ranking of variations.
2. Addressing migration patterns and formulating relevant urban policies.

It's important to note that the current phase of the research has not yet integrated behavioural models. However, future advancements may introduce a modal shift model, providing a means to validate the efficient use of public transportation for the associated trip demand

References

[1]. Almasi, M.H., Sadollah, A., Kang, S. and Karim, M.R., 2019. Optimization of an Improved Intermodal Transit Model Equipped with Feeder Bus and Railway Systems Using Metaheuristics Approaches. Sustainability, 8(6), p.537.

[2]. Ciaffi, F., Cipriani, E. and Petrelli, M., 2018. Feeder bus network design problem: a new metaheuristic procedure and real size applications. Procedia-Social and Behavioral Sciences, 54, pp.798-807.

[3]. Jiaqing, W., Rui, S., Wangtu, X. and Liu, Y., 2017, June. Transit Network Optimization for Feeder Bus of BRT Based on Genetic Algorithm.

[4]. In Digital Manufacturing and Automation (ICDMA), 2018 Fourth International Conference on (pp. 1627-1630). IEEE.

[5]. Gori S, Nigro M, Petrelli M. 2017. Walkability Indicators for Pedestrian-Friendly Design. TRB 93rd Annual Meeting Compendium of Papers. Accepted for publication in Transportation Research Record.

[6]. Keuchel S. & Richter C. (2020). Applying Integrated Hierarchical Information Integration to Mode Choice Modelling in Public Transport. Procedia Social and Behavioral Sciences 20, 875–884.

[7]. May A.D., Kelly C. Shepherd S. & Jopson A. (2017). An option generation tool for potential urban transport policy packages. Transport Policy, 20, 162–173.

[8]. N. Monteiro, R. J. F. Rosseti, P. Campos and Z. Kokkinogenis “A Framework for a Multimodal Transportation Network: An Agent Based Model Approach”, Elsevier, Transportation Research Procedia, vol. 4, pp 213-227, 2017.

[9]. J. Camargo-Perez; R. Jairo, M. Torres, H. Martha, C. Ramlrez “Multicriteria Decision Making for Locating Multimodal Transfer Nodes In Passenger Transport Systems” International Conference on Systems, Man, and Cybernetics, IEEE, pp 718-723, 2019.

[10]. C. Minal, and R. Shekhar, “Mode Choice Analysis: The Data, Models and Future Ahead” International Journal for Traffic and Transport Engineering, vol. 4, no. 3, pp 269-285, 2019.

[11]. Toan, T.D. 0DQDJLQJ WUDIILF FRQJHVWLRQ LQ D FLW\$ VWXG\ RI 6LQJDSRUHV experiences. Proceeding/ International Conference on Sustainability in Civil Engineering. Hanoi, Vietnam (2018).4858

[12]. Chin, H.C. and Foong, K.W. Issues in transportation planning ± the Singapore experience. WIT Transactions on State of the Art in Science and Engineering, vol. 22, pp127-158. WIT Press (2018).

[13]. Ghasemlou, Kiarash, et al. "Exploring Equity in Public Transportation Planning Using Smart Card Data." Sensors, vol. 21, no. 9, 26 Apr. 2021, p. 3039, 10.3390/s21093039.

[14]. Schwedes, O.; Hoor, M. Integrated Transport Planning: From Supply- to DemandOriented Planning. Considering the Benefits. Sustainability 2019, 11, 5900. https://doi.org/10.3390/su11215900

[15]. Paul Waddell (2011) Integrated Land Use and Transportation Planning and Modelling: Addressing Challenges in Research and Practice, Transport Reviews, 31:2, 209-229.