Enhancing the I-S-P Method (Inverse Stops-Passengers) Using the Monte Carlo Simulation Method

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Abstract. Previous research has developed a method to infer the number of passengers that the lift car is carrying based on the number of stops that it makes in the up-direction or the down-direction (1992). The method was denoted as the I-S-P method (or the Inverse Stops-Passengers method). The application of the method was found to be sensitive to the prevailing mix of traffic in the building (e.g., incoming, outgoing or lunchtime). Developing those equations analytically becomes mathematically complex.

This paper will use the Monte Carlo simulation method to numerically develop the ISP relationship under any mix of traffic (i.e., by using the percentage of incoming traffic, outgoing traffic and inter-floor traffic), without the need to resort to deriving analytical equations. The ISP method gives an estimate of the passenger traffic intensity based on a very basic dispatching control system.

The main advantage of such an enhanced tool is that it can be used in real time to infer the number of passengers inside the car by simply monitoring the stops in any one of the two directions and under any type of traffic.

1 INTRODUCTION

Once a lift system has been installed, the need might arise for checking the performance of the lifts, or, if the lifts have been in service long enough, to refurbish the lift system. In order to do this, the actual number of passengers using the lift system in different traffic conditions and the profiles of the traffic patterns have to be available. These could either be assessed or surveyed.

Assessment techniques rely on using a percentage of the building population [1,2]. This method expresses the expected worst five minute up-peak demand as a percentage of the building population, with different figures for different types of buildings.

Manual surveys on the other hand give the size of the traffic and the profile against time but are limited by the length of time for which human observers can conduct them, unless more human resources are deployed. A good overview of surveys can be found in [3]. From a practical point of view, manual surveys are not usually conducted for more than 2 - 4 hours a day, and for 2 - 3 days per building. Another disadvantage is that manual surveys can only be conducted at one floor, (usually the main terminal), and thus do not take into consideration other heavy traffic floors (unless more human resources are employed). If a complete performance analysis is needed, at least one observer is needed on every floor and in every car [4].

Other research has been carried out in order to analytically attempt to extract the full details of passenger movements in the building by logging the landing calls and the car calls [5,6]. This method assumes that the landing call and car call data is fully available to the algorithm.

Previous work has attempted to allow the inference of the number of passengers boarding the lift car in either direction by counting the number of stops in that direction and applying it to a lookup table (denoted as the ISP table). The entries in the table were derived analytically. This was only done for pure up traffic (or incoming traffic) [7, 8, 9, 10]. Extending the equation derivation for the more complex cases of mixed traffic conditions and inter-floor traffic becomes very complicated.

It is worth noting that the number of elevator stops/starts depends not only on the passenger traffic and the traffic mix, but also the control system [1].

This paper attempts to extend this table to general traffic conditions by using a numerical method (as opposed to the original analytical method) called the Monte Carlo simulation method. The Monte Carlo simulation method has been used recently in the area of lift traffic engineering. It was used to find the value of the round-trip time under incoming traffic conditions [11] and then under general traffic conditions [12]. It was also used to find the value of the average travelling time [13]. In some of the more recent papers, it was used to evaluate the round-trip time for hypothetical traffic systems [14, 15, 16] and even under destination group control [17]. Comparisons have been carried out between the value of the round-trip time resulting from the Monte Carlo simulation method and existing techniques, whereby the Monte Carlo simulation method was also used as an extension to existing methods [18]. Special emphasis was also given to the effect of the adopted dispatcher [18].

Section 2 presents definitions of the stop and the procedure for generating the tables using the Monte Carlo simulation method. Section 3 shows the resultant tables under morning peak traffic conditions and lunchtime traffic conditions. An example of the application of the method to ten consecutive round trips is presented in section 4. Section 5 draws conclusions and suggests the most relevant piece of further works.

2 DEFINITIONS AND PROCEDURE

The code to generate the ISP tables was implemented in MATLAB. The building number of floors (entrance floors with their respective entrance bias and occupant floors with their relative occupant populations) are entered into the software, as well as the traffic mix (incoming: outgoing: interfloor). All this information is used to generate an origin-destination matrix (OD matrix) and then a probability density function and a cumulative distribution function for the passenger origin-destination pairs. More details can be found in [19]. The number of passengers served in each round trip (P) is entered in order to generate the ISP array. The number of passengers P was selected as equal to the rated car capacity (although in future work this will be varied to cater for different arrival rates.

Th code was repeated for a large number of trials (e.g., 100 000 trials). The term trial is a Monte Carlo simulation expression. In this case, each trial represents one full round trip of the lift, during which the rated number of passengers (P) is generated in accordance with the origin-destination matrix. The number of up travelling passengers was extracted as well as the number of up stops. The same was applied to the down direction. At the end of the 100 000 trials, the cases for the same number of stops were aggregated together in each direction and the average of all the corresponding number of passengers was calculated. These entries were placed in the two ISP tables (one for the up direction and one for the down direction).

The tables were developed for two mixes of traffic:

1. Morning peak (85% incoming traffic; 10% outgoing traffic; and 5% interfloor traffic).
2. Lunchtime peak (45% incoming traffic; 45% outgoing traffic; 10% interfloor traffic).

Another critical factor that was fixed was the number of passengers generated in one round trip. This represents the traffic intensity. In the example used in this case, it was set to 13 passengers.

Prior to developing the software to generate the ISP tables, it was necessary to define what constitutes an up stop and a down stop. A stop is classified as an up stop in either of the following two cases

1. If the lift car is stopping to pick up one or more passengers travelling up the building.
2. If the lift car is stopping to drop off one or more passengers travelling up the building

A stop is classified as a down stop in either of the following two cases

1. If the lift car is stopping to pick up one or more passengers travelling down the building.
2. If the lift car is stopping to drop off one or more passengers travelling down the building

There are obviously cases where a *physical* stop could represent both an up stop and a down stop (e.g., a lift car that is travelling in the up direction to drop off an up travelling passenger and to pick an up or a down travelling passenger). This could be referred to as a coincidental stop and was counted twice: once as an up stop and once as a down stop. The MATLAB software can detect that this is a coincidental stop.

Later in this paper, the use of an accelerometer that is placed on the floor of the lift car is presented as a simple and non-intrusive tool to detect the physical stoppage of the lift. However, the accelerometer inside the lift car will not be able to detect whether the stop described above is a coincidental stop or not.

3 RESULTANT ISP TABLES FOR A SAMPLE BUILDING

The software was written in MATLAB, for the following sample building:

1. The building has a total of 10 floors (2 entrance floors and 8 occupant floors). The entrance bias was set to 0.3 for the lower entrance and 0.7 for the upper entrance.
2. The number of passengers generated in each round trip was set to P=13 passengers. The number of passengers P in each round trip is a representation of the traffic intensity.
3. The number of trials was set to 100 000 trials.

The four resultant ISP tables are shown in

Table **1** and

Table **2** for the morning peak and the lunchtime peak, respectively. For the traffic mix, two tables were generated: one for the up direction and the other for the down direction. Improbable cases (cases which have not occurred during the 100 000 round trips) are highlighted in orange. Impossible cases (e.g., one passenger generating only one stop) are highlighted in yellow. It is worth noting that the kinematics and door timings are irrelevant to these tables and would not have any effect on their contents.

Table 1: Morning Peak ISP Table generated using MCS for P=13 passengers.

	Up ISP Table											
Morning Peak (85%:10%:5%)	**Stops**	0	1	2	3	4	5	6	7	8	9	10
	Passengers	improbable	impossible	improbable	improbable	5	6.8333	8.4812	9.7798	11.1658	12.2563	13
	Down ISP Table											
	Stops	0	1	2	3	4	5	6	7	8	9	10
	Passengers	0	impossible	1.0415	2	2.3746	3.163	4.0882	5.0822	6.1225	7.45	improbable

Table 2: Lunchtime Peak ISP Table generated using MCS for P=13 passengers.

	Up ISP Table											
Lunchtime Peak (45%:45%:10%)	**Stops**	0	1	2	3	4	5	6	7	8	9	10
	Passengers	0	impossible	1.3153	2.1511	3.2291	4.3923	5.5713	6.8272	8.2874	9.5912	11.1897
	Down ISP Table											
	Stops	0	1	2	3	4	5	6	7	8	9	10
	Passengers	0	impossible	1.3333	2.1789	3.252	4.4035	5.5681	6.8269	8.2872	9.6075	11.213

4 APPLICATION OF THE METHOD

The aim of applying this method is to place an accelerometer inside the lift car and log the number of stops in the up direction and the number of stops in the down direction in each round trip. The method would use the produced tables (shown in the previous section) to infer the number of up passengers in each round trip (based on the number of stops in the up direction) and to infer the number of down passengers in each round trip (based on the number of stops in the down direction).

An example that shows how this method has been applied to 10 consecutive round trips is shown in Figure 1. It shows the actual number of passengers in each round trip against the inferred number of passengers for each round trip. Generally, the numbers agree reasonably well. However, this is due to the fact that the system has exact knowledge of the mix and intensity of traffic.

Figure 1 was generated during simulation. Further work will include actual site data surveyed.

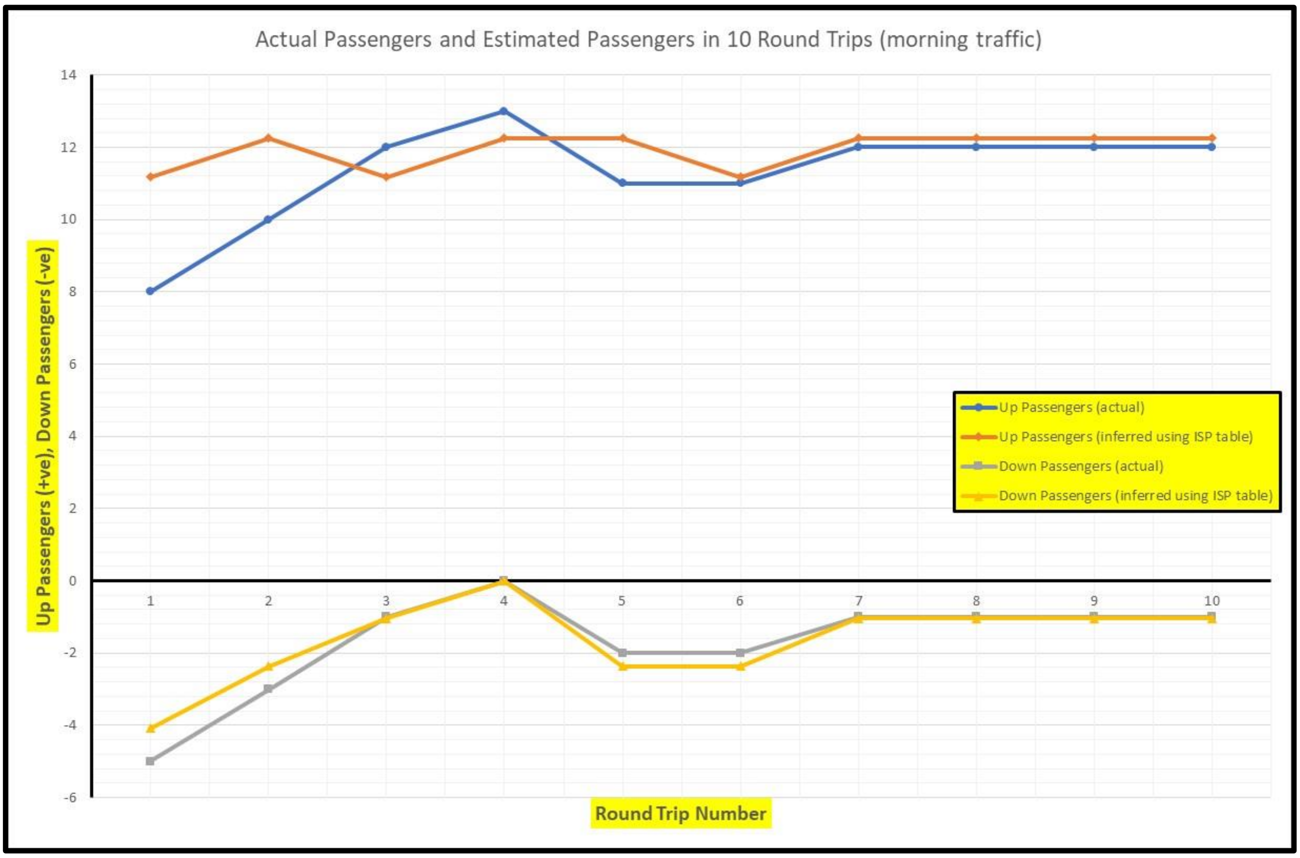

Figure 1 Actual passengers and inferred passengers for 10 round trips.

Another possible application of the method is to have it built within a dispatcher that is linked to the lift controller, that already knows about the stops.

In real life applications, only an estimate of the traffic mix and intensity would be available to the application and the accuracy of the method would suffer.

An alternative would be to develop a "Robust Control" method, where the ISP tables are generated without assuming exact knowledge of the traffic mix and intensity. This will however lead to lower accuracy but will be better than using the tables that assume exact knowledge when the assumption is incorrect. Hence this method would be termed a "Robust" method.

This would be the aim of the application. More details about this are contained in the "Future Work" section at the end of this paper.

5 CONCLUSIONS

The ISP method was developed in order to derive suitable equations that allow the user to infer the number of passengers using the lift in any one direction from the number of stops.

In this paper, the ISP method has been further extended, using the Monte Carlo simulation method, to be applicable to any traffic mix and implemented in order to generate lookup tables that will allow users to infer (a best estimate of) the number of passengers travelling in the lift car in a specific direction based on the number of stops that the car makes in that direction.

The main disadvantage of the method, however, is that it does require an estimate of the intensity of traffic prevailing in the building at the time of the survey, as well as the mix of traffic being split into incoming, outgoing and inter-floor percentages. In cases where this information is not available, it is possible to resort to robust control techniques and develop an ISP table that is independent of the traffic intensity and traffic mix, but which will yield less accurate results.

Although there are other methods that can be used to infer the number of stops and the number of passengers using the lift car, they mainly rely on hardware (e.g., light ray). The main purpose of the ISP method is to simply use an accelerometer inside the lift car to infer the number of passengers.

6 FURTHER WORK

Further work will concentrate on assessing the loss in accuracy that results from resorting to the robust method, as opposed to the error that will result from using the tables that assume exact knowledge and applied under incorrect traffic conditions.

Moreover, for the method to be practical, it must not assume any prior knowledge of the intensity of the prevailing traffic in the building or the mix of traffic. So, another aim of future work would be to develop a method that can be used to estimate the intensity of traffic in the building and the mix of traffic. The overall method would operate by first estimating the intensity of traffic and the traffic mix in the building and then generating and applying the corresponding ISP tables to estimate the exact traffic patterns in the building.

A further study could be addressed to discover the traffic intensities where the number of stops/starts begins to saturate and how much the saturation depends on the number of floors and the car capacity.

Improving the accuracy of the method could also be achieved by considering multiple days in the analysis (e.g., collecting a month’s worth of data and then taking the average of the number of up/down stops in each 5-minute period).

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BIOGRAPHICAL DETAILS

Lutfi Al-Sharif is currently the Dean of Engineering Technology and Professor of Electrical Engineering 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.

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