OPTIMIZATION OF ADDIS ABABA LRT STADIUM STATION INTERCHANGE BASED ON MICROSIMULATION MODELING

BZ DUBE[1] and YM EMAGNU[2]

[1]National Railways of Zimbabwe Graduate Civil Engineer, 890 Nkulumane 5, Bulawayo;
Tel: +263 78 202 0304; +251 94 111 4964; Email: bubuyadube75@gmail.com
[2]Road and Transport Engineering, School of Civil and Environmental Engineering, Addis Ababa University, King George VI Street, Addis Ababa, Ethiopia; Tel: +251 98 704 8608;
Email: yoethio2003@gmail.com; yonas.minalu@aait.edu.et

ABSTRACT

The research explored integration of transit modes at Addis Ababa's LRT stadium station, to address the city's population growth and consequent strain on the transit system. Lack of modal integration presented challenges to commuters navigating between buses, trains and minibuses. To address the aforementioned, a microsimulation model was conducted on AIMSUN, employing the social force model, to assess 3 options on top of the existing transit system based on transfer times, distances and space availability. The simulated options were further evaluated using a judgement matrix, based on the aforementioned parameters. Results indicated that option B from the simulated options [index value of 0.32], optimized transfer distances and times which improved passenger circulation, achieving acceptable Levels of Service. Hence the study recommended option B for its practicality and future demand considerations, highlighting the need for further research on integrated ticketing systems and modal integration at the network level. The proposed transit setup aimed to enhance passenger transportation efficiency and overall urban mobility in Addis Ababa.

Keywords: Integration, Interchange, Microsimulation.

1. INTRODUCTION

Due to continuous population growth in major cities worldwide, there is an increased need of interconnected end user services (Conticelli *et al.*, 2021). Addis Ababa is no stranger to this phenomenon, with an expected annual population growth of 4.4 % which has resulted in an increased strain on the city’s transit system. This has disrupted mobility patterns, hence a light rail train was introduced as a relief mechanism to buses and taxis (Aklilu & Necha, 2018). Without coordination, the main purpose of effectively transporting users is not fully realized. Introduction of interchanges at strategic points becomes a viable option to improve inter-modality and coordination of involved operators (Ezana Haddis Weldeghebrael, 2021). This requires a significant interest in understanding how services in public transport stations and hubs can be improved (Hickman *et al.*, 2015; Lucietti, Hoogendoorn & Cré, 2016). Simulation techniques have evolved over the years to address transit problems as they offer advantages in modelling transit environments within a controlled time frame whilst producing recommendable results (Lois, Monzón & Hernández, 2018).

1.1 Aim of Paper

To evaluate and optimize the current transit setup through use of microsimulation modelling using Addis Ababa stadium Interchange as a case study.

1.1.1 Problem Statement

As commuters transfer between public transit options, difficulties may be encountered in the absence of effective modal integration. The Addis Ababa LRT stadium station plays a critical role in linking people who use buses, minibuses, and trains. Therefore, assessing waiting spaces, transfer times and distances is essential in advancing integrated mobility.

1.1.2 Scope

The study explored the integration of transit modes at Addis Ababa's LRT stadium station with more emphasis on transfer times, distances, and waiting spaces due to the direct impact of these factors to passenger experience and operational efficiency. The scope was narrowed to the aforementioned constraints due to the complexity of factors affecting transit system efficiency. To conduct a comprehensive analysis on factors affecting transit system efficiency often requires extensive resources, time, and data collection efforts.

2. LITERATURE REVIEW

To reach a destination, a rider is often required to utilize multiple transit options with different schedules. To achieve this, walking between transit options is required which is likely to affect end user experience (Filipe and Ramos, 2015). Therefore, an efficient interchange requires a well-built system that prioritizes modal transfer with minimum inconveniences. A poorly designed public facility can be a threat to the effectiveness of the station (Turnbull & O'higgins, 2013). Hence this requires inclusion of universal design standards so as to keep up with end user requirements. Interchange stations should be designed to fit the operational and community environment (Tilahum, 2017; Solecka, Nosal Hoy & Deryło, 2020). This can be achieved through gathering methodology gaps to optimize human capability, maintainability, and overall system performance (Desiderio, 2004).

2.1 Pedestrian Modelling Techniques

System modeling is a tool used to solve real-world issues that cannot be addressed through experiments due to cost, risk, or practicality (Alodhaibi *et al.*, 2019). In this case, creating a computer model of the real system becomes more practical. The model is less complex than the real system as it assumes certain level of abstraction, where pertinent system aspects are incorporated (Rifai, 2021). There are 3 main types of models; microscopic models: which consider each pedestrian as a unique entity with its own properties, macroscopic models: determine average pedestrian dynamics by density, flow and velocity as functions of space and time, and mesoscopic models: which are between the 2 as they often include individual entities but model interactions between common fields (Enciso, Vargas & Martínez, 2016). Pedestrian microsimulation has become a critical research tool due to its ability to accurately simulate the behavior of individual agents. The most common models are; cellular automata and social force model. The automata model disregards preference and heterogeneity, assuming agents to be homogeneous. The social force model is effective for agents having personalized attributes in a dynamic system. Despite its simplicity, it accurately models commuter dynamics and fills in the gaps not addressed by other models. Pedestrian speed is equated to a social force, which represents the effect of surroundings on the pedestrian's behavior. Its success is due to the ability to reproduce the self-organization phenomena observed in real context (Cortés, Burgos & Fernández, 2010; Filipe & Ramos, 2015).

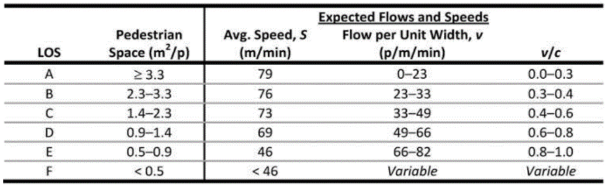
3. RESEARCH METHODOLOGY

3.1 Methods

Relevant data was gathered from multiple sources, including transit authorities, on site surveys and previous studies. These sources provided information on travel patterns, transit routes, infrastructure, demographics, and other necessary variables. The survey collected data on passenger speeds, transit behaviour and spaces. Transit routes were obtained from the transit operators. Transfer distances were obtained from Google Earth. Level of Service was evaluated using Table 1 obtained from the Highway Capacity Manual 3rd edition 2013.

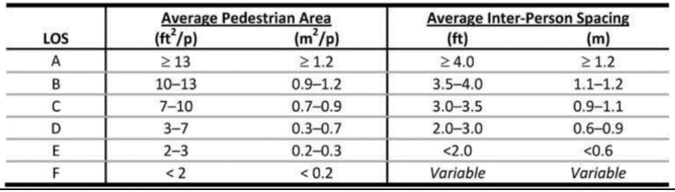
Table 1: Level of Service [LOS] assessment (Brinckerhoff, 2013)

Walkway LOS



LOS	Pedestrian Space (m^2/p)	Avg. Speed, S (m/min)	Expected Flows and Speeds Flow per Unit Width, v (p/m/min)	v/c
A	≥ 3.3	79	0–23	0.0–0.3
B	2.3–3.3	76	23–33	0.3–0.4
C	1.4–2.3	73	33–49	0.4–0.6
D	0.9–1.4	69	49–66	0.6–0.8
E	0.5–0.9	46	66–82	0.8–1.0
F	< 0.5	< 46	*Variable*	*Variable*

Waiting Area LOS



LOS	Average Pedestrian Area (ft^2/p)	(m^2/p)	Average Inter-Person Spacing (ft)	(m)
A	≥ 13	≥ 1.2	≥ 4.0	≥ 1.2
B	10–13	0.9–1.2	3.5–4.0	1.1–1.2
C	7–10	0.7–0.9	3.0–3.5	0.9–1.1
D	3–7	0.3–0.7	2.0–3.0	0.6–0.9
E	2–3	0.2–0.3	<2.0	<0.6
F	< 2	< 0.2	*Variable*	*Variable*

The collected data underwent thorough processing, calibration and validation through comparison of simulated outputs with observed site data to fine-tune model parameters and ensure its accuracy and consistency in replicating actual travel patterns. Microsimulation modelling was conducted on AIMSUN [social force model] to determine the best transit orientation for the stadium Interchange and the model's steps are depicted in Figure 1.

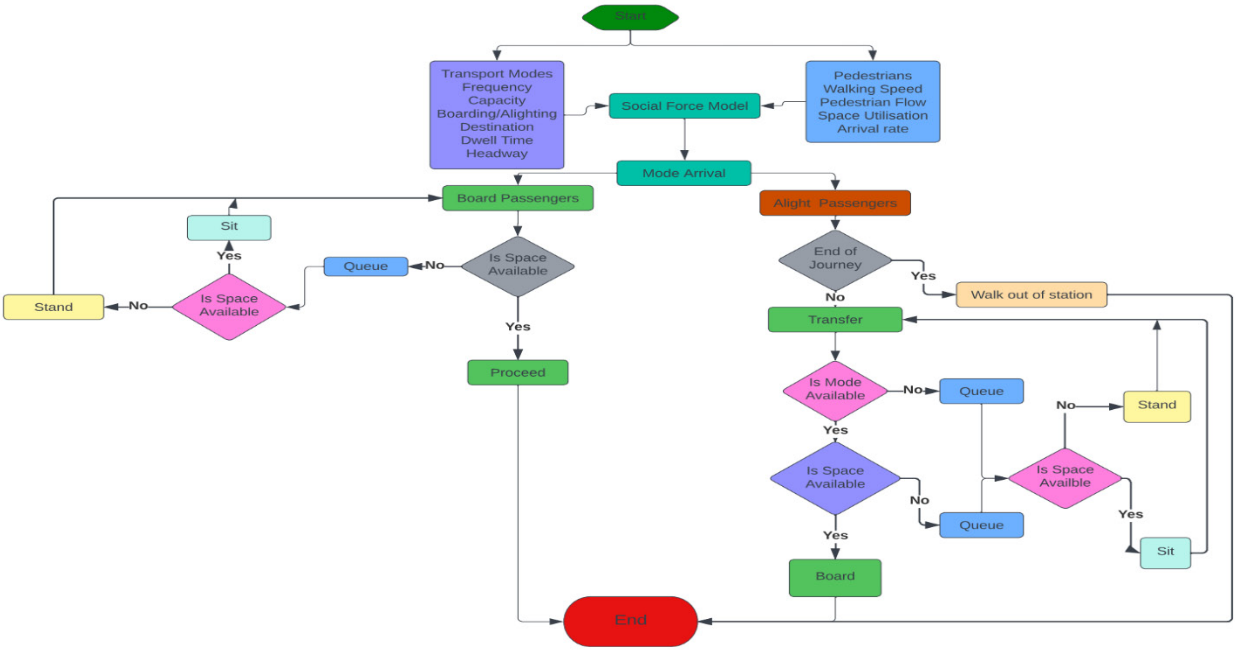


Figure 1: Passenger Modelling Flow Chart (Soltész et al., 2017; Sanders et al., 2021)

The origin destination matrix for initiating agent movement is shown in Figure 2.

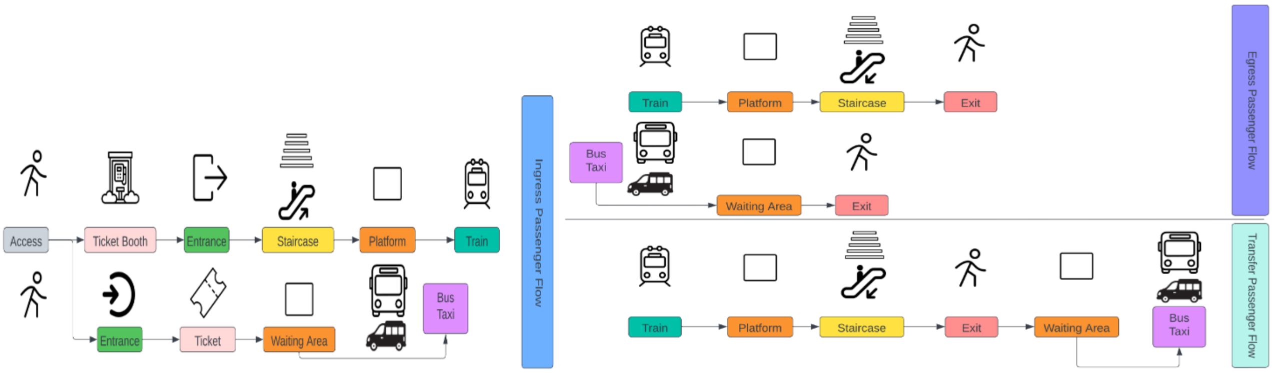


Figure 2: Origin-Destination Matrix (Soltész et al., 2017; Sanders et al., 2021)

3.2 Transit System Development

The study was conducted with reference to Addis Ababa LRT stadium station. The LRT station is situated next to a taxi and bus station as shown in Figure 3.

Figure 3: Addis Ababa LRT stadium station configuration (Google Earth)

The simulation environment was developed based on the above configuration. The first simulation evaluated the current transit setup [base case]. Option A consolidated taxis at point D. Option B considered consolidation of taxis in at point C. Option C considered moving all taxis from their respective positions to the bus station (Point B). As a result of security concerns only 2 entrances out of 4 were functional hence affecting transfer times between the bus and train station. Option B and C considered all entrances to be functional.

3.3 Model Calibration

The model was validated through use of the Mean Absolute Percent Error (MAPE) due to its transparency and easy-to-interpret metric that provides a clear indication of the model accuracy predictions compared to the actual values. MAPE is robust against outliers and scale variations, making it suitable for evaluating the performance of the model across different scenarios. The difference between the simulations and actual site observations were noted and evaluated and Galiza et al. (2009) recommended a difference no higher than 5%. The validation process considered transfer times and flows which were then compared to the simulated parameters using the formula below:

$$\mathrm{MAPE} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \left| \frac{\mathrm{T_{RL}} - \mathrm{T_{SIM}}}{\mathrm{T_{RL}}} \right|$$

Where: T_{SIM} = simulated parameter, T_{RL} = Observed real-life parameter
N = Number of validation observations

3.4 Simulation Evaluation

Transfer time analysis for the respective simulations was conducted based on the transfer classification standard recommended by Liu and Wang (2016) as shown in Table 2.

Table 2: Transfer Levels Standard (Liu & Wang, 2016)

Transfer level	A	B	C	D	E
Classification	Ideal	Desirable	Acceptable	Tolerable	Intolerable
Transfer time (s)	<90	90-150	150-300	300-480	>480
NB* transfer times do not include waiting times					

An indexing system was further utilized to evaluate the respective simulation options. This was based on classifying the key parameters from a value of 1 up to 4 [lowest to highest]. The judgement index matrix evaluation procedure is detailed below. The first step was to calculate the product of each line element using the following formula;

$$M_j = \prod_{k=1}^{m} a_{jk} \quad j = 1, 2, \dots., m \quad [m = number\ of\ parameters\ per\ row, a = parameter\ value]$$

The m^th^ root of M_j was calculated using the following formula;

$$\varpi_J = \sqrt[m]{M_j}$$

Obtaining the weight of the evaluation index *w*:

$$\omega = \frac{\varpi_j}{\sum_{j=1}^{m} \varpi_j} \qquad \bar{\omega}_j = \sqrt[m]{M_j}$$

4. RESULTS AND DISCUSSIONS

4.1 Base Case

Transfer times were evaluated based distances summarized on Table 3 and the simulation was executed for evening peak hours [16:00-19:00], as shown in Figure 4.

Table 3: Walking Distances [Base Case]

No	Segment	Distance	Comment
1	Point A to B	140 m	Train to bus station
2	Point A to C	120 m	Train to taxi point 1
3	Point A to D	200 m	Train to taxi point 2
4	Point B to C	210 m	Bus station to taxi point 1
5	Point B to D	290 m	Bus station to taxi point 2
6	Point C to D	80 m	Taxi point 1 to Taxi point 2

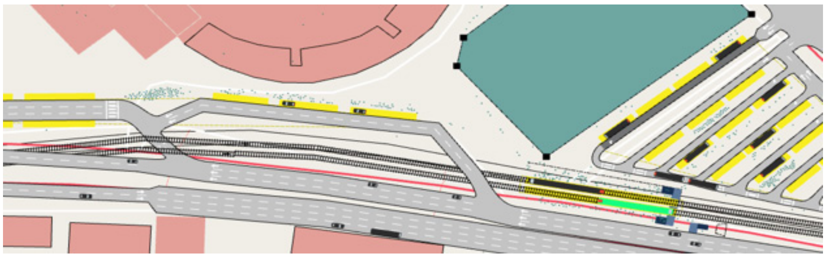


Figure 4: Base Case Simulation

Simulated transfer times are summarized in Figure 5.

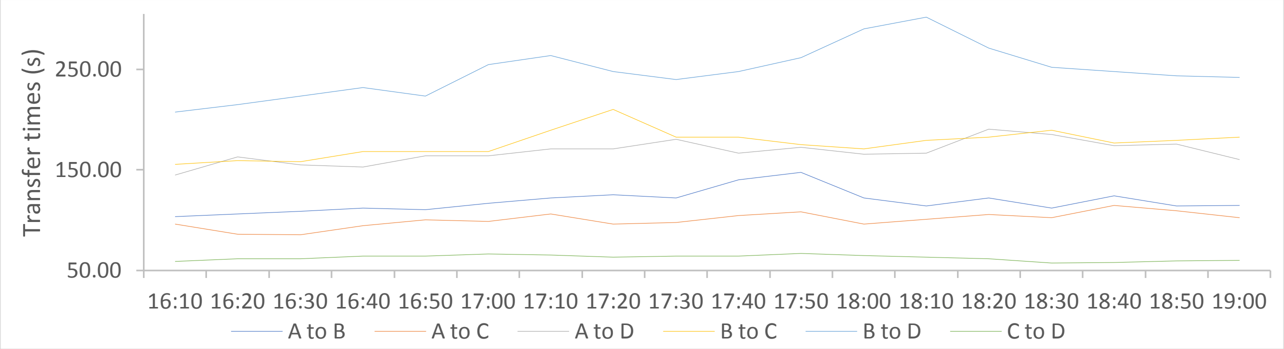


Figure 5: Simulated Transfer Times [Base Case]

The average simulated transfer times were compared to the real transfer times observed on site and it yielded a MAPE value of 1.92%, which is within the 5% error margin. A maximum transfer time of 302s from the bus station to the taxi station, with an average of 247s was obtained from simulation [transfer level C which is acceptable]. From the train station to the taxi station, a maximum transfer time of 191s, with an average of 168s was obtained from simulation [transfer level C which is acceptable]. From the train station to the bus station a maximum transfer time of 148s, with an average of 118s was obtained from simulation [transfer level B which is desirable]. Transfers which were of concern were from the bus to the taxi station. The base case had ample of space, which is key for uninterrupted passenger circulation and future expansion purposes as highlighted by the maximum passenger LOS C (47 p/m/min) and queuing LOS C (0.80 m^2/p). Part of the taxi station was noted to only serve a maximum of 3 routes and was mainly used for dropping off passengers.

4.2 Option A

The simulation distances and setup are summarized in Table 4 and Figure 6 respectively.

Table 4: Walking Distances [Option A]

No	Segment	Distance	Comment
1	Point A to B	140 m	Train Station to Bus Station
3	Point A to D	200 m	Train station to Taxi Point 2
5	Point B to D	290 m	Bus station to Taxi Point 1

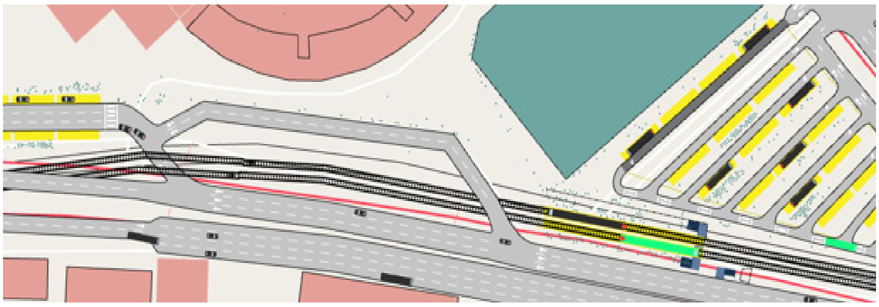


Figure 6: Option A

Observed simulated Transfer times are summarized in Figure 7.

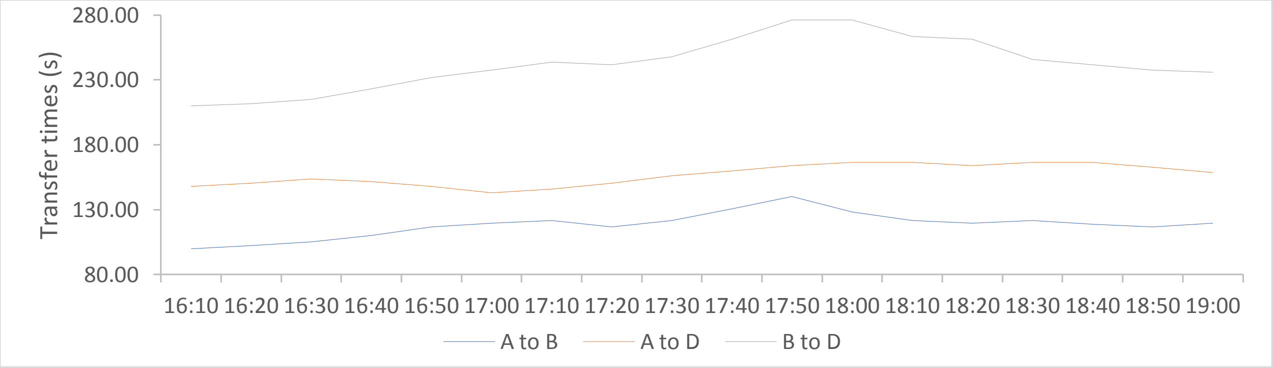


Figure 7: Simulated transfer Times [Option A]

Transfer times were noted to generally decrease in comparison to the base case as a result of fewer obstacles within the transit environment. This is in sync with what was observed on site, as queues at point C affected commuters passing by. Consolidation of taxis into one station aided in the operational aspect making it easier to deliver the required services. The simulated transit environment was observed to be operating at LOS C (40 p/m/min) and queuing LOS C (0.85m^2/p). A maximum transfer time of 277s, with an average of 243s, was obtained from the bus station to the taxi station for the simulation, translating to transfer level C which is acceptable. From the train to the taxi station, a maximum transfer time of 167s, with an average of 157s was obtained from simulation [transfer level C which is acceptable]. From the train to the bus station, a maximum transfer time of 140s, with an average of 119s was obtained, classified under transfer level B which is desirable. The setup was noted to be affected by challenges pertaining to cost of required facilities and transfer distances.

4.3 Option B

The simulation setup and distance are summarized in Figure 8 and Table 5 respectively.

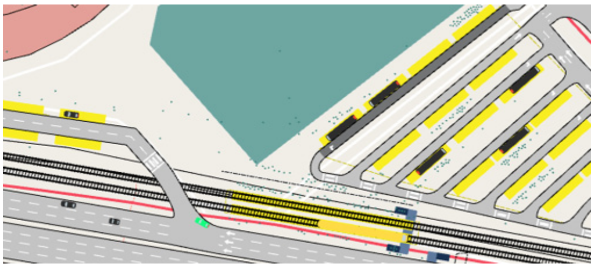


Figure 8: Option B Simulation

Table 5: Transfer Distances [Option B]

No	Segment	Distance	Comment
1	A to B	30 m	Train to Bus Station (Through Staircase C)
2	A to B’	140 m	Train to Bus Station (Through Staircase D)
3	A to C	120 m	Train to Taxi Station (Through Staircase D)
4	B to C	210 m	Bus to Taxi Station (Same Level [Ground Level])

All access staircases were considered to be operational to evaluate the effect on flow and transfer times. The observed simulated transfer times are summarized in Figure 9.

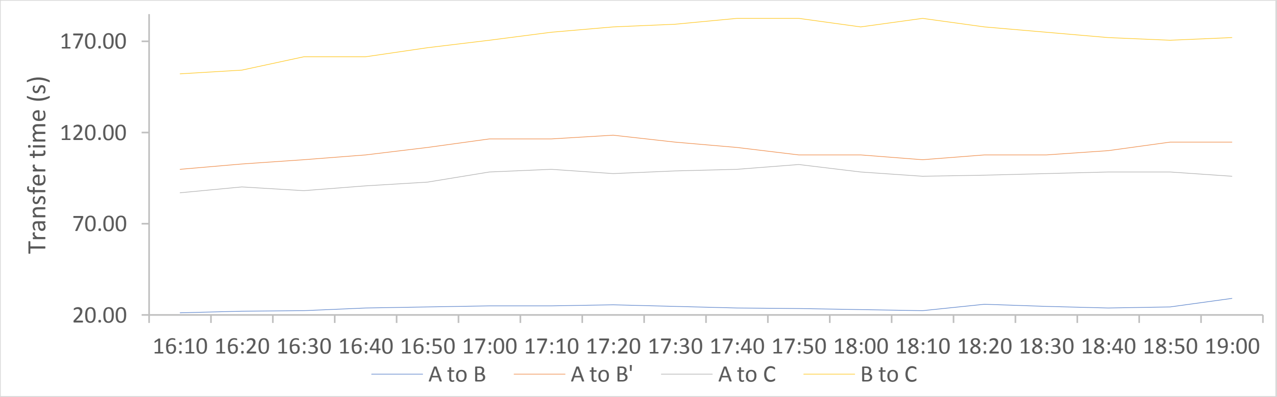


Figure 9: Simulated Transfer Times [Option B]

Transfer times were observed to be minimized compared to option A and the base case from a holistic point of view. A maximum transfer time of 30s, with an average of 25s, was obtained for the train to bus station (through staircase C), classified under transfer level A which is ideal. Some passengers still transferred from the bus to train station using staircase D. A maximum transfer time of 119s, with an average of 110s, was obtained, classified under transfer level B which is desirable. From the bus to taxi station, the distance was now limited to 210m. A maximum transfer time of 183s, with an average of 172s was obtained, indicating transfer level C which is acceptable. Passenger LOS D (55 p/m/min) and queuing LOS C ($0.75m^2/p$) were obtained from simulation allowing for improved waiting conditions as segments were now limited to 3, making it easier for management of the facility.

4.4 Option C

Buses and taxis were consolidated at position B. Some taxi transit lines had to share loading bays to fit within the station. Staircase C was rendered operational to evaluate its effect on transfer times. Table 6 was used to analyse simulated transfer times shown in Figure 10.

Table 6: Transfer Distances [Option C]

No	Segment	Distance	Comment
1	A to B	30 m	Train to Bus Station (Through Staircase C)
2	A to B’	140 m	Train to Bus Station (Through Staircase D)

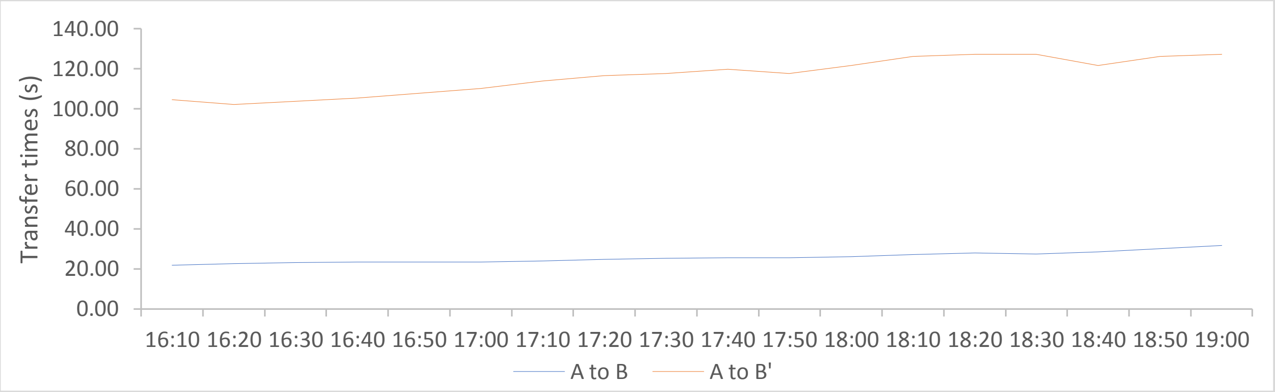


Figure 10: Simulated Transfer Times [Option C]

Transfer times were kept to a minimum compared to the other simulated options [base case, option A and B], which was important when transferring between the modes. It was noted that exits C or D were the paths of interaction between the two stations. Entry C translated to transfer level A, which is perfect for transit stations, with a maximum transfer time of 32s and an average of 26s. For entrance D, a maximum transfer time of 128s was noted, with an average of 117s. This translates to an acceptable transfer level of B which is desirable. As seen in Figure 11, increasing passenger flow, space occupation, and passenger conflicts resulted in pedestrian LOS E (76 p/m/min) and waiting LOS E (0.22m2/p). Although the transfer distances were short, density of passengers occupying the station played a major role in realizing effective transfer distances.

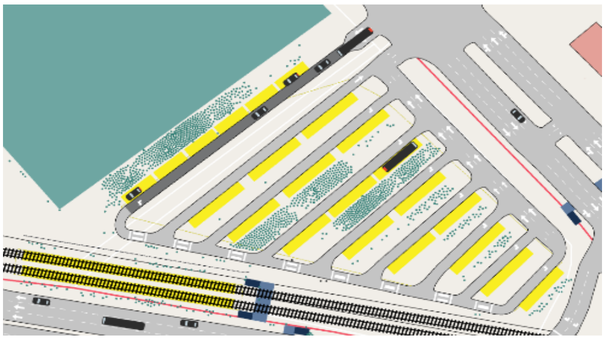


Figure 11: Option C Simulation

Since passengers were sharing spaces with vehicles, safety of passengers was likely to be affected. Although this setup was favorable for operator coordination, passenger circulation was affected by lack of space and increased passenger density. This also affected parking space for layover buses/taxis. Comparison of the simulation outcomes is shown in Table 7.

Table 7: Transfer Times Summary

Option	Segments	Distance	Average Transfer Time	Comment
Base Case AS=5825 m^2	Point A to B	140 m	119 s	Train to Bus Station (Entrance D)
	Point A to C	120 m	101 s	Train to Taxi Point 1 (Entrance D)
	Point A to D	200 m	167 s	Train to Taxi Point 2 (Entrance D)
	Point B to C	210 m	177 s	Bus to Taxi Point 1
	Point B to D	290 m	248 s	Bus to Taxi Point 1
	Point C to D	80 m	63 s	Taxi Point 1 to Taxi Point 2
Option A AS=5025 m^2	Point A to B	140 m	119 s	Train to Bus Station (Entrance D)
	Point A to D	200 m	157 s	Train to Taxi Point 2 (Entrance D)
	Point B to D	290 m	243 s	Bus station to Taxi Point 1
Option B AS=4700 m^2	A to B	30 m	24 s	Train to Bus Station (Entrance C)
	A to B’	140 m	110 s	Train to Bus Station (Entrance D)
	A to C	120 m	96 s	Train to Taxi Station (Entrance D)
	B to C	210 m	172 s	Bus to Taxi Station
Option C AS=3900 m^2	A to B	30 m	26 s	Train to Bus Station (Entrance C)
	A to B’	140 m	117s	Train to Bus Station (Entrance D)
AS = Available Space				

Option B and C had minimum transfer times from the train station to the bus station. This resulted from entry C being open, permitting ease of transfer between the stations. Option C's transfer times were a bit more than option B because of the pedestrian density factor, even though the two cases had identical transfer distances. Option C has the lowest transfer time for the train to the taxi station, followed by option B. Due to the shared LOS (buses and taxis) and entry C's access to these stations, option C had the lowest transfer times. Due to shared space between taxis and buses, option C was not represented from the bus to the taxi station. As a result, option B had the lowest transfers between the bus and the taxi rank. Option C was better for compatibility and transfer times, while the base case was better for space availability. The recommended transit setup was chosen based on a judgement matrix that considered waling speeds, space, transfer times and distances. From Table 8, the index value closest to 1 was considered to be the most appropriate in this case option B.

Table 8: Judgement Matrix

Option	Space	Transfer Time	Transfer Distance	Walking Speeds	M_j	$\hat{W}_j$	W_j
Base case	4	1	1	2	8	1.68	0.19
A	3	2	2	3	36	2.45	0.27
B	2	3	3	4	72	2.91	0.32
C	1	4	4	1	16	2.00	0.22
						$W_{ixT} = 9.04$	

5. PROPOSED INTERCHANGE STRUCTURE BASED ON OPTION B

The proposed interchange layout shown in Figure 12 was structured based on the simulation results of option B and interchange sizing standard detailed in Table 9.

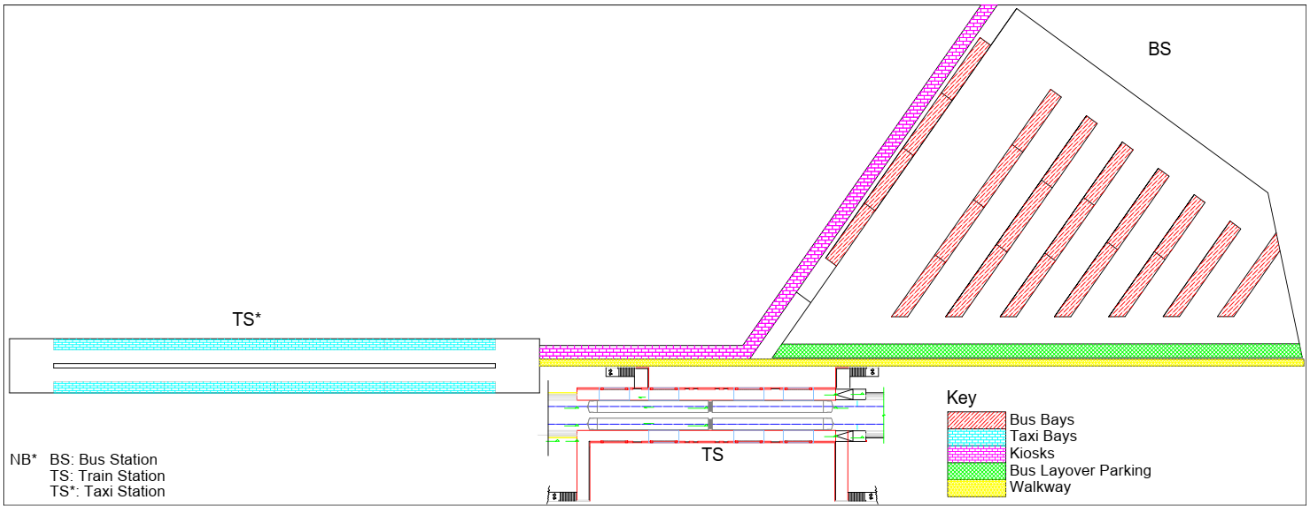
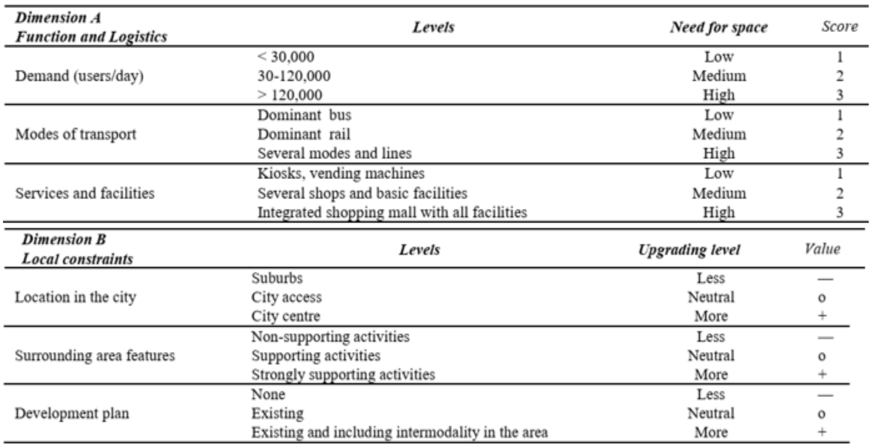


Figure 12: Proposed Interchange Layout and infrastructure

Table 9: Interchange sizing standard (Monzón, Hernández & Di Ciommo, 2016)



Dimension A *Function and Logistics*	*Levels*	*Need for space*	*Score*
Demand (users/day)	< 30,000	Low	1
	30-120,000	Medium	2
	> 120,000	High	3
Modes of transport	Dominant bus	Low	1
	Dominant rail	Medium	2
	Several modes and lines	High	3
Services and facilities	Kiosks, vending machines	Low	1
	Several shops and basic facilities	Medium	2
	Integrated shopping mall with all facilities	High	3

Dimension B *Local constraints*	*Levels*	*Upgrading level*	*Value*
Location in the city	Suburbs	Less	—
	City access	Neutral	o
	City centre	More	+
Surrounding area features	Non-supporting activities	Less	—
	Supporting activities	Neutral	o
	Strongly supporting activities	More	+
Development plan	None	Less	—
	Existing	Neutral	o
	Existing and including intermodality in the area	More	+

The values given in dimension A determined space usage of the interchange based on transit demand, modes of transit and services which can be offered within the transit environment. A total score lower than 4 required a small interchange, whilst a score of 5-7 indicated the need for a medium one, and a score higher than 8 means indicated the need of a big interchange. The dimension B aspect could be negative, positive or neutral, which modifies the aforementioned scores [dimension A], determining the type of interchange required. The results allow choosing one of the three basic interchange types which are cold/hot, partially integrated and fully integrated (Monzón, Hernández and Di Ciommo, 2016). From site observations, the daily demand was determined to be between 80,000 and 100 000 passengers per day, from an average flow rate of 6000 passengers/hour and a 15-hour operation period. This resulted in a score of 2 denoting the need for medium space. Three transit modes share the station: city buses, minibuses, and LRT, yielding a score of three. Informal traders who offered services pertaining to fast foods, clothes, stationery and other necessary services were observed to be operating within the vicinity of the station (score of 1). The vending stalls were on either sides of passenger walkways and some were on non-functional buses which were turned to kiosks. Unutilized spaces around the bus station were noted, which could then be reclaimed and monetarized through opportunity creation and rentals by the respective operators. A total score of 6 was achieved; hence a medium exchange was recommended. The second stage evaluated the effect of location and surroundings of the interchange. The stadium station is located around Meskel Square which is a busy city section and this gives a positive value indicating need for upgrades. The station is a major point of access to a banks, schools and recreational activities (shopping, restaurants and hotels), a positive value for surroundings indicating that there are strong supporting activities. From interviewing transit organizations, a city integration plan exists, whilst the interchange plan was at a development stage. The project was to be spearheaded by the Ministry of Transport and Addis Ababa City Administration Transportation Bureau. This equated to a neutral value, translating to an overall value of +6 indicating the need of a medium interchange (Monzón, Hernández & Di Ciommo, 2016). Option B ensured effective utilization of space. A partially integrated interchange was recommended for the investigated parameters and the proposed interchange layout is shown in Figure 12.

.

6. CONCLUSION

In conclusion, the research paper delved into integration of transit modes at Addis Ababa's LRT stadium station, to address the city's evolving transit needs amidst growing population. The study identified the lack of modal integration at the stadium station as a daily challenge for commuters, necessitating a focused assessment on the transit environment to enhance integrated mobility. Through utilization of microsimulation modeling on AIMSUN Next with the social force model, the study evaluated three options alongside the existing transit system based on transfer times, distances, and space availability. Results indicated that Option B, with an index value of 0.32, optimized transfer distances and times, thereby improving passenger circulation and achieving acceptable Levels of Service. Hence, Option B was recommended for its practicality and consideration of future demand, emphasizing the need for further research on integrated ticketing systems and mode integration at the network level. By narrowing the research scope to transfer times, distances, and waiting spaces, the study provided valuable insights into improving passenger transit efficiency and urban mobility in Addis Ababa. The proposed transit setup aimed to address the challenges posed by the city's growing population while enhancing the overall quality of transit services. Ultimately, the study serves as a foundation for future urban transport planning, aiming to create more seamless and accessible transit experiences for Addis Ababa residents.

7. ACKNOWLEDGEMENTS

My sincerest gratitude goes to my academic supervisors, Doctor Yonas Emagnu and Mr. Biniyam Ayalew. I would also like to acknowledge the support of Hallelujah, Etsubdink and Doctor Rodgers Makwinja who aided me questionnaire structuring and distribution. I would like to also acknowledge Doctor Sara Hernandez, an established researcher in transport engineering, through here research work, development of this thesis was made easier. Special thanks go to AIMSUN for providing a platform for conducting simulation work. Special acknowledgement goes to ARCE, AALRT, ERC, Anbessa City Bus and AATAB for providing the critical information which was necessary for this study to be a success.

8. REFERENCES

Aklilu, A & Necha, T. 2018. Analysis of the Spatial Accessibility of Addis Ababa's Light Rail Transit: The Case of East-West Corridor, *Urban Rail Transit*, 4(1):35-48. Doi: 10.1007/s40864-018-0076-6.

Alodhaibi, SS *et al.* 2019. A model to simulate passenger flow congestion in airport environment, *International Journal of Engineering & Technology*, 7(4):6943-6946. Doi: 10.14419/ijet.v7i4.19417.

Brinckerhoff, P. 2013. *Transit Capacity and Quality of Service Manual, Third Edition*, *Transit Capacity and Quality of Service Manual, Third Edition*. doi: 10.17226/24766.

Conticelli, E *et al.* 2021. Assessing the performance of modal interchange for ensuring seamless and sustainable mobility in European cities, *Sustainability (Switzerland)*, 13(2):1-26. Doi: 10.3390/su13021001.

Cortés, CE, Burgos, V & Fernández, R. 2010. Modelling passengers, buses and stops in traffic microsimulation: Review and extensions, *Journal of Advanced Transportation*, 44(2):72-88. Doi: 10.1002/atr.110.

Desiderio, ND. 2004. Requirements of Users and Operators on the Design and Operation of Intermodal Interchanges, *Technishe Universitat Darmstadt, Fachgebiet Verkehrsplanung und Verkehrstechnik Durmisevic.* Available at: http://www.verkehr.tu-darmstadt.de/media/ verkehr/.

Enciso, J, Vargas, J & Martínez, P. 2016. Modeling and Simulation of Passenger Traffic in a National Airport, (July), pp. 20-22. Doi: 10.18687/laccei2016.1.1.217.

Ezana Haddis Weldeghebrael, B. 2021. Addis Ababa: City Scoping Study, (June).

Filipe, A & Ramos, F. 2015. Performance analysis of a public transport interchange from the pedestrian circulation perspective using microsimulation tools: The Colégio Militar case study, *Master Degree in Transport Planning and Operations*, pp. 1-11.

Hickman, R *et al.* 2015. Improving interchanges in China: The experiential phenomenon, *Journal of Transport Geography*, 42:175-186. Doi: 10.1016/j.jtrangeo.2014.12.004.

Liu, LF & Wang, W. 2016. Analysis of urban rail transit seamless transfer standard, *MATEC Web of Conferences*, 81. Doi: 10.1051/matecconf/20168103002.

Lois, D, Monzón, A & Hernández, S. 2018. Analysis of satisfaction factors at urban transport interchanges: Measuring travellers' attitudes to information, security and waiting, *Transport Policy*, 67:49-56. April. Doi: 10.1016/j.tranpol.2017.04.004.

Lucietti, L, Hoogendoorn, C & Cré, I. 2016. New Tools and Strategies for Design and Operation of Urban Transport Interchanges, *Transportation Research Procedia*, 14:1240-1249. Doi: 10.1016/j.trpro.2016.05.195.

Monzón, A, Hernández, S & Di Ciommo, F. 2016. Efficient Urban Interchanges: The City-HUB Model, *Transportation Research Procedia*, 14:1124-1133.
Doi: 10.1016/j.trpro.2016.05.183.

Rifai, AI. 2021. Analysis of Pedestrian Services in Metropolitan CitiesCase of Jakarta Business Area, pp. 647-653.

Sanders, G *et al.* 2021. Agent-Based Modelling and Simulation of Airport Terminal Operations Under COVID-19-Related Restrictions, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 12946 LNAI(March 2020), pp. 214-228. Doi: 10.1007/978-3-030-85739-4_18.

Solecka, K, Nosal Hoy, K & Deryło, A. 2020. Assessment of transport interchanges for the needs of people with reduced mobility, *Travel Behaviour and Society*, 21(May), pp. 48-56. Doi: 10.1016/j.tbs.2020.05.004.

Soltész, T *et al.* 2017. PFS method for pedestrian origin-destination surveys of enclosed areas, *Transportation Research Procedia*, 27:680-687. Doi: 10.1016/j.trpro.2017.12.082.

Tilahum, RA. 2017. Evaluation of the transportation system for disables versus policy implementation.

Turnbull, R & O'higgins, T. 2013. Public Transport Interchange Design Guidelines Public Transport Interchange Design Guidelines 2013 Quality Assurance Statement, *Public Transport Interchange Design Guidelines*, (February), pp. 1-55.