Project Notes:

Project Title:
Name: Aansh Patel

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
How do you simulate peoples movements	Reading papers	All throughout my article summaries	10/5/24
How do you simulate multiple lines	Reading article 2	In the summary for article 2	9/13/24
How do you find the optimal amount for different variables	Reading article 7 and 8	In the summary for articles 7 and 8	9/28/24
How do you test how optimized your simulation is	Reading article 10	In the summary for article 10	10/5/24
How do you test how much usage the lines are actually getting	Reading article 3	In the summary for article 3	9/15/24
Best software to use for simulations			

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Science direct	Metro simulation	I was able to find the first article
Google patents	Subway Simulation (Lang = EN)	I found my patents (Article 11 + 12)

Tags:

Tag Name	
Efficiency	Computing Systems
Data	ML
Simulation	Dynamic systems
Capacity	Optimizations

Article #0 Notes: Title

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

Article #1 Notes: Valuation of passenger satisfaction of urban multi-mode public transport

Article notes should be on separate sheets

Source Title	valuation of passenger satisfaction of urban multi-mode public transport
Source citation (APA Format)	Zhang, X., Liu, H., Xu, M., Mao, C., Shi, J., Meng, G., & Wu, J. (2020). Evaluation of passenger satisfaction of urban multi-mode public transport. *PLoS ONE*, *15*(10), e0241004. http://dx.doi.org.ezpv7-web-p-u01.wpi.edu/10.1371/journal.pone.0241004
Original URL	https://go-gale-com.ezpv7-web-p-u01.wpi.edu/ps/retrieve.do?tabID=T002&resultListType=RESULT_LIST&searchResultsType=SingleTab&retrievalId=d52cdfe8-18c0-48b0-a967-f9b181510d38&hitCount=20812&searchType=BasicSearchForm&currentPosition=15&docId=GALE%7CA638966564&docType=Report&sort=Relevance&contentSegment=ZONE-MOD1&prodId=AONE&pageNum=1&contentSet=GALE%7CA638966564&searchId=R1&userGroupName=mlin_c_worpoly&inPS=true&aty=ip
Source type	Report
Keywords	Public transit, Efficiency, Organization
#Tags	#Efficency #Data
Summary of key points + notes (include methodology)	When improving public transport, a clear way to get an idea of how to improve and where to improve is by getting ratings of different transit by the people riding it, however this is sometimes difficult as there are lots of variables outside of the ride that impacts how someone perceives the quality of something. Here the scientists aimed to solve this by using multiple methods including the analytic hierarchy process (AHP), entropy weight method (EWM) and fuzzy comprehensive evaluation(FCE) method, all of which helped remove biases in the human surveys. When all the numbers were crunched, a total of over 5,000 ratings were used to analyze the transit of Ningbo city; they were able to conclude that the rail transit was marginally more satisfactory than the bus transit, however they both were within 5 points of each other.
Research Question/Problem/ Need	What are good ways to determine the quality of the riding experience on different forms of transport.
Important Figures	"Ningbo city is calculated to be 89.27, which includes the satisfaction of

	conventional bus transit at 88.32 and the rail transit at 92.10.”
VOCAB: (w/definition)	AHP - A systematic approach for structuring and analyzing complex decisions, grounded in mathematics and psychology. EWM - This method establishes the relative significance of attributes and their relationship to the evaluation or final outcome. FCE - A comprehensive assessment method based on fuzzy mathematics, known for producing practical and reliable results, making it widely applicable in fields like petroleum and construction.
Cited references to follow up on	Zadeh LA. Fuzzy sets. Information and Control. 1965; 8(3):38-53. Saaty TL. The analytic hierarchy process. McGraw Hill. New York. 1980; 71-83. Ding X. W., Chong X., Bao Z. F., Xue Y., and Zhang S. H. Fuzzy comprehensive assessment method based on the entropy weight method and its application in the water environmental safety evaluation of the heshangshan drinking water source area. Three Gorges Reservoir Area. 2017; 9:15.
Follow up Questions	1) Why was rail transit more satisfactory than bus transit? 2) What demographics typically use the public transport in NingBo city? 3) What do the satisfaction points exactly mean in context, how would they stack up against Boston or New York public transit?

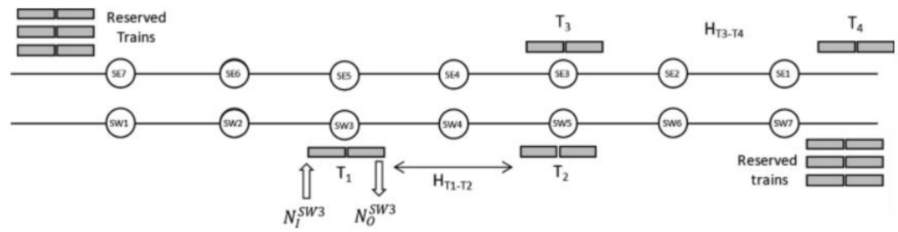
Article #2 Notes: Station Capacity Analysis of a Metro Line with Discrete Event Simulation

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Station Capacity Analysis of a Metro Line with Discrete Event Simulation**
Source citation (APA Format)	ıldırım, M.S., Aydın, M.M. (2022). Station Capacity Analysis of a Metro Line with Discrete Event Simulation. In: Prentkovskis, O., Yatskiv (Jackiva), I., Skačkauskas, P., Junevičius, R., Maruschak, P. (eds) TRANSBALTICA XII: Transportation Science and Technology. TRANSBALTICA 2021. Lecture Notes in Intelligent Transportation and Infrastructure. Springer, Cham. https://doi.org/10.1007/978-3-030-94774-3_67
Original URL	https://link.springer.com/chapter/10.1007/978-3-030-94774-3_67

Source type	Conference paper
Keywords	Station capacity discrete event Metro line Train Simulation
#Tags	#simulaton #Capacity #Data
Summary of key points + notes (include methodology)	While there are many studies analyzing discrete event simulations of metro lines, they often create their own metros. This aims to test the capacity of an existing metro line. They used Arena 14.0 simulation software to create the model, who's purpose was the simulate passenger movements, including queuing, transferring, and other movements. They assumed the hourly passenger rate was constant, they assumed all the passengers would get off and on, and the percentages of the passenger from origin were the same. They used "blocks" to describe how the train moves, they had a create block for headways, they used signal and search blocks to model the loading and unloading of passengers and a leaving block for the trains departing. They used a probability matrix to determine how many passengers would get off at each station. They compared the stations max capacity by using 2 variables, the amount of people waiting, and the amount of people still waiting after a train came because the train reached max capacity. They used an 18-hour operational period and have morning and evening rushes. They also validated the model completely; however, they didn't fully explain how they validated everything. They checked the stochastic variables and constants. They then tested for varying headways times and varying amount of people per station. Across the board the number of people waiting increased, however stations 1&8 suffered the most, with almost a 7.2-time increase. Increasing headways slightly had a large impact on the passengers waiting. The probability matrix was also incredibly important and small shifts had large impacts.
Research Question/Problem/ Need	Can we use simulations to determine how station capacities fluxuate?

Important Figures	**Fig. 1.**  MSM layout and stations.
VOCAB: (w/definition)	OD probability matrix – A square matrix where each next step represents the probability of something occurring, each row adding up to 100
Cited references to follow up on	Motraghi, A., Marinov, M.V.: Analysis of urban freight by rail using event based simulation. Simul. Model. Pract. Theory **25**, 73–89 (2012) Singhania, V., Marinov, M.: An event-based simulation model for analysing the utilization levels of a railway line in urban area. PROMET-Traffic Transp. **29**(5), 521–528 (2017)
Follow up Questions	What would happen if the passenger rate wasn't constant every hour? What would happen if some stops were more popular than others? What if you expanded this to 2 metro lines, how would the simulation handle cocnoursing?

Article #3 Notes: An event-based simulation model for analyzing the utilization levels of a railway line in urban area

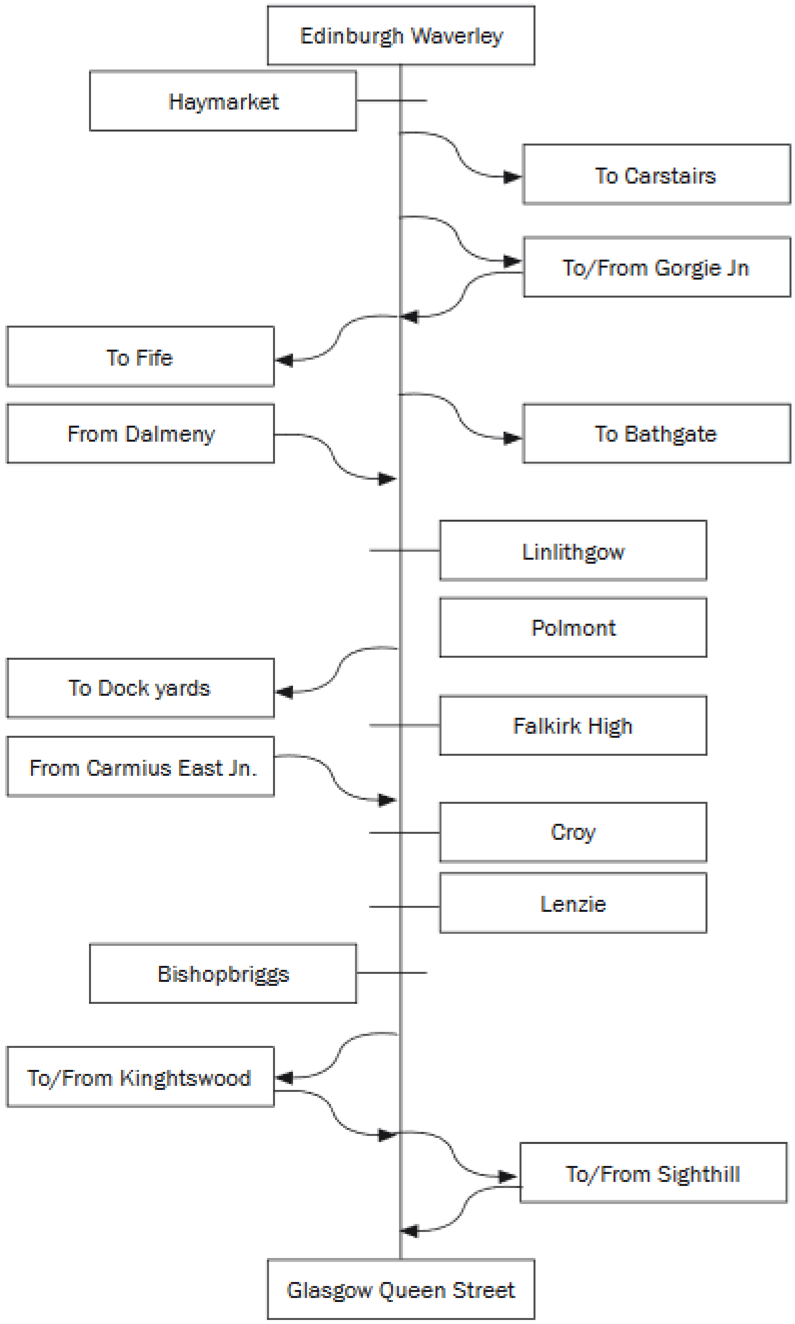
Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	AN EVENT-BASED SIMULATION MODEL FOR ANALYSING THE UTILIZATION LEVELS OF A RAILWAY LINE IN URBAN AREA
Source citation (APA Format)	Singhania, V., & Marinov, M. (2017). An Event-based Simulation Model for Analysing the Utilization Levels of a Railway Line in Urban Area. *Promet - Traffic&Transportation*, *29*(5), 521-528. https://doi.org/10.7307/ptt.v29i5.2306
Original URL	https://traffic.fpz.hr/index.php/PROMTT/article/view/2306
Source type	paper
Keywords	rail line, rail freight, passenger trains, freight trains, urban area, simulation,

	utilization,
#Tags	#simulation #Data #capacity
Summary of key points + notes (include methodology)	Due to an increase in the demand for freight trains in the UK to transport oil and coal, there's a need to see if the infrastructure can handle it. This paper aims to see if the capacity for these rail networks is reaching max, and if so, what needs to be improved. They used SIMLUAT8 to make a simulation of the Edinburgh Waverly – Glasgow Queen street line. They collected data and then identified potential gaps in the system where freight trains are fed. They then plan to make the most accurate model they can so they can then test it. They used decomposition to study the train movements in the line and broke the track down into segments. Each segment was roughly 1.6 km, which is already defined as a block, which is a trains stopping distance given they stop at a reasonable pace. They used a block system and visual logic to indicate the travel times for trains along with their pace and how far they've travelled. Passenger trains also use the rail system, and they found that freight trains take 1.5 times the amount of time passenger trains take. They found that the usage was only 49.8%, and adding 1 more train only raised it to 54.0%. They were able to conclude the freight train railways weren't nearly maxed out, and many trains could be added. This includes passenger trains, which there are currently 4 per hour, and this could be improved.
Research Question/Problem/ Need	Could a simulation be used to figure out if a rail network could benefit by more trains being on it?

Important Figures



igure 1 – Graphical represenation of the junctions along the rail line in study

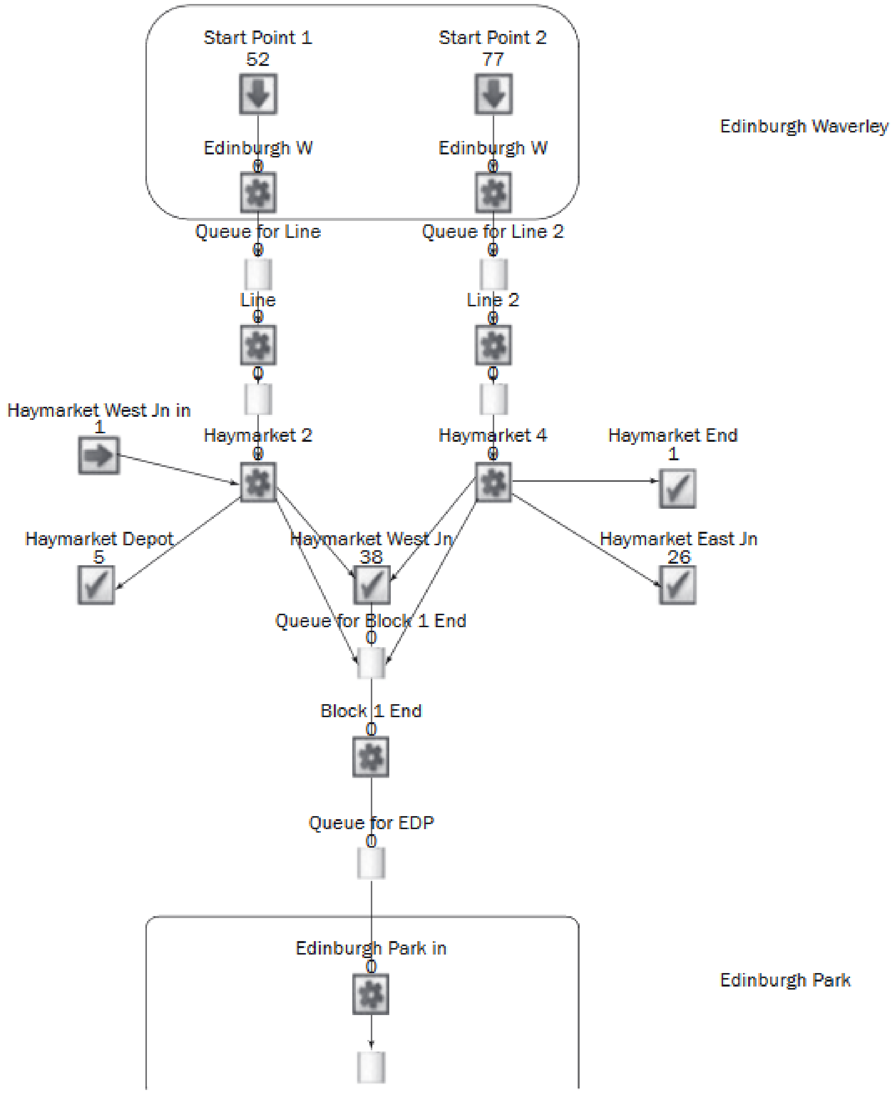


Figure 2 – A screenshot representing a part of the rail network in SIMUL8 environment

VOCAB: (w/definition)	Generators – entry points of simulations Work centers – server clients for the simulation Visual logic – the adding and removing of trains in the system
Cited references to follow up on	Dessouky M, Leachman R. A Simulation Modeling Methodology for Analyzing Large Complex Rail Net-works. Simulation. 1995;65(2):131-142. Marinov M, Viegas J. A Mesoscopic Simulation Model ling Methodology for Analyzing and Evaluating Freight Train Operations in a Rail Network. Simulation Model ling Practice and Theory. 2011;19: 516-53

Follow up Questions	Why were the passenger trains so much faster? What could be the causes of the rails being so underutilized? How did the simulation handle the merge between liens 1 and 2?

Article #4 Notes: Modeling and optimization of average travel time for a metro line by simulation and response surface methodology

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Modelling and optimization of average travel time for a metro line by simulation and response surface methodology**
Source citation (APA Format)	Özgür Yalçınkaya, G. Mirac Bayhan, Modelling and optimization of average travel time for a metro line by simulation and response surface methodology, European Journal of Operational Research, Volume 196, Issue 1, 2009, Pages 225-233, ISSN 0377-2217, https://doi.org/10.1016/j.ejor.2008.03.010. (https://www.sciencedirect.com/science/article/pii/S0377221708002853)
Original URL	https://doi.org/10.1016/j.ejor.2008.03.010
Source type	paper
Keywords	Average passenger travel time Optimization Simulation Metamodel Response surface methodology The Derringer–Suich optimization procedure
#Tags	#Data #simulation #optimization #Capacity
Summary of key points + notes (include methodology)	Changing headways (time between trains) results in trains holding less people, and people getting to places faster, the first is bad but the second is good.

	They use discrete-event simulation and response surface methodology They broke the problem up into weekday and weekend and morning and evening, for 4 groups. They used random numbers for the interval time, # of passengers and repair times. They used RSM to find a relationship between the controllable inputs and the desired outputs. The first phase is when the author assumes it's linear, hence the first big equation. The second equation they used to model the data is a quadratic. The DSMR is then used is then used to find the optimal headway. They also used real data got from a questionnaire to determine the probability people leave at each station. They used math models to show the relationship between average travel time, carriage fullness and time between trains. They are both better from the consumer POV, but the first is bad for the company. They use response surface methodology because it allows for less number simulations to analyze the data. They then took the data and calculated an average train fullness along with average travel time for many different numbers.
Research Question/Problem/ Need	How do we find the optimum headway for a metro line?
Important Figures	$y_{kl} = \beta_0 + \sum_i \beta_i x_i + \sum_j \sum_i \beta_{ij} x_i x_j + \varepsilon_{kl}, \quad kl = 1, 2, \qquad (1)$ $y_{kl} = \beta_0 + \sum_i (\beta_i x_i + \beta_{ii} x_i^2) + \sum_j \sum_i \beta_{ij} x_i x_j + \varepsilon_{kl} \; kl = 1, 2. \qquad (2)$

Ö. Yalçınkaya, G. Mirac Bayhan / European Journal of Operational Research 196 (2009) 225–233

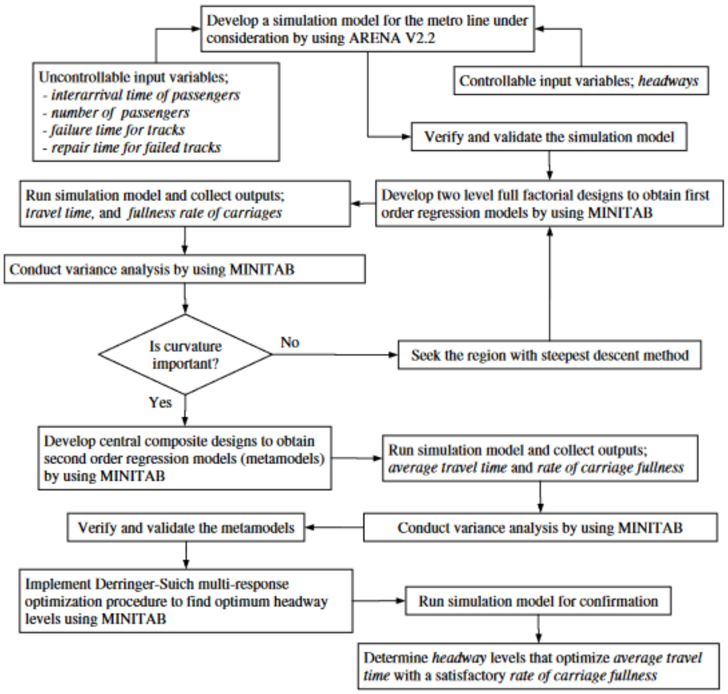


Fig. 1. Flowchart of the proposed procedure.

Table 3
Low and high level of input factors (headways) for two-level full factorial designs

Problem name	Input factor (headway)	For time period	Low level (coded value − 1) natural value (in second)	High level (coded value + 1) natural value (in second)
WMP	X_1	06:00–07:00	300	600
	X_2	07:00–07:30	300	600
	X_3	07:30–09:00	300	600
	X_4	09:00–09:30	300	600
	X_5	09:30–11:30	300	600
WAP	X_1	11:30–17:00	300	600
	X_2	17:00–18:30	300	600
	X_3	18:30–19:00	300	600
	X_4	19:00–22:00	300	600
	X_5	22:00–24:00	600	900
STP	X_1	06:00–11:00	300	600
	X_2	11:00–19:00	300	600
	X_3	19:00–22:00	300	600
	X_4	22:00–24:00	600	900
SNP	X_1	06:00–09:00	600	900
	X_2	09:00–20:00	600	900
	X_3	20:00–24:00	600	900

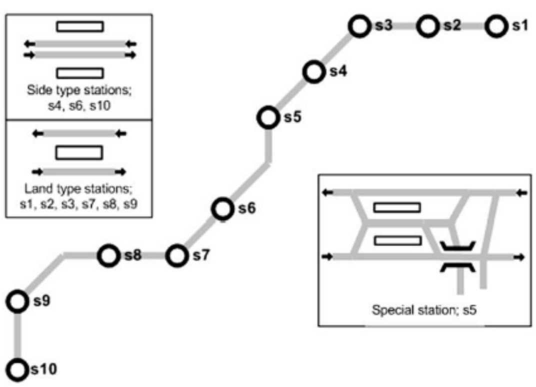


Fig. 2. Line-station diagram of the metro line (single corridor network).

VOCAB: Discrete event simulation – simulating multiple events that don't have an impact on each other

(w/definition)	and end at a set point. Responsive surface methodology – a methodology that uses limited data to make conclusions about data without having tons of trials on said data, very useful if the data has some relationship to model said relationship.
Cited references to follow up on	Wânderson O. Assis, Basílio E.A. Milani, Generation of optimal schedules for metro lines using model predictive control, Automatica, Volume 40, Issue 8, 2004, Pages 1397-1404, ISSN 0005-1098, https://doi.org/10.1016/j.automatica.2004.02.021. (https://www.sciencedirect.com/science/article/pii/S0005109804000755) J.F. Guan, Hai Yang, S.C. Wirasinghe, Simultaneous optimization of transit line configuration and passenger line assignment, Transportation Research Part B: Methodological, Volume 40, Issue 10, 2006, Pages 885-902, ISSN 0191-2615, https://doi.org/10.1016/j.trb.2005.12.003. (https://www.sciencedirect.com/science/article/pii/S0191261506000154)
Follow up Questions	How did they program the concourse on station 5? How exactly does RSM work? How did they arrive at the equations in figures 1&2?

Article #5 Notes: Formulation of the Transit Link Transmission Model

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	Formulation of the Transit Link Transmission Model
Source citation (APA Format)	Gentile, G. (2017). Formulation of the Transit Link Transmission Model. *20th EURO Working Group on Transportation Meeting, EWGT 2017, 4-6 September 2017, Budapest, Hungary*, *27*, 889–896. https://doi.org/10.1016/j.trpro.2017.12.105
Original URL	https://doi.org/10.1016/j.trpro.2017.12.105

Source type	paper
Keywords	dynamic network loading; public transport network; vehicle capacity constraints, passenger queue at stop; schedule based assignment
#Tags	#simulation #capacity #Data
Summary of key points + notes (include methodology)	They took a piece of land and made a bunch of zones. Each zone has its own distinct socioeconomic activities (not specified) and each zone has a centroid point, which is basically the travel hub. Then some demand is given to each piece of land, and it changes based on the time. They also represent passengers as little particles of a compressible fluid. Public transit info is preestablished (Lines, connections, stop capacity). Arcs are drawn between each centroid. There are also 3 types of arcs, seated, standing, and vehicles (carriers operating the line) and the amount of people on a given train is split between the 3 arcs because the liquid model can't show the difference between standing and sitting. It also assumes people will prioritize sitting. The arcs are meant to show each step of the journey (walking to the station, waiting at the station, getting on the first train, etc). Also the LTM can handle a time-table based public transit system and a frequency based system.
Research Question/Problem/ Need	How could we simulate congestion in simulation systems.
Important Figures	*Guido Gentile / Transportation Research Procedia 27 (2017) 889–896* 893 $\rho_a = Min\left(1, \frac{\hat{g}_b}{\sum_{c \in A_i^-} \hat{h}_c \cdot p_{cb}} : b \in A_i^+, p_{ab} > 0\right) \quad , a \in A_i^-$ $\quad q_{ab} = \hat{h}_a \cdot p_{ab} \cdot \rho_a \quad , a \in A_i^-, b \in A_i^+$; $e_a = \sum_{b \in A_i^+} q_{ab} \quad , a = A_i^-$; $f_b = \sum_{a \in A_i^-} q_{ab} \quad , b = A_i^+$ (3) The above model (5) implicitly assumes no conflicting maneuvers and that the receiving flow g_b of each outgoing arc $b \in A_i^+$ is partitioned among the incoming arcs $a \in A_i^-$ proportionally to the sending flows $\hat{h}_a \cdot p_{ab}$. Then, for each arc $a \in A$, the cumulative entry flow F_{at} and the cumulative exit flow E_{at} at time $t \in T$ can be updated as follows: $F_{at} = F_{at-1} + f_{at} \quad , \quad E_{at} = E_{at-1} + e_{at}$. (4)
VOCAB: (w/definition)	Arc- a connection between nodes Nodes – a data point representative of the space around it Kinematic Wave Theory – an area of physics that deals with liquids and such moving through tubes LTM – link transmission model, which is a way to move things through links in a chain that goes from point A to point B (like subway stops).
Cited references to follow up on	Guido Gentile, Using the General Link Transmission Model in a Dynamic Traffic Assignment to Simulate Congestion on Urban Networks, Transportation Research Procedia, Volume 5, 2015, Pages 66-81, ISSN 2352-1465,

	https://doi.org/10.1016/j.trpro.2015.01.011. Fabien Leurent, Ektoras Chandakas, Alexis Poulhès, A Passenger Traffic Assignment Model with Capacity Constraints for Transit Networks, Procedia - Social and Behavioral Sciences, Volume 54, 2012, Pages 772-784, ISSN 1877-0428, https://doi.org/10.1016/j.sbspro.2012.09.794.
Follow up Questions	How did they compare it to other systems? How did they process all the variables? How did exactly did they model the lunch rush and stuff? What was the math behind how the arcs operated?

Article #6 Notes: Using the General Link Transmission Model in a Dynamic Traffic Assignment to Simulate Congestion on Urban Networks

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Using the General Link Transmission Model in a Dynamic Traffic Assignment to Simulate Congestion on Urban Networks**
Source citation (APA Format)	Guido Gentile, Using the General Link Transmission Model in a Dynamic Traffic Assignment to Simulate Congestion on Urban Networks, Transportation Research Procedia, Volume 5, 2015, Pages 66-81, ISSN 2352-1465, https://doi.org/10.1016/j.trpro.2015.01.011.
Original URL	https://www.sciencedirect.com/science/article/pii/S2352146515000125
Source type	Journal paper
Keywords	Dynamic User Equilibrium Dynamic Network Loading Theory of Kinematic Wave time discretization algorithm convercence macroscopic flow models queue spillback Intelligent Transport Systems

	traffic forecast.
#Tags	#simulation #dynamicSystems #optimization
Summary of key points + notes (include methodology)	Shows 2 models that are suited for ITS. Modern congestion models have static kind of "move slower" but the new flexible models allow for spillback and the congestion affecting more parts of the system. Dynamic traffic assignment is still hard to do. Models either have to sacrifice realism on the supply side (point-queue models, no spillback congestion) or on the demand side (instantaneous shortest paths). Someone leaving a node make a choice to go to a specific arc and the time will be evaluated for each person. They are either calculated by the flow propagation model that is consistent with he drivers behavior but not congestion phenomena, or the network congestion model with is consistent with congestion phenomena, but not drivers behavior. These are used in equilibrium with each other. They used GLTM to simulate it. The specific model looked at the overall flow of traffic, not induvial cars, and used the kinematic wave function to describe it. The model had 2 waves, the hypocritical and hyper critical waves, which represented the traffic free flow speeds and conjected traffic respectively. It then processes the traffic at each node at a set time interval, and divides the time in temporal layers. However this means that no waves can go faster than the simulation speed so traffic doesn't jump from one node to another. The second method uses time intervals of a few minutes for modeling he traffic flow which allows for more data to be used. It uses internal iterations to change the flow on the supply side to show the effects of congestion. It considers the flow of the roads along with bottlenecks for travel times. It is constantly adjusting to make it so the amount of people going into an arc is the same going out of an arc. Both models work and have very similar times. The first approach is more resource intensive, but it doesn't always reach an equilibrium making it more accurate.
Research Question/Problem/ Need	How can we better simulate congestion?

Important Figures

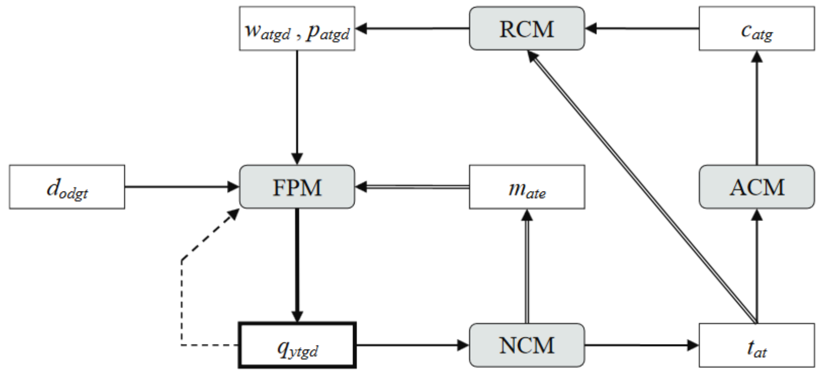


Figure 1. Schema of the DTA model and algorithm. The dashed arrow indicates that the iterate variable is used in the next iteration. The thick arrow recalls that an algorithmic transformation of the iterate (e.g. through MSA or Gradient Projection) is required to provide a descent direction for the convergence of the equilibrium as a fixed-point problem.

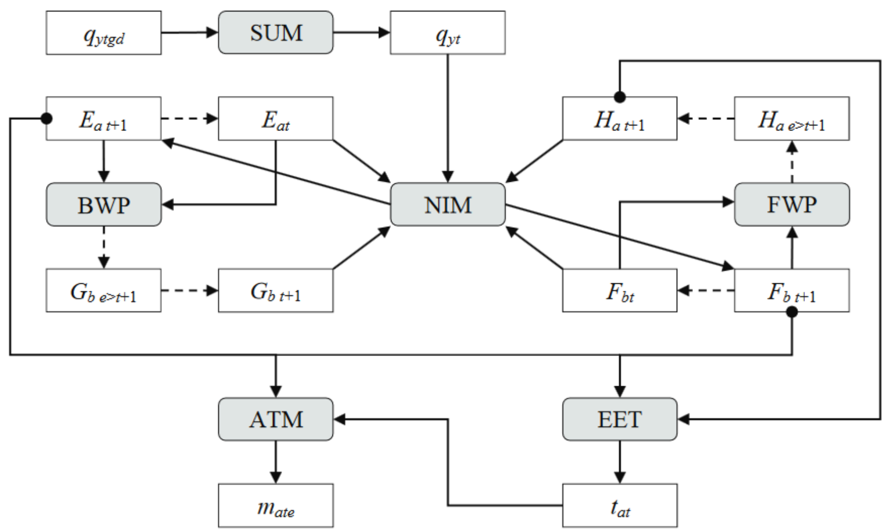


Figure 2. Schema of the simulation algorithm based on the GLTM for a given time interval. Rounded boxes are functions, while sharp boxes are variables. The dashed arrows indicate a relation between different temporal layers. The arrow with initial bullet indicate a relation that involves the entire temporal profile of a variable.

Notation of the GLTM

q_{yt} equivalent flow (volume) passing through turn $y \in Y$ during time interval $[\tau_t , \tau_{t+1})$ with $t \in T$
F_{at} cumulative inflow of arc $a \in A$ at time τ_t , with $t \in T$
E_{at} cumulative outflow of arc $a \in A$ at time τ_t , with $t \in T$
G_{at} cumulative receiving flow of arc $a \in A$ at time τ_t , with $t \in T$
H_{at} cumulative sending flow of arc $a \in A$ at time τ_t , with $t \in T$

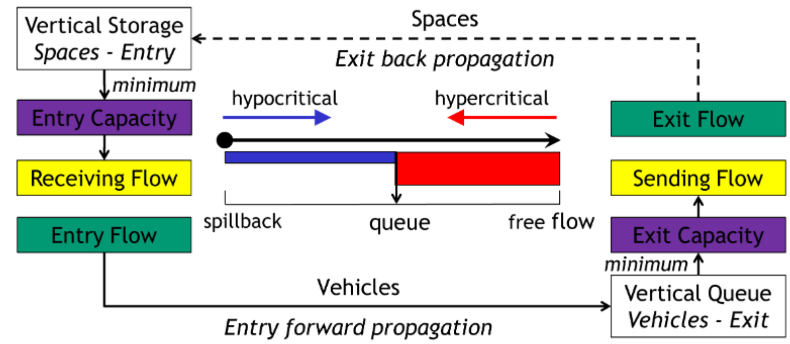


Figure 3. Link model. Forward propagation of entry flows and backward propagation of exit flows (spaces) through Newell's solution of Kinematic Wave Theory based on cumulative flows.

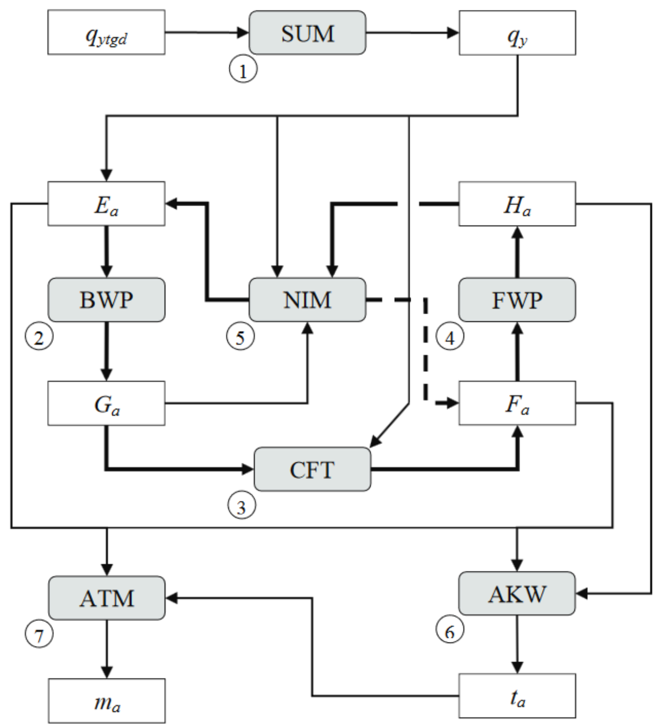


Figure 7. Schema of the NCM model with functional approach. The circled numbers indicate the sub-models sequence. The sub-sequence 2-3-4-5 forms a cycle that identifies a fixed point problem.

flow	0	60	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960
1	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
2	750	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
3	600	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
4	450	900	900	900	900	900	900	900	900	900	900	900	900	750	400	400	400
5	300	900	900	900	900	900	900	900	900	633	400	400	400	400	400	400	400
6	150	900	900	900	900	517	400	400	400	400	400	400	400	400	400	400	400
7	0	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400

flow	1020	1080	1140	1200	1260	1320	1380	1440	1500	1560	1620	1680	1740	1800	1860	1920	1980
1	900	900	900	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	900	900	900	150	0	0	0	0	0	0	0	0	0	0	0	0	0
3	867	400	400	400	400	400	153	0	0	0	0	0	0	0	0	0	0
4	400	400	400	400	400	400	400	400	400	400	400	400	0	0	0	0	0
5	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
6	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
7	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400

flow	2040	2100	2160	2220	2280	2340	2400	2460	2520	2580	2640	2700	2760	2820	2880	2940	3000
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	267	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	400	400	400	400	400	400	133	0	0	0	0	0	0	0	0	0	0
7	400	400	400	400	400	400	400	400	400	400	400	400	0	0	0	0	0

time	0	60	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960
1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	45	120	195
4	10	10	10	10	10	10	10	10	10	10	62	137	212	287	340	340	340
5	10	10	10	10	10	10	80	155	230	305	340	340	340	340	340	340	340
6	10	22	97	172	247	322	340	340	340	340	340	340	340	340	340	340	340
7	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

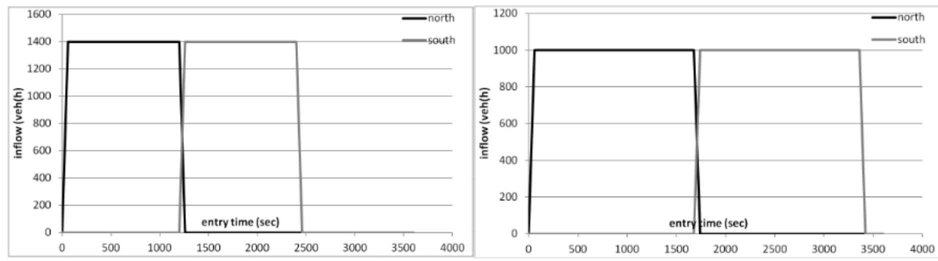
time	1020	1080	1140	1200	1260	1320	1380	1440	1500	1560	1620	1680	1740	1800	1860	1920	1980
1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10	27	102	177	140	80	20	10	10	10	10	10	10	10	10	10	10
3	270	340	340	340	340	340	340	300	240	180	120	60	10	10	10	10	10
4	340	340	340	340	340	340	340	340	340	340	340	340	340	280	220	160	100
5	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340
6	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340
7	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

time	2040	2100	2160	2220	2280	2340	2400	2460	2520	2580	2640	2700	2760	2820	2880	2940	3000
1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
4	40	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
5	340	320	260	200	140	80	20	10	10	10	10	10	10	10	10	10	10
6	340	340	340	340	340	340	340	300	240	180	120	60	10	10	10	10	10
7	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

r_u	0	60	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960
1	95	145	220	294	366	440	520	595	668	741	820	895	969	1042	1120	1195	1270

r_u	1020	1080	1140	1200	1260	1320	1380	1440	1500	1560	1620	1680	1740	1800	1860	1920	1980
1	1344	1420	1493	1534	1479	1419	1361	1308	1248	1188	1128	1068	1008	948	888	828	768

r_u	2040	2100	2160	2220	2280	2340	2400	2460	2520	2580	2640	2700	2760	2820	2880	2940	3000
1	712	657	597	537	477	418	364	310	250	191	134	90	70	70	70	70	70

	 Figure 9. Inflows of the North and South bounds resulting after the first (left picture) and second (right picture) teration.
VOCAB: (w/definition)	Functional approach – Take what all the factors mean and only focus on that Simulated approach – Abstract almost every factor to create an accurate model of an event Forward propagation – A calculation that occurs when something hits a node
Cited references to follow up on	Barcelo J., 2010. Fundamentals of Traffic Simulation, Springer, New York, USA, Pallottino S., Scutellà M.G., 1998. Shortest path algorithms in transportation models: classical and innovative aspects. Equilibrium and advanced transportation modelling, ed.s P. Marcotte, S. Nguyen, Kluwer Academic Publisher, Dordrecht, The Netherlands, pp. 245-281
Follow up Questions	How does the kinematic wave function tie into all of this? How did decide which sub model to use? Since they treated the people as a fluid, why did they use wave functions and not fluid dynamics?

Article #7 Notes: Generation of optimal schedules for metro lines using model predictive control

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Generation of optimal schedules for metro lines using model predictive control**
Source citation (APA Format)	Wânderson O. Assis, Basílio E.A. Milani, Generation of optimal schedules for metro lines using model predictive control, Automatica, Volume 40, Issue 8, 2004, Pages 1397-1404, ISSN 0005-1098, https://doi.org/10.1016/j.automatica.2004.02.021.
Original URL	https://www.sciencedirect.com/science/article/pii/S0005109804000755

Source type	Brief paper
Keywords	Traffic control; Optimal scheduling; Model predictive control; Linear programming
#Tags	#optimization #data #dynamic systems
Summary of key points + notes (include methodology)	They used a linear programming based model predicative control formula to compute optimal train schedules. The model has a bunch of dynamic equations that uses a variety of equations that is very efficient at developing schedules for entire days of operation. They then tested this on the north south line of the sao paulo underground. There was a model created by Cury et al in 1980 which used a similar idea, using linear programs to optimize train schedules. However due to limitations it was only able to generate a schedule of 15 trains at a time, along with assuming passenger demand is constant. The traffic model they used is comprised of 2 sets of dynamic equations which are for the headway and passenger load. They made a general dynamic model for the headway, in terms of dwell time and running time, and added it to a matrix which captures the relationship between consecutive headways. They made several of these equations and used them to minimize the performance index which is a combination of the passenger waiting times, deviation of passenger loads, train trip duration, and traffic smoothness. The result was the equation was mostly linear. This is what algorithm 1 is. Algorithm 1 can solve the boundary constrained schedule problem. This makes it useful for adapting the schedule during operation if something outside of the ordinary happened causing the normal schedule to not be as effective. Or create schedules for whole day operations, given the peak and off peak.
Research Question/Problem/ Need	Can we develop a model that given the amount of people during peak and off peak hours, along with the time of a train journey, and train size, can develop a schedule for the train, built of the foundations of the Cury et al (1980) paper?

<table>
<tr>
<td>Important Figures</td>
<td>

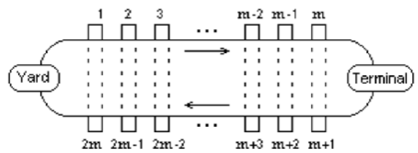


Fig. 1. Metro line.

2.1.2. Passenger load equations

The passenger load equations can be expressed as functions of passenger flows Cury et al., 1980:

$$p(k+1) = p(k) + \nabla(k+1)x(k+1) - \sum_{j=1}^{k} \Gamma(j,k+1)x(j), \quad (6)$$

$$p(k) \triangleq [p_1(k)\ p_2(k) \cdots p_n(k)]^{\mathrm{T}}, \quad (7)$$

$$\nabla(k) \triangleq diag(\alpha_1(k)\alpha_2(k) \cdots \alpha_n(k)), \quad (8)$$

$$\Gamma(j,k) \triangleq diag(\gamma_1(j,k) \cdots \gamma_n(j,k)), \quad (9)$$

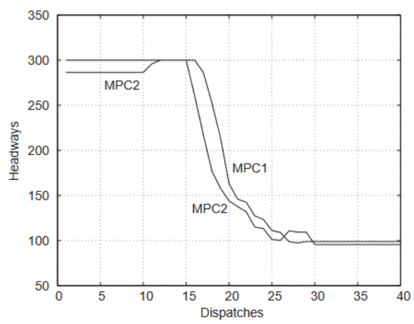


Fig. 3. Headway profiles at yard.

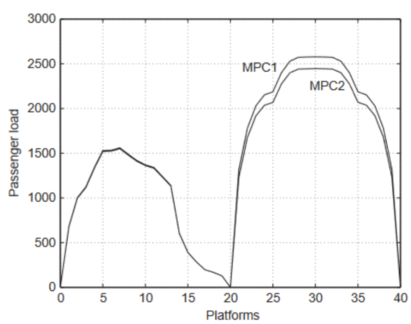


Fig. 4. Passenger load profiles of 20th train.

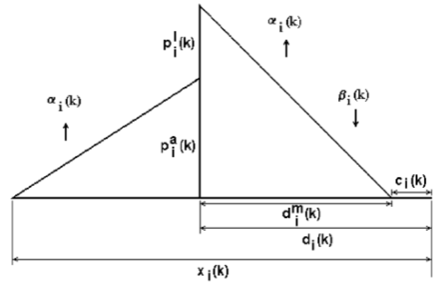


Fig. 2. Passenger flows at platform *k*.

traffic continuity at yard and terminal stations and train traffic smoothness at the platforms of the line.

2.2.1. Safety and operational limits

Safety circulation rules, track and train technical characteristics impose the following bounding type constraints:

$$\check{x}_i(k) \leqslant x_i(k) \leqslant \hat{x}_i(k), \quad \check{d}_i(k) \leqslant d_i(k) \leqslant \hat{d}_i(k), \quad (10)$$

$$\check{r}_i(k) \leqslant r_i(k) \leqslant \hat{r}_i(k), \quad 0 \leqslant p_i(k) \leqslant \hat{p}_i(k). \quad (11)$$

</td>
</tr>
<tr>
<td>VOCAB: (w/definition)</td>
<td>Iterative hierarchical multilevel decomposition method – A method that iterates through multiple versions that takes the data and decomposes it through different levels, each with their own decomposition algorithm</td>
</tr>
<tr>
<td>Cited references to follow up on</td>
<td>Cury, J., Gomide, F., & Mendes, M. (1980). A methodology for generation of optimal schedules for an underground railway system. IEEE Transactions on automatic control, 25(2), 217-222.</td>
</tr>
</table>

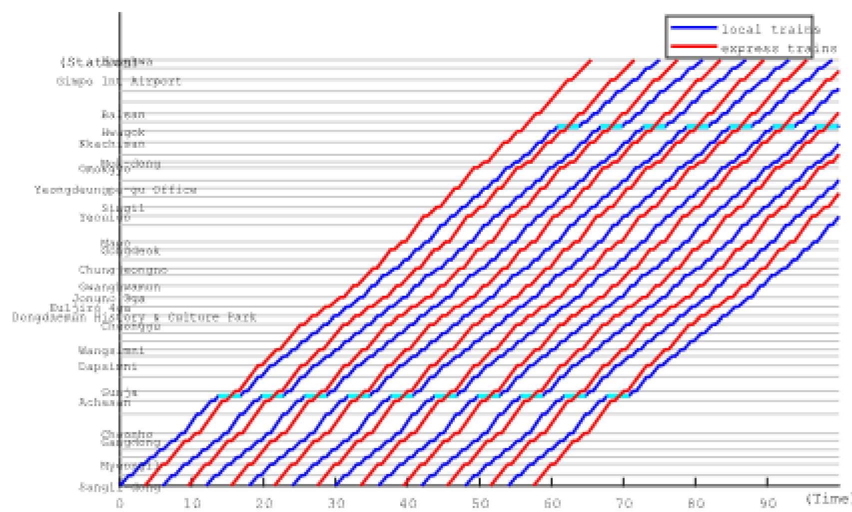
Follow up Questions	Why linear programming? Was there an advantage to treating the trains as vectors? How exactly did they encode the train data as a vector? How would the model deal with fluctuating demand?

Article #8 Notes: Implementation of a rapid metro system utilizing the existing infrastructures and high-performance trains

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Implementation of a rapid metro system utilizing the existing infrastructures and high-performance trains**
Source citation (APA Format)	Kyeongjun Ko, Jungtai Kim, Jaesung Hong, Moosun Kim, Implementation of a rapid metro system utilizing the existing infrastructures and high-performance trains, Alexandria Engineering Journal, Volume 106, 2024, Pages 217-226, ISSN 1110-0168, https://doi.org/10.1016/j.aej.2024.06.086.
Original URL	(https://www.sciencedirect.com/science/article/pii/S1110016824006999)
Source type	Journal article
Keywords	Rapid metro system Local train Express train Construction cost Acceleration/deceleration
#Tags	#simulation #optimization
Summary of key points + notes (include methodology)	In south Korea a lot of the infrastructure around the metro wasn't built with high speed rail in mind. Here they're proposing a way to adapt that line to high speed rail that doesn't involve building an entirely new system. They also talk about rail scheduling to prevent express trains and normal trains interfering with each other because they share tracks.

	The current most common version of this are trains that stop at every other station operating along side trains that stop at every station on the same line, which are increasingly becoming more common. The biggest factor when it comes to these express trains, is the acceleration. Most of the time the speed of a train is capped by the track itself, however having a good acceleration keeps the train at that max speed for longer. Considering how many times a train stops, a trains acceleration is a key part in determining the trains speed. They also found that the size of a trains doors played a big impact in the time the trains stays at a station, however they didn't use that in the simulation, and just assumed a flat decrease in the time spent at the station. They used matlab to simulate the optimal acceleration of each train (the trains can't be too fast because it will run into the trains ahead of it). They made 9 different simulations based upon the max speed of a train on different tracks. In conclusion, they developed a simulation which figured out the optimal acceleration for a train that skipped every other station, allowing for a decrease in time to get somewhere ranging from 10-26.5% with the only cost being new trains.
Research Question/Problem/ Need	Is there a way to decrease the time it takes for trains to travel without new infrastructure?
Important Figures	 **Fig. 4.** An example of train operation diagram for both express and local trains in Seoul Metro line no. 5.

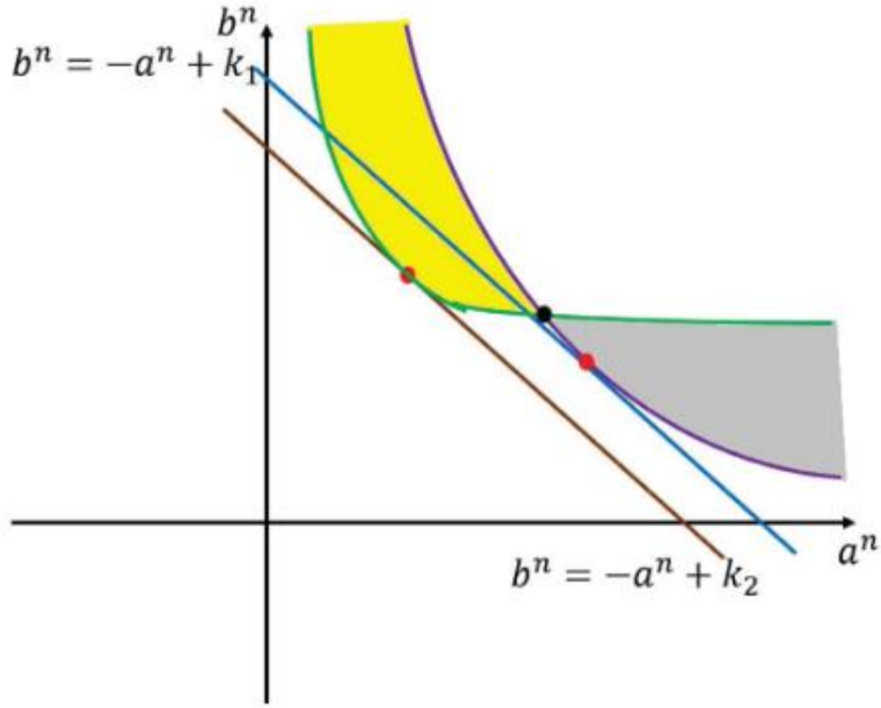


Fig. 6. An example of the optimal solution cases when $\min(M, M^Y) < \max(m, m^Y)$.

Table 2
Acceleration and Deceleration Values of a High-Performance Train by T_g in Downward Direction (Banghwa → Sangil-dong) of Seoul Metro Line no. 5. (acc: acceleration, dec: deceleration).

acc, dec \ T_g	30	40	50	60
a^n_m	4.4766	4.5654	4.6578	4.7540
a^n_M	4.9843	4.8817	4.6303	4.2445
b^n_m	4.6097	4.7011	4.7962	4.8953
b^n_M	5.1277	5.0222	4.7283	4.3344
$\tilde{a}^n$	−0.0408	−0.0659	2.0827	0.2942

VOCAB: (w/definition)

diffusion ratio of housing - The rate at which new houses are made in an area
side tracks – rails on the side of the tracks for emergency use

Cited references to follow up on

Kim, M. S., Kim, J., Kim, T., Park, S. S., Hong, J. S., Cho, Y. H., & Min, J. H. (2013) the metropolitan rapid transport system to minimize sidetrack construction. *Journal of Korean Society for railway*, *16*(5), 402-409.

Follow up Questions

How did they calculate many of the optimal solutions?
Would the slower trains ever just slow down the faster ones?
What do the cyan lines represent in Fig 4?

Article #9 Notes: Comparative analysis of nonlinear impacts on the built environment within station areas with different metro ridership segments

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Comparative analysis of nonlinear impacts on the built environment within station areas with different metro ridership segments**
Source citation (APA Format)	Jiandong Peng, Xinli Fu, Chengxi Wu, Qi Dai, Hong Yang, Comparative analysis of nonlinear impacts on the built environment within station areas with different metro ridership segments, Travel Behaviour and Society, Volume 38, 2025, 100898, ISSN 2214-367X, https://doi.org/10.1016/j.tbs.2024.100898.
Original URL	https://www.sciencedirect.com/science/article/pii/S2214367X24001613
Source type	Journal article
Keywords	Built environment Metro ridership segments Spatiotemporal heterogeneity Nonlinear effects Machine learning
#Tags	#data #optimization #ML
Summary of key points + notes (include methodology)	It's been accepted that there are 5 factors that influence ridership, density, design, diversity, distance to transit, and destination accessibility distance to transit is self explanatory destination accessibility is also self explanatory diversity means how diverse is the land use, people are likely to want to go to places where its part apartments, restaurants, parks, etc. than just miles of office buildings. density is how close people live to each other. The relationship between the build environment (how the stations are actually built) and ridership hasn't been researched enough, even though the relationship is complex and has nuanced nonlinear behavior. For example people use the metro for different reasons on weekdays and weekends so certain decisions made

	regarding design would attract one but detract the other. They wanted to investigate these relationships and decided to use gradient boosted decision trees to figure it out. However GBDT don't have the most significant test results, which is why they used a quantile regression model for most of the stronger linear relationships to help develop a stronger conclusion. It's been shown more road density leads to better accessibility by commuters. What they're doing is using the GBDT model to develop ideas and test them with the QR model. They used the GBDT model to generate up to 10,000 trees with a depth of 10 utilized, with a shrinkage parameter of .01. They then regressed the data with pseudo-r^2 values for a GOF test. They also tested separately for weekends and weekdays because the criteria for what is an important destination changes based on weekday or weekend (the office is super important to get to Monday, versus Saturday nobody wants to go). The biggest factor in the usage of a metro station is what it's around. The study as a success, however there were limitations. There was an 800 meter buffer zone. They also considered weekdays and weekends as a whole and didn't account time of day. Also there were smaller sample sizes than liked. However the usage of GBDT to develop trees and then to test how factual they are to prevent overfitting with a regression model did work well.
Research Question/Problem/ Need	Goals: (1) Does the association between the built environment and passenger flow in a metro station area vary according to the passenger flow segment? (2) What are the differences in the effects of the built environment on passenger flow on weekdays and weekends for subway stations with different traffic levels? (3) Which key built environment variables are more important for predicting subway passenger flow at stations with different levels of passenger flow, and what are the effective threshold ranges for their impacts on subway passenger flow at stations with different levels of passenger flow?

Important Figures

Table 4
Relative contributions of significant variables at different ridership quantiles.

	Weekday			Weekend		
	Variable	Rank	RI (%)	Variable	Rank	RI (%)
25th	Number of bus stops	1	45.7	Population density	1	44.5
	Population density	2	15.2	Number of sports facilities	2	19.6
	Number of sports facilities	3	13.7	Number of shopping mall	3	15.3
	Plot ratio	4	12.3	Number of science, educated and cultural facilities	4	10.6
	Number of science, educated and cultural facilities	5	10.6	Street density	5	10.0
	Street density	6	2.5			
50th	Street density	1	32.1	Land use mixture	1	31.8
	Population density	2	26.0	Street density	2	23.5
	Number of sports facilities	3	22.6	Number of shopping mall	3	19.2
	Number of bus stops	4	9.7	Population density	4	8.9
	Plot ratio	5	9.6	Number of tourist attraction	5	8.4
				Number of sports facilities	6	8.2
75th	Population density	1	29.3	Number of tourist attraction	1	43.3
	Number of bus stops	2	22.1	Number of bus stops	2	25.1
	Number of enterprises	3	17.3	Number of shopping mall	3	17.4
	Distance to city centre	4	13.2	Number of sports facilities	4	9.8
	Number of shopping mall	5	12.3	Land use mixture	5	4.0
	Number of sports facilities	6	5.5	Street density	6	0.4
	Street density	7	0.3			

Table 3
Result of QR of metro ridership.

Variable	Weekday metro ridership 25th Coef.	Weekday metro ridership 50th Coef.	Weekday metro ridership 75th Coef.	Weekend metro ridership 25th Coef.	Weekend metro ridership 50th Coef.	Weekend metro ridership 75th Coef.
Built environment features						
Population density	0.251***	0.246***	0.181***	0.161**	0.123**	0.0632
	(0.000)	(0.000)	(0.001)	(0.047)	(0.035)	(0.317)
Plot ratio	0.156**	0.105**	0.0247	0.101	0.070	0.010
	(0.015)	(0.049)	(0.620)	(0.184)	(0.197)	(0.868)
Land use mixture	−0.092	0.007	0.340	0.195	0.654**	0.781**
	(0.809)	(0.983)	(0.255)	(0.667)	(0.045)	(0.028)
Street density	−0.606**	−0.548***	1.154**	0.987**	−1.012***	0.025***
	(0.012)	(0.003)	(0.038)	(0.035)	(0.001)	(0.004)
Number of shopping mall	0.0256	0.0320	0.0978*	0.148*	0.145**	0.195***
	(0.699)	(0.562)	(0.059)	(0.060)	(0.011)	(0.002)
Number of enterprises	−0.944	−0.104	1.048**	−0.908	−0.164	1.072
	(0.545)	(0.204)	(0.031)	(0.643)	(0.985)	(0.302)
Number of tourist attractions	−1.037	0.079	0.958	−0.0263	0.139**	0.197***
	(0.427)	(0.997)	(0.427)	(0.744)	(0.017)	(0.002)
Number of science, educated and cultural facilities	0.127*	0.0928	0.0281	0.154*	0.050	−0.070
	(0.090)	(0.137)	(0.629)	(0.082)	(0.428)	(0.313)
Number of sports facilities	0.826***	0.285***	−1.112*	0.171**	0.904***	−1.074**
	(0.002)	(0.002)	(0.066)	(0.013)	(0.000)	(0.016)
Number of parking lots	0.956	−1.039	0.083	−0.218	−0.873	1.091
	(0.478)	(0.366)	(0.350)	(0.396)	(0.201)	(0.363)
Distance to city center	−0.0903	−0.0509	−0.152*	−0.097	−0.019	−0.142
	(0.413)	(0.580)	(0.078)	(0.458)	(0.842)	(0.164)
Number of bus stops	0.208*	0.202**	0.184**	0.194	0.137	0.202*
	(0.083)	(0.044)	(0.050)	(0.171)	(0.178)	(0.069)
R-squared	0.501	0.442	0.413	0.435	0.402	0.381

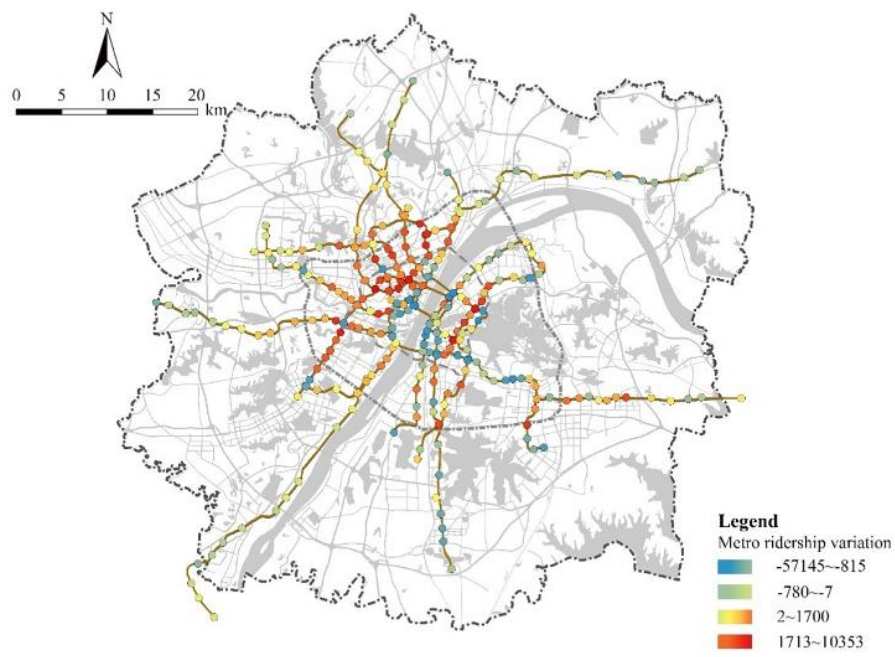


Fig. 4. Difference in metro ridership between weekdays and weekends.

VOCAB: (w/definition)	Built environment – The infrastructure surrounding a station that is immutable. Regression – Using different equations to map the correlation between 2 variables
Cited references to follow up on	Caset, F., Blainey, S., Derudder, B., Boussauw, K., & Witlox, F. (2020). Integrating node-place and trip end models to explore drivers of rail ridership in Flanders, Belgium. *Journal of Transport Geography*, *87*, 102796. https://doi.org/10.1016/j.jtrangeo.2020.102796
Follow up Questions	Did they test every single idea the GBDT model spat out? If not, how did they sort them and decide which ones were worth putting through the regression model?

	How did the regression model exactly take in all of the inputs and balance them?

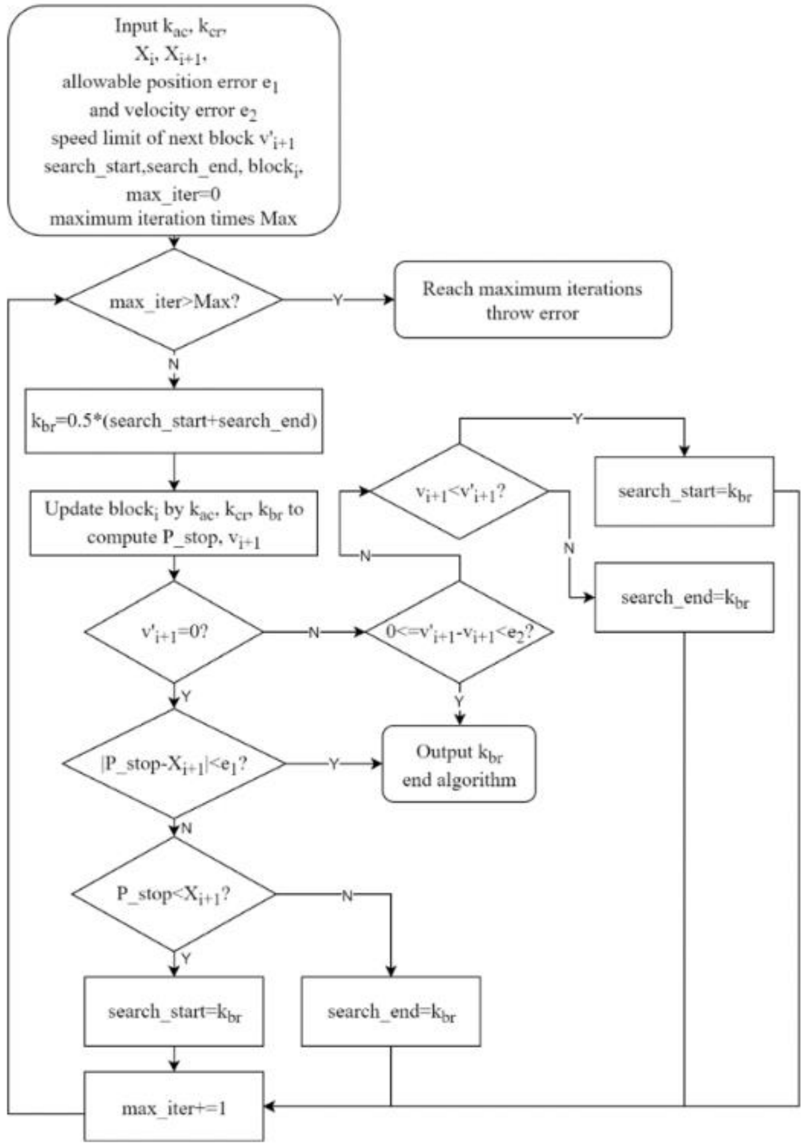
Article #10 Notes: Discrete-event simulations for metro train operation under emergencies: A multi-agent based model with parallel computing

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	Discrete-event simulations for metro train operation under emergencies: A multi-agent based model with parallel computing
Source citation (APA Format)	Yang Li, Xin Yang, Jianjun Wu, Huijun Sun, Xin Guo, Li Zhou, Discrete-event simulations for metro train operation under emergencies: A multi-agent based model with parallel computing, Physica A: Statistical Mechanics and its Applications, Volume 573, 2021, 125964, ISSN 0378-4371, https://doi.org/10.1016/j.physa.2021.125964.
Original URL	https://www.sciencedirect.com/science/article/pii/S0378437121002363
Source type	Journal article
Keywords	Train simulation Discrete-event method Multi-agent Model Metro emergency Parallel computing
#Tags	#Simulation #optimization #ComputingSystems
Summary of key points + notes (include methodology)	With the rapid growth of public transit in many places in the world, the system is getting more and more complicated. This leads to more points of failure, and an increase in emergencies (signal delays, train malfunctions, unauthorized entries to the track). These result in trains getting delayed, and entire timetables needing to be redone. The CA (cellular automata) model is a way to model how the train moves through a bunch of discrete journeys, each with a corresponding time. Speed and position are continuous in this model, which helps dictate how the trains interact with one

	another. In the paper they used a discrete event simulation with a multi-agent model due to its superior efficiency compared to a traditional discrete-time method. They used 3 algorithms to compute train speed for normal running times and reduced speed for when they're under the influence of an emergency. The structure of the tracks are 6 stations, 3 on each side with a point to turn back, similar to an oval. To simplify the calculations, they take the interval between stations and make blocks which they use to calculate speed. They use a passenger agent to mimic how passenger behave, however it is noteworthy to point out the passenger agent is a crowd of people with the same destination, the arrival of passengers follows a poisson distribution. The boarding function is used to get the people on the train, however if there aren't enough people, it generates new people. They used parallel processing on all the different functions in order to try and increase efficiency and decrease time. They then ran the simulation again without the parallel processing and compared the results. They found that when an emergency occurred the arrival rate slowed, and so did the departing rate, and there was a linear relationship between the delays and the time it took.
Research Question/Problem/ Need	How can we model a simulation for wat happens when trains run into emergencys and slow down.

Important Figures	 Fig. 3. Flow chart of the binary search method to compute k_{br}.

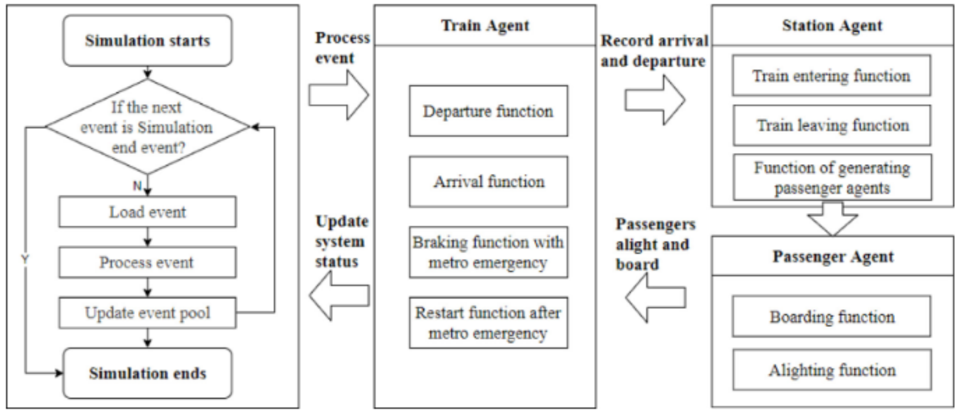


Fig. 6. Flow chart of the proposed simulation model.

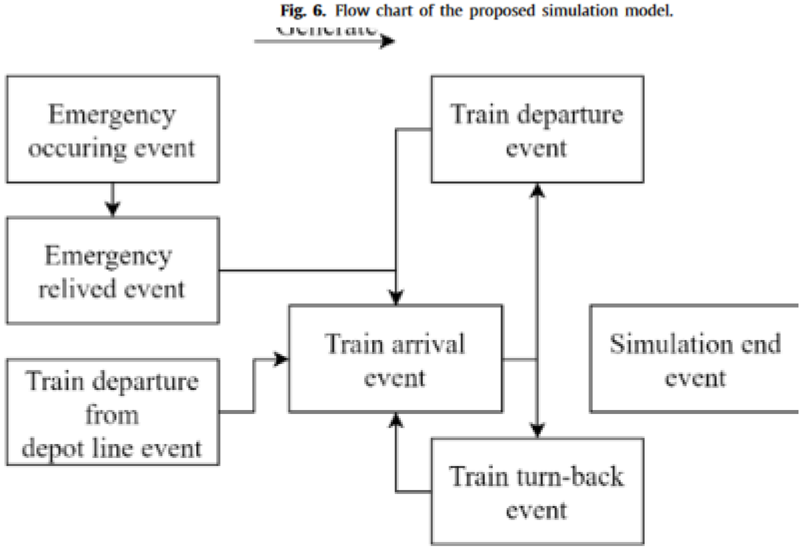
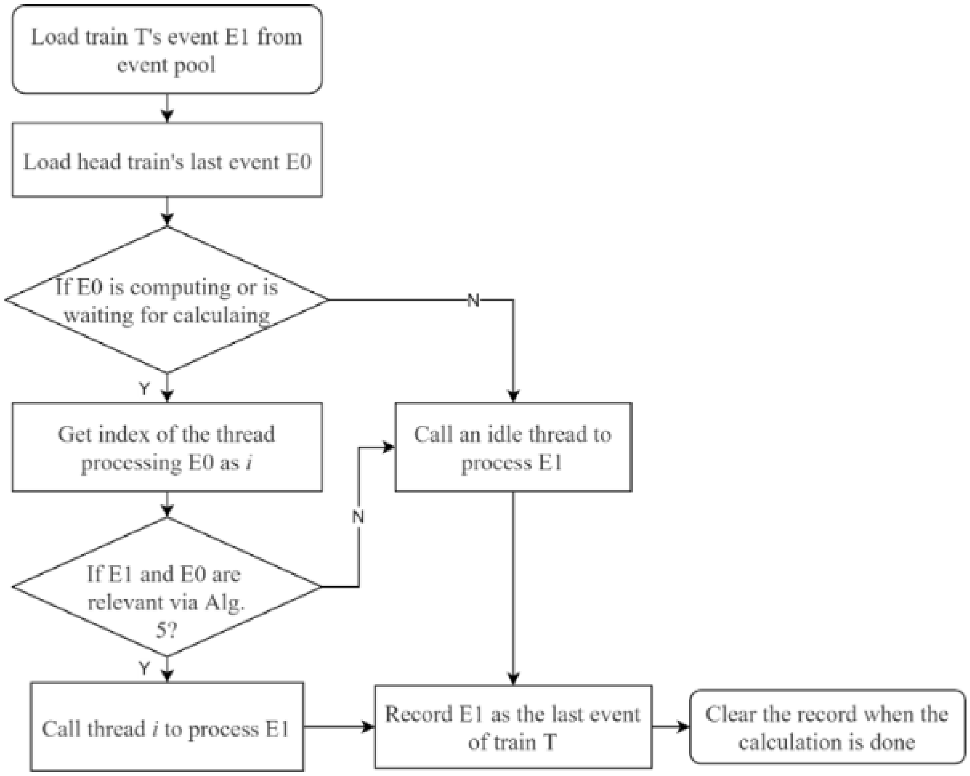
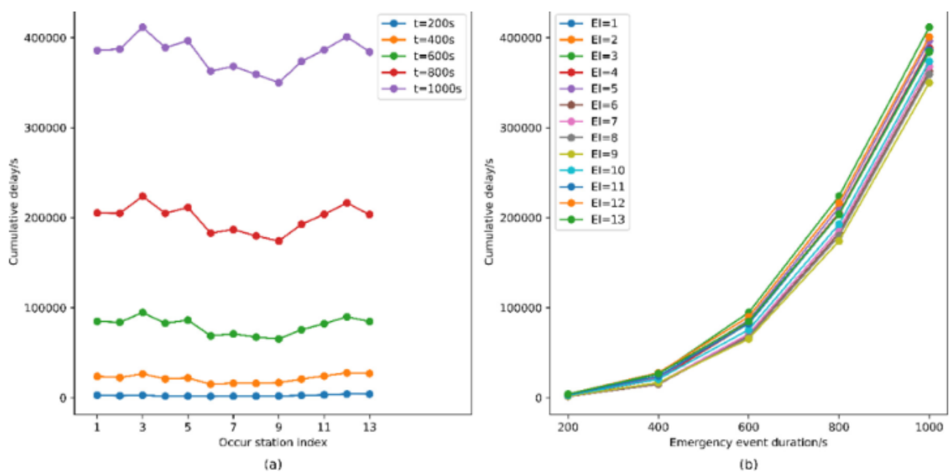


Fig. 7. Flow chart of the generating relation between events.

	 **Fig. 8.** Flow chart of the parallel computing.  **Fig. 9.** (a) shows the line chart of cumulative train delays grouped by emergency duration. (b) shows the line chart grouped by *El*.
VOCAB: (w/definition)	Agent – a function that activates when an event occurs Event pool – storing the properties of an event only for when it's called in one area of a computer Poisson distribution – a distribution that can help determine if 2 events are independent, similar to a normal distribution.
Cited references to follow up on	Xin Yang, Qiuchi Xue, Meiling Ding, Jianjun Wu, Ziyou Gao, Short-term prediction of passenger volume for urban rail systems: A deep learning

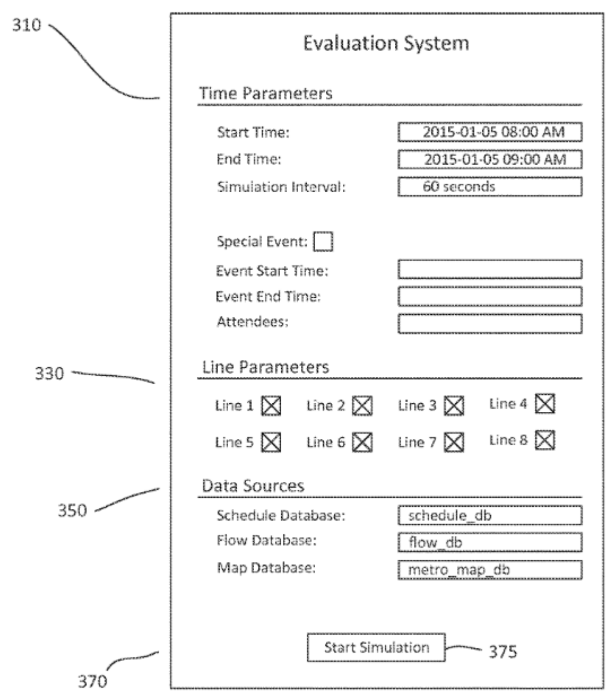
	approach based on smart-card data, International Journal of Production Economics, Volume 231, 2021, 107920, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2020.107920. Erfan Hassannayebi, Arman Sajedinejad, Soheil Mardani, Urban rail transit planning using a two-stage simulation-based optimization approach, Simulation Modelling Practice and Theory, Volume 49, 2014, Pages 151-166, ISSN 1569-190X, https://doi.org/10.1016/j.simpat.2014.09.004.
Follow up Questions	Do they think parallel process was worth all the time and power? Would what their simulation concluded be different if they had a larger area? What would happen if they tested the emergency on a model that’s better with processing traffic?

Article #11 Notes: A kind of site-teaching for track traffic training manages system and method

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**A kind of site-teaching for track traffic training manages system and method**
Source citation (APA Format)	涛, 武 (2016), Chinese patent CN106228860A, Chinese patent and trademark office
Original URL	https://patents.google.com/patent/CN106228860A/en?q=(Metro+simulation)&oq=Metro+simulation
Source type	patent
Keywords	Network simulation, metro systems, computer systems, transportation
#Tags	#Simulation #dynamicSystems #data

Summary of key points + notes (include methodology)	-The way they made this simulation is very similar to a lot of the other papers I've read so I'm going to focus on how its different -They use up to 8 different lines for the simulation with multiple concourses -They take a lot of the data from spreadsheets of historical data, and use that to determine the passenger flow rate, how often trains come, station capacity etc. -The use the passenger flow rate to determine the "state" of stations and trains. The stations and trains are effectively hard coded, so they do "check ins" on the trains to see how the passenger flow rate has an impact on the trains -At the end of the time that generates a report of all the passenger flow rates and the state of the trains and stations, like a play by play. -That report can then be analyzed to see when the stations and trains have been stressed the most, and the passenger flow rate leading up to it
Research Question/Problem/ Need	How to simulate a large number of passengers on a metro line efficiency while being user friendly.
Important Figures	

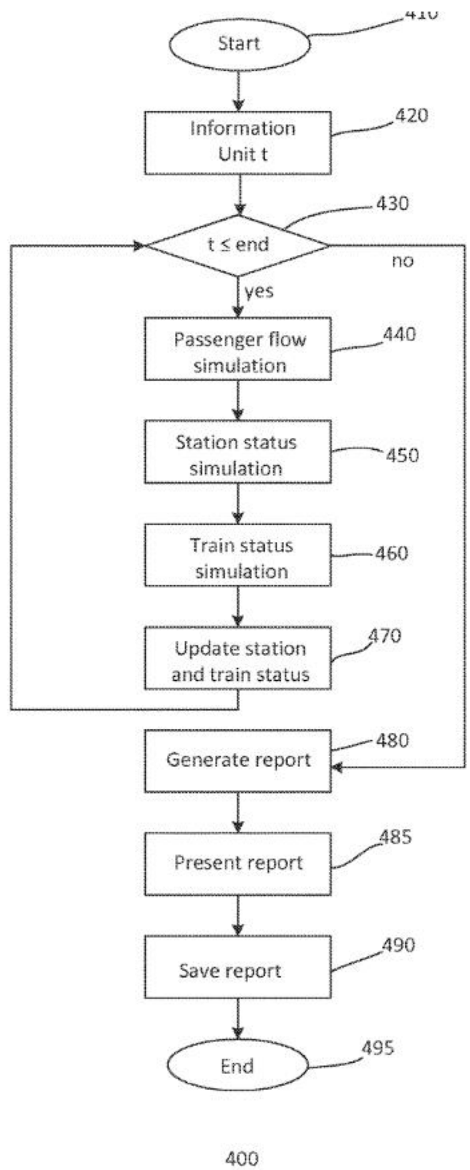


FIG. 4

VOCAB: (w/definition)	Input module – a way for simulations to take in data, for example through a spreadsheet to use in the simulation Configuration component – A way to translate said data into things usable for the simulation, using the numbers to change variables
Cited references to follow up on	Cury, J., F. Gomide, and M. Mendes. "A methodology for generation of optimal schedules for an underground railway system." IEEE Transactions on automatic control 25.2 (1980): 217-222. Li, Janice P. "Train station passenger flow study." Simulation Conference, 2000. Proceedings. Winter. Vol. 2. IEEE, 2000.
Follow up Questions	Where did they get the data they used to test?

	Was the 8 lines based on a preexisting city? Is there a way we can feed the machine the subway map of a preexisting city?

Article #12 Notes: Looking glass: a hybrid simulation system to model cascading events within a black box system

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	**Looking glass: a hybrid simulation system to model cascading events within a black box system**
Source citation (APA Format)	Booch E et al, (2011). Looking glass: a hybrid simulation system to model cascading events within a black box system (US patent NO. US8498850B2) US patent office, https://patentimages.storage.googleapis.com/e3/6b/2f/35f2ec2411f69e/US8498850.pdf
Original URL	https://patentimages.storage.googleapis.com/e3/6b/2f/35f2ec2411f69e/US8498850.pdf
Source type	patent
Keywords	Hybrid simulation, simulation systems, cascading events, black box
#Tags	#Simulation #computingSystems
Summary of key points + notes (include methodology)	A simulation is really a system of systems that works to take certain inputs and output a model of the real world. However, one thing that hasn't been talked about is the effectiveness of using black box systems in these simulations. Black boxes are just subsystems than aren't accessible by other parts of the simulation. By allowing multiple black boxes to communicate with one another only through their inputs and outputs, building a system of systems from them. They transfer data and time from one another to keep the simulation running. They receive data and from that build a field, which the black boxes then update regularly. Black boxes provide an interesting alternative as they're more secure due to how they work being inaccessible, and they're also modular since the only thing they rely on is 1 input and 1 output.
Research Question/Problem/ Need	Could black boxes be used in simulations effectivley?

Important Figures

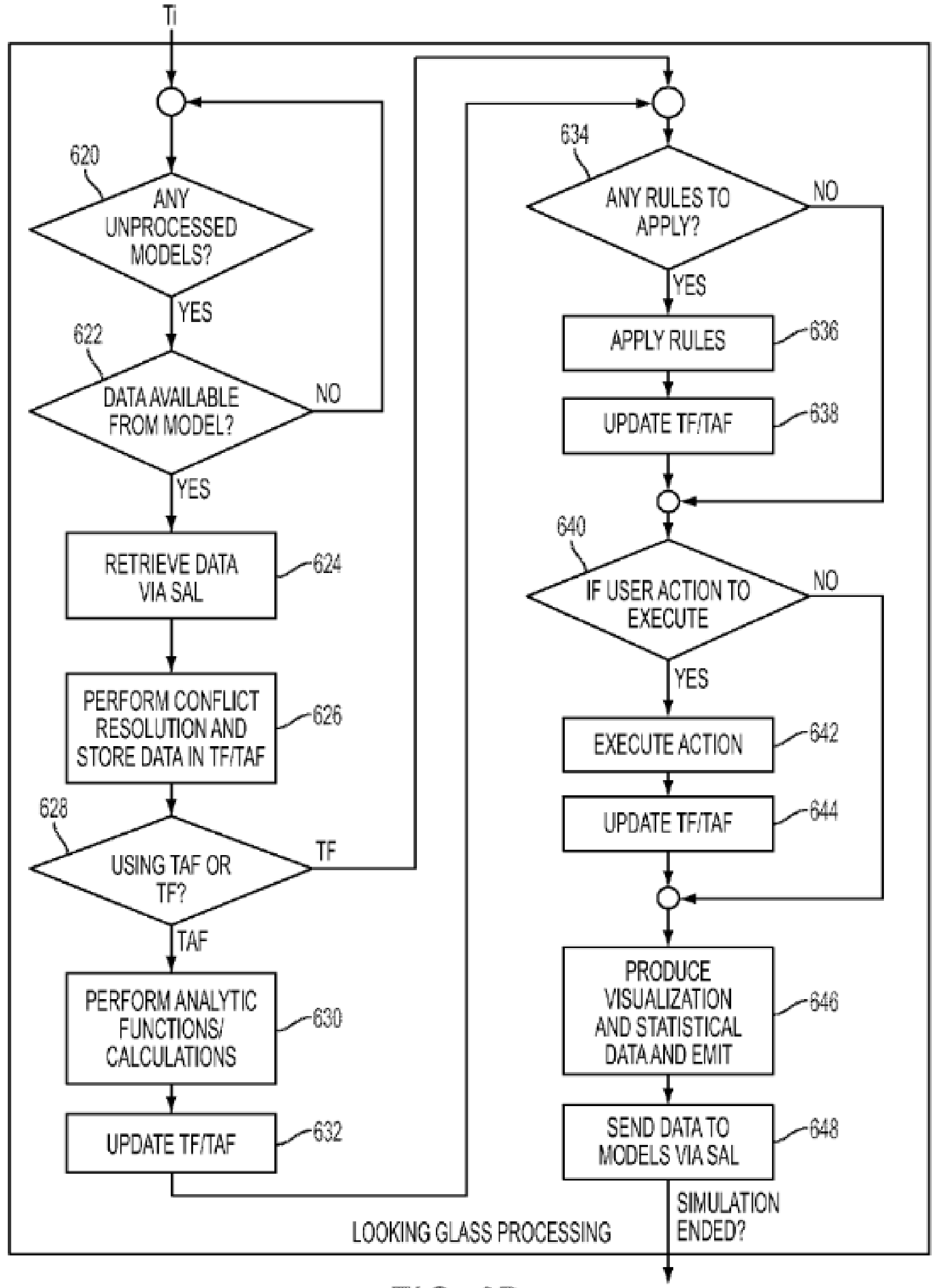
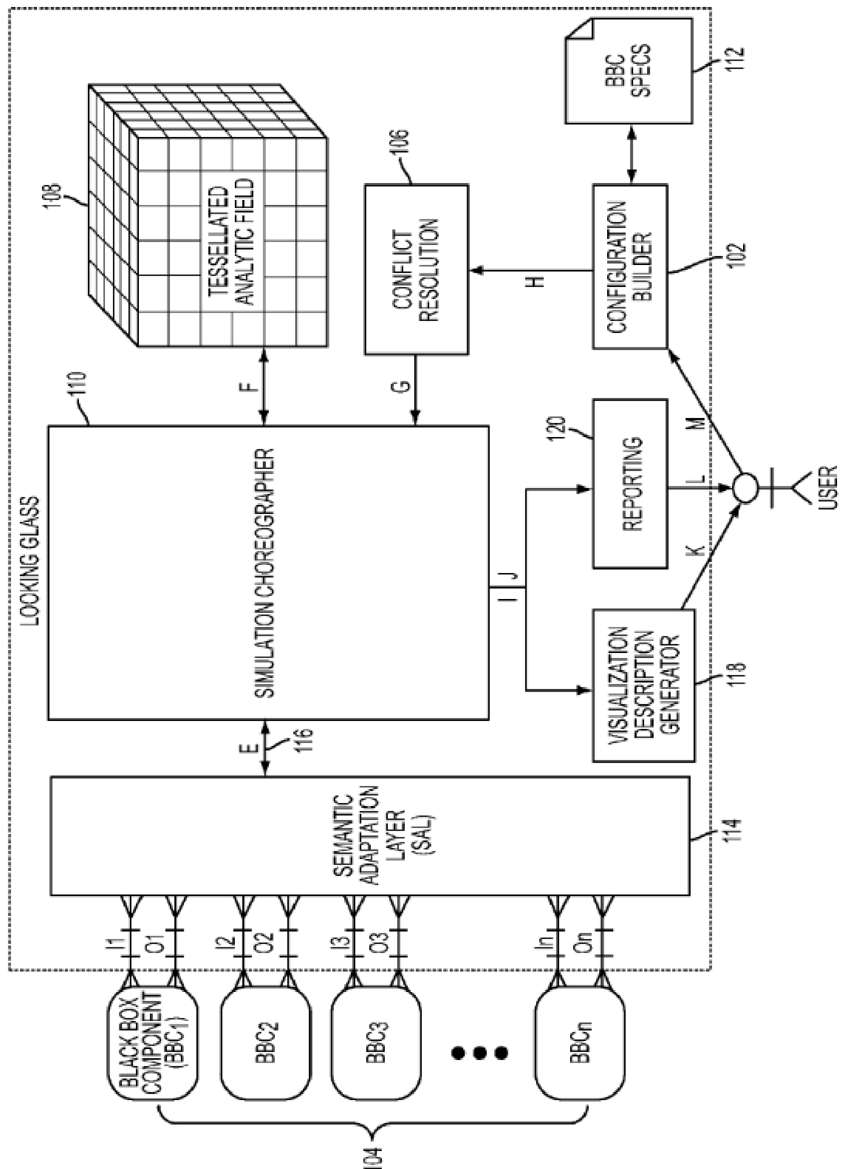


FIG. 6B

	 FIG. 1
VOCAB: (w/definition)	Black box – a subsystem that isn't accessible by the rest of the system and only takes 1 input and output Cascading events – when an event ends another one is initialized using the previous data Looking glass – A big black box for the entire system
Cited references to follow up on	Prehofer, C.; "Plug-and-Play Composition of Features and Feature Interactions with Statechart Diagrams"; In Proceedings of FIW; pp. 43-58; 2003.
Follow up Questions	How does the looking glass work exactly? What makes black boxes so modular? How is it ensured the black box stays black?

Article #13 Notes: Title

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	