Estimating the Traffic Mix in a Building by Analysing the Stops Data per Round Trip

Lutfi Al-Sharif[1,2,3], Richard Peters[2], Matthew Appleby[2], Tahani Ghaben[1]

[1]Al Hussein Technical University, Amman, Jordan
[2]Peters Research Ltd., United Kingdom
[3]The University of Jordan, Mechatronics Engineering Department, Amman 11942, Jordan

Keywords: The Round Trip; elevator; lift; incoming traffic; outgoing traffic; interfloor traffic; occupant floor; entrance floor.

Abstract. It has long been believed that the number of up stops and down stops in a building, as well as the ratio between them, could be used to estimate the mix of traffic prevailing in the building and its intensity. With modern lift traffic analysis and data collection methods, it is now possible to generate large amounts of representative data in a reasonable time and with reasonable processing power. This paper attempts to use the generated data as training and testing data to estimate the mix of traffic in a building. The method will first be applied to one representative building and then extended to more general cases.

1 INTRODUCTION

It has long been believed that the number and ratio of up stops and down stops in a building can be used to estimate the mix of traffic prevailing in the building. Simple methods used the ratio of up stops to down stops to decide whether the building is experiencing uppeak traffic, down peak traffic or balanced traffic. As a simple example, the ratio of the up stops to the down stops can be used to detect the presence of an uppeak condition [1]. A follow up piece of work used artificial neural networks to assess the type of prevailing traffic in the building, such as uppeak, down peak, two-way traffic or off peak [2].

This paper attempts to develop a more detailed methodology that can be used to arrive at the mix of the traffic in a building based on the number of stops in the up direction and the down direction. The paper relies heavily on the definition of the floors as occupant floors and entrance/exit floors, as defined in [3]. Moreover, the advent of the Monte Carlo Simulation method (MCS), can now be used very effectively to generate large data sets.

The concept of attempting to infer traffic data based on the number of stops was first suggested in 1992 [4] in what was called then the I-S-P method. The term came from the fact that in classical round trip time calculations, tables are used to find the expected number of stops based on the number of passengers boarding the lift car. The inversion implied that the expected number of passengers would be inferred from the actual number of stops in a round trip. Further work on this concept was carried out in 2022 [5] whereby the tables relating the expected number of stops in the up direction and the down direction were generated based on large amounts of data generated using the Monte Carlo Simulation (MCS) method. This enabled the generation of large amounts of data for ‘training’ without the need for manual surveys, as was the case in 1992.

The second section discusses the methodology for generating the raw data. The third presents the analysis of the data and suggests simple methods for finding the mix of traffic from the processed raw data. The last section presents conclusions from the paper and suggests the next steps required.

2 GENERATION OF THE RAW DATA

As was mentioned earlier, the raw data was generated using the Monte Carlo Simulation method. The MCS method can be used to faithfully generate large amounts of round-trip data [6, 7]. The MCS employs random sampling methods that ensure that the resultant data is a faithful representation of the parameters of the building. The MCS tool was used to generate round trip stops based on the following (similar to what is used in [3]):

- The specific number of passengers per round trip (P=13 passengers in this case).
- A predefined mix of traffic showing the relative strength of the incoming traffic, outgoing traffic, inter-floor traffic and inter-entrance floor.
- The number of occupant floors and the number of entrance/exit floor (eight occupant floors and two entrance floors for this building).
- The relative populations of the occupant floors (all occupant floors have equal populations in this case; the actual absolute number is irrelevant to the generated data).
- The relative arrivals at the entrance/exit floors (30% for the lower entrance floor and 70% for the upper entrance floor).

The MCS methodology did not need to generate the kinematics of the lift system or produce the speed-time profiles. Moreover, it did not need to carry out any allocation of landing calls to the cars. This makes the method independent of the dispatching algorithm. But more importantly, this is an excellent example of the abstraction capability of the MCS method, where it only generates the data that is needed for the case in question, rather than spending time generating kinematic curves or allocation calls. This approach speeds up the generation of the raw data.

For each of the cases studied, one million trials/scenarios were generated. This ensured that the resultant numbers had converged to the final correct value. The average number of stops was taken for the 1 million scenarios for each of the cases of the traffic mixes. The four parameters that were extracted from the data are:

- Number of stops in the up direction on all occupant floors, which will be denoted as SUocc.
- Number of stops in the down direction on all occupant floors, which will be denoted as SDocc.
- Number of stops in the up direction on all entrance floors, which will be denoted as SUent.
- Number of stops in the down direction on all entrance floors, which will be denoted as SDent.

Each of these parameters has units of stops/round trip. In order to make these numbers meaningful, they have been normalised by dividing by the maximum number of possible stops. In the case of the entrance floors, the maximum number of possible stops would be the number of entrance floors. In the case of the occupant floors, the maximum number of possible stops would be the number of occupant floors. (Strictly speaking the maximum number of stops should be minimum of the number of passengers in a round trip and the number of occupant floors.)

For the purpose of understanding the data and being able to come up with a suitable approach, two sets of scenarios were generated:

- The first set of scenarios attempts to keep the ratio between the incoming traffic and the outgoing traffic constant, while varying the percentage of the inter-floor traffic. The results for this set of scenarios are shown in Table 1.
- The second set of scenarios keeps the percentage of the inter-floor traffic constant at 40%, while varying the ratio of the incoming traffic to the outgoing traffic. The results for this set of scenarios are shown in Table 2.

In all cases, the inter-entrance traffic is kept at 0%.

Table 1 Generated Stops per round trip data for varying interfloor traffic and constant ratio of incoming traffic and outgoing traffic.

Mix of traffic	Ent/Occ	Raw Stops		Normalised		Normalised	
		Up Stops	Down Stops	Up Stops	Down Stops	Up Stops	Down Stops
0:0:100:0	Entrance	0.00000	0.00000	0.000000	0.000000		
	Occupant	6.59070	6.59070			0.823838	0.823838
5:5:90:0	Entrance	0.54967	0.54854	0.274836	0.274270		
	Occupant	6.45368	6.45211			0.806710	0.806513
10:10:80:0	Entrance	0.93776	0.93727	0.468882	0.468633		
	Occupant	6.30589	6.30245			0.788236	0.787807
15:15:70:0	Entrance	1.21462	1.21484	0.607308	0.607422		
	Occupant	6.14227	6.14222			0.767784	0.767777
20:20:60:0	Entrance	1.41071	1.41267	0.705354	0.706335		
	Occupant	5.96730	5.96570			0.745913	0.745712
25:25:50:0	Entrance	1.55474	1.55407	0.777368	0.777033		
	Occupant	5.77566	5.77466			0.721958	0.721833
30:30:40:0	Entrance	1.66049	1.65929	0.830244	0.829646		
	Occupant	5.56582	5.56462			0.695727	0.695578
35:35:30:0	Entrance	1.73757	1.73731	0.868783	0.868656		
	Occupant	5.34209	5.33855			0.667762	0.667319
40:40:20:0	Entrance	1.79595	1.79553	0.897976	0.897763		
	Occupant	5.09899	5.09513			0.637373	0.636891
45:45:10:0	Entrance	1.84080	1.84150	0.920400	0.920750		
	Occupant	4.82840	4.83310			0.603550	0.604138
50:50:0:0	Entrance	1.87540	1.87600	0.937700	0.938000		
	Occupant	4.54140	4.54290			0.567675	0.567863

The following are the exact definitions of the four types of traffic. Incoming traffic is traffic that originates at an entrance/exit floor and terminates at an occupant floor. Outgoing traffic is traffic that originates at an occupant floor and terminates at an entrance/exit floor. Inter-floor traffic is traffic that originates at an occupant floor and terminates at an occupant floor. Inter-entrance traffic is traffic that originates at an entrance/exit floor and terminates at an entrance/exit floor.

Table 2 Generated Stops per round trip data for the case of constant interfloor traffic and varying ratios of incoming and outgoing traffic.

Mix of traffic	Ent/Occ	Raw Stops		Normalised		Normalised	
		Up Stops	Down Stops	Up Stops	Down Stops	Up Stops	Down Stops
60:0:40:0	Entrance	1.923493	0.000000	0.961747	0.000000		
	Occupant	6.588813	3.892514			0.823602	0.486564
50:10:40:0	Entrance	1.875354	0.938490	0.937677	0.469245		
	Occupant	6.302391	4.543945			0.787799	0.567993
40:20:40:0	Entrance	1.796325	1.413573	0.898163	0.706787		
	Occupant	5.967130	5.095104			0.745891	0.636888
30:30:40:0	Entrance	1.659743	1.659612	0.829872	0.829806		
	Occupant	5.567667	5.567087			0.695958	0.695886
20:40:40:0	Entrance	1.412383	1.795378	0.706192	0.897689		
	Occupant	5.099343	5.966518			0.637418	0.745815
10:50:40:0	Entrance	0.938535	1.875284	0.469268	0.937642		
	Occupant	4.540635	6.306636			0.567579	0.788330
0:60:40:0	Entrance	0.000000	1.923013	0.000000	0.961507		
	Occupant	3.893164	6.591467			0.486646	0.823933

3 ANALYSIS

Based on the first set of scenarios, it is possible to estimate the percentage of the inter-floor traffic by subtracting the average of the normalised stops in the entrance floors from the number of the normalised stops in the occupant floors. The exact relationship is shown in Figure 1, which is based on Table 1.

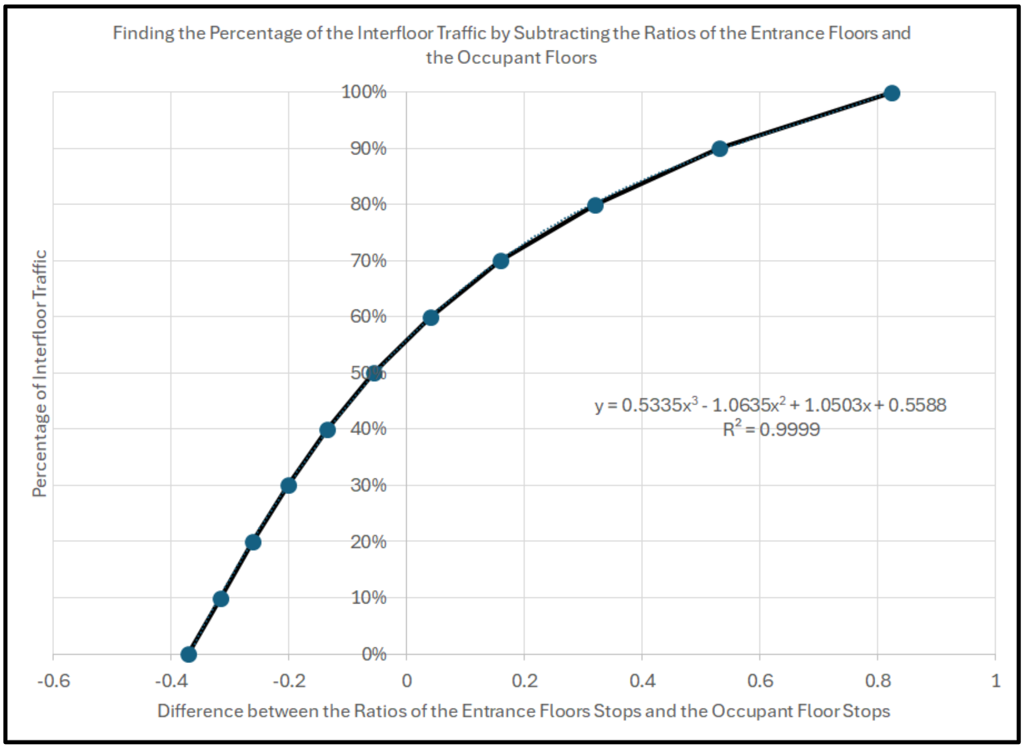

Figure 1 Finding the Interfloor Traffic percentage from the difference between the average of the normalised stops in the occupant floors and the entrance floors.

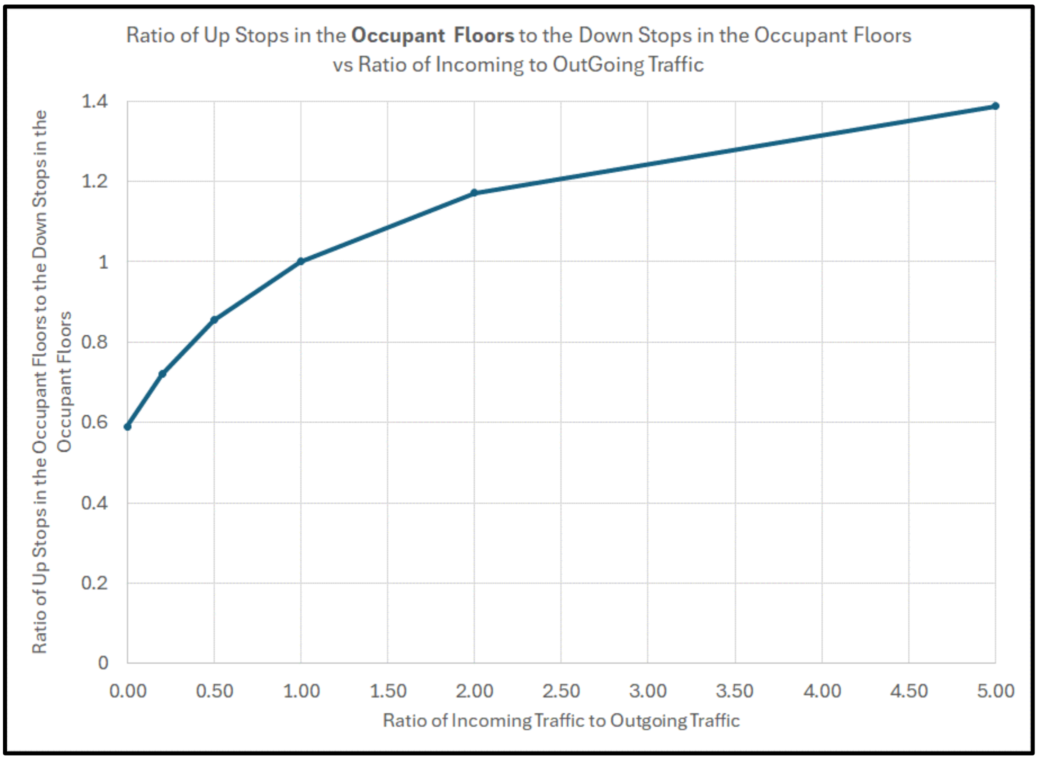

Figure 2 Relationship between the up stops and down stops in the occupant floors and the ratio of incoming traffic and outgoing traffic

Another relationship has been found by plotting the ratio of the normalised stops in the up floors to the normalised stops in the down floors and plotting it versus the ratio of incoming traffic and outgoing traffic. This is shown in Figure 2 for the occupant floors and in Figure 3 for the entrance floors, which are based on Table 2.

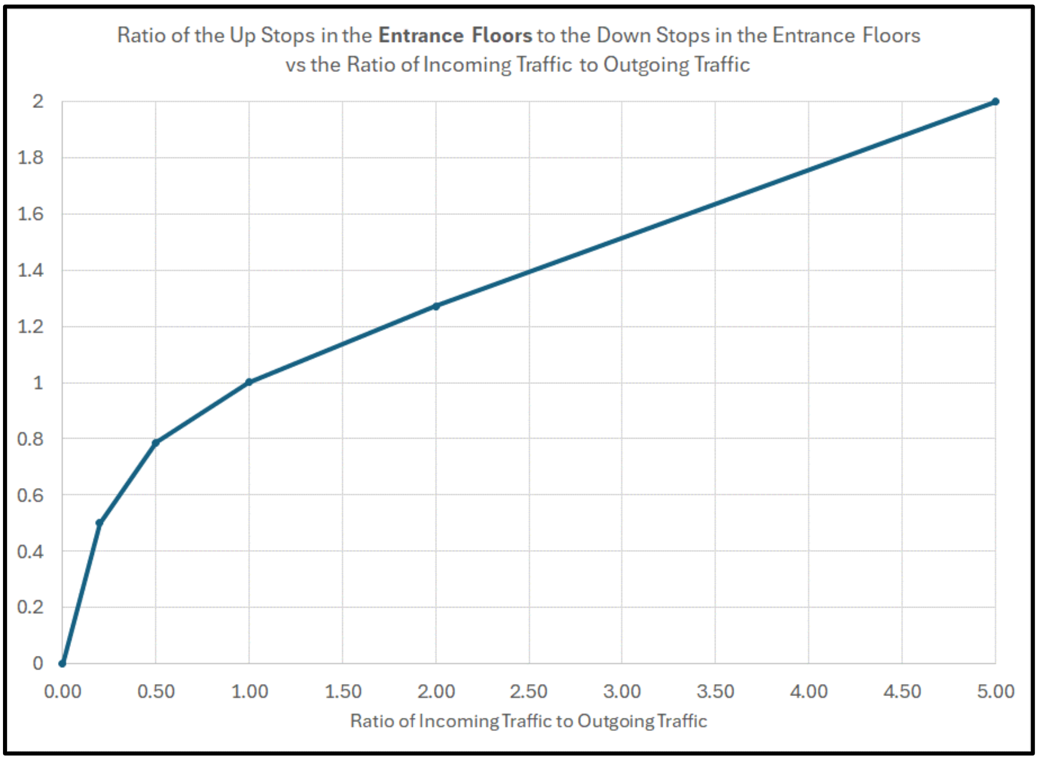

Figure 3 Relationship between the up stops and down stops in the entrance floors and the ratio of incoming traffic and outgoing traffic

4 CONCLUSIONS AND FURTHER WORK

This paper has presented a simple overview of the use of basic rules of thumb in attempting to find the mix of traffic in a building by monitoring the stops within the building. The method assumes knowledge of the types of floors within the building, namely occupant floors and entrance/exit floors. The method relies on the following pieces of data:

- Number of stops in the up direction on all occupant floors.
- Number of stops in the down direction on all occupant floors.
- Number of stops in the up direction on all entrance floors.
- Number of stops in the down direction on all entrance floors.

Further research will be carried out to cover the following:

- The analysis presented in this paper has used very basic machine learning tools (effectively regression tools). Further work will need to be carried out to apply more advanced machine learning methods to analyse the data.
- The data generated in this paper was only based on one building. In future work, a variety of buildings will be used.
- The MCS method will be used to generate large and more varied amounts of data.

In the analysis followed in this paper, two scenarios were studied: fixing the inter-floor traffic and varying the ratio of incoming and outgoing traffic; and fixing the ratio the incoming traffic and outgoing traffic and varying the inter-floor traffic. The challenge for future research is to cope with a variety of scenarios including both of the above variations.

REFERENCES

[1] J.R. Beebe. *Lift Management*. Ph.D. Thesis, The University of Manchester, 1980 pp 114-116.

[2] ATP So, JR Beebe, WL Chan, SK Liu. An Artificial Neural-Network based Traffic Patterns Recognition System. *The International Journal of Elevator Engineering*, volume 1, October 1996.

[3] Al-Sharif L, Abu Alqumsan AM. An integrated framework for elevator traffic design under general traffic conditions using origin destination matrices, virtual interval, and the Monte Carlo simulation method. *Building Services Engineering Research and Technology*. 2015;36(6):728-750. doi:10.1177/0143624415595521.

[4] Al-Sharif L. *Predictive Methods in Lift Traffic Analysis*. The University of Manchester, 1992.

[5] L.R. Al-Sharif, R.D.Peters, M.Appleby. Enhancing the ISP Method (Inverse Stops-Passengers) Using the Monte Carlo Simulation Method. *13th Symposium on Lift & Escalator Technologies* 13 (1), 7-14

[6] Appleby M and Peters R D. The Round-Trip Time Simulation: Monte Carlo Implementation and Consistency with Other Techniques. *Proceedings of the 11th Symposium on Lift and Escalator Technologies (online)*. 2020.

[7] Al-Sharif L. A Universal Methodology for Generating Elevator Passenger Origin-Destination Pairs for Calculation and Simulation. In the Book (chapter 6): *Smart Cities-Their Framework and Applications*, published by IntechOpen, 25th September 2020.

BIOGRAPHICAL DETAILS

Lutfi Al-Sharif is currently the Vice President at Al-Hussein Technical University in Amman/Jordan and jointly Professor of Building Transportation Systems at the Department of Mechatronics Engineering, The University of Jordan. He received his Ph.D. in elevator traffic analysis in 1992 from the University of Manchester, U.K. He worked for 10 years for London Underground, London, United Kingdom in elevators and escalators. He has over 50 papers published in peer reviewed journals and conferences in vertical transportation systems, is co-inventor of four patents and co-author of the 2nd edition of the Elevator Traffic Handbook, and author of the "indoor transportation" chapter in the Elsevier Encyclopedia of Transportation.

Richard Peters has a degree in Electrical Engineering and a Doctorate for research in Vertical Transportation. He is a director of Peters Research Ltd and a Visiting Professor at the University of Northampton. He has been awarded Fellowship of the Institution of Engineering and Technology, and of the Chartered Institution of Building Services Engineers. Dr Peters is the principal author of Elevate, elevator traffic analysis and simulation software.

Matthew Appleby is a Software Engineer with Peters Research Ltd. He is the lead developer for the front end of the new online Elevate. He joined Peters Research in 2019 and recently attained a first-class (Hons) degree in Software Development.

Eng. Tahani Ghobon has been working as a teaching assistant at the Electrical Engineering Department at Al Hussein Technical University (HTU) for the last 6 years. She completed her undergraduate degree in electrical engineering (Electrical Power) from the Jordan University of Science and Technology (JUST). Eng. Tahani has vast experience in the area of Machine Learning and its applications in electrical engineering applications.