The Impact of Luggage on Passenger Boarding and Alighting Rates

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1 Introduction

As railways become busier, it becomes necessary to plan to greater accuracy levels, and not just to the nearest minute; this is important both for inter-station running times and for station stop times. It is also important to understand the likely day-to-day variability, in order to make the best decisions about appropriate timing allowances. Allowances for station stops have perhaps historically had less attention than for running times.

Some early work in this field was undertaken by London Underground. In 1989, Weston proposed a series of formulae for the three types of passenger: alighters, "remainers" and boarders, where the "remainers" were those passengers who remained on the train in the vestibule throughout the station stop, without alighting, but using up space which therefore reduced the speed of other passengers' movements.

$$Alighting\ time = 1.5 \cdot \left(1 + 0.9 \cdot \frac{T}{VC}\right) + A^a \cdot DWF$$

$$Interaction\ time = 0.027 \cdot A \cdot B$$

$$Boarding\ time = 1.3 \cdot \left(1 + 0.8 \cdot \frac{T}{VC}\right) + B^b \cdot DWF$$

where A = number of alighters a = alighting power

B = number of boarders b = boarding power

DWF = Door Width Factor (adjusting the door with that of a 'standard' LU tube train)

T = through passengers VC = Vestibule Capacity

The power terms a and b were allowed to vary in different circumstances, but the numerical hard-coded values merely reflected LU conditions. We later discovered that these relationships broke down at very high levels of passenger movement (Harris, 2006); we understood this to reflect the fact that, when there are many alighters, the extra space created in the train enables faster movements of boarders into that space. Over the years, we have sought to generalise this equation to fit a much wider range of types of railway environment.

However, a number of authors (e.g. Weidmann (1992 and others), Heinz (2003), Thoreau et al (2017)) have provided further insights in this area over the years, generally either from theoretical or laboratory-based perspectives. Because station management issues are most acute in urban areas, most research has also been on metro and suburban railways. Over the years, a wide range of factors has been isolated and quantified, in terms of their impacts on passenger movement. These factors broadly cover the characteristics of passengers, rolling stock, platforms, the unperturbed timetable, and day-to-day management.

2 Datasets Available

The Railway Consultancy Ltd (RCL) and RTSC Imperial College London have been collaborating over the years in the development of a database of station stop surveys undertaken to a uniform method, originally based on the method London Underground had used to support their early work. However, this method has now been applied to over 200 locations around the world where observations of actual day-to-day rail operations have been made. This is in contrast to the 'laboratory condition' approach taken by researchers at UCL (London) and in Chile (e.g. Fernandez et al (2015)).

At the critical door at each survey site, we collect information on passenger movements (alightings and boardings, and also the number of people remaining in the vestibule during the station stop), and the time taken for these movements to occur. We also measure the time taken for a number of processes which have to take place during a station stop, including door opening and closing, and despatch. Lastly, we collect a range of information on passenger flow, platform and train characteristics. Each datapoint in our database typically includes a statistically-significant 30 or more observations of trains at the same platform. Wherever possible, if there are mixed train fleets, we have attempted to get 30 observations of each train type.

3 Development of Work Programme and Method

Our previous work has led to two strands of outputs. First, we have undertaken statistical-type analyses of passenger movement rates (e.g. Harris et al, 2014) to derive a series of parameters which reflect factors governing these rates. Secondly, we have undertaken more practically-based work, such as the identification and quantification of sub-threshold delays (e.g. Harris, 2015).

From the former, we have developed a model which enables us to forecast the expected performance of a type of train or station configuration, before construction. Variables for which we have established robust parameter values include some of the variables originally noted by Weston (e.g. the ratios of vestibule load/capacity, and of boarding/alighting passengers) but also others (such as seating density and train:platform stepping distance). This model is already being used by a ROSCO to help inform its specifications for new rolling stock.

In general, the 'expected' values are good forecasts of the measurements taken, but there appear to be three types of error:

(a) When passenger numbers are very small, the error in measuring times is disproportionately large, which introduces an inaccuracy;
(b) When passengers are 'non-standard' (for instance, if there is a high proportion of mobility-impaired passengers);
(c) When passengers are 'too standard'. We notice that, in some cities (typically, but not exclusively, in China) observed movement rates are higher than we would otherwise expect. For many years, we wondered if this was a cultural factor, but (as it is also apparent in a few other cities around the world) we now believe it to be more a function of familiarity with the station and railway network: some railways have fewer infrequent and unfamiliar passengers than others. London Underground once identified that, in their cosmopolitan city of many tourists, 10% of their passengers were not from Britain, whilst another 15% did not live within the M25 (London's orbital motorway), so were less likely to be frequent users. An adjustment for the % of tourists might therefore be a possible development of our work in the future.

However, this paper concentrates on a specific segment of error type (b), namely luggage. One would hypothesise that passengers with larger and/or heavy luggage would take longer to board or alight from trains. This is both because of the extra physical effort involved, and also because restrictions (such as door width) are more constraining. Our hypothesis appears also to be supported by the only other work we have seen which specifically addresses luggage as an issue, which is shown in a couple of diagrams within Heinz's thesis, but only relates to conditions in Stockholm. It was not clear whether her earlier work was of more general application, hence our desire to understand this issue more deeply.

Over the last couple of years, RCL has had the opportunity to test this hypothesis as part of work with several British mainline rail operators to improve train service performance, including at airport stations and on longer-distance routes. Research locations have included London's Gatwick Airport, and on the prestigious East Coast Main Line (linking London with Edinburgh), with surveys undertaken at Grantham, Newark, Durham and Berwick. Although having some local/commuting traffic, these are all inter-city stations, where passengers typically have a greater amount of luggage. Grantham is an interchange point for the holiday town of Skegness, whilst Durham has a large university.

With our detailed observations available to support quantitative analysis, we have also managed to record the quantities of 'large' luggage being carried by passengers, as well on the numbers of boarding and alighting passengers, and the times taken for passenger movement. We defined 'large' luggage as including large rucksacks and suitcases (whether wheeled or not). This data on luggage has been used as the statistical basis for estimating the reduction in passenger movement rates that this causes.

4 Analysis

Our interest in the issue of luggage was piqued during fieldwork, when we noticed passengers with luggage struggling up or down large steps between the train and the platform (a variable about which we had calculated parameters, over two decades ago (RCL, 1996)).

The first stage of our work was then to examine, *within* individual station-level data-sets, the average passenger movement rates between different trains, taking into account the number of passengers encumbered by large luggage.

Analyses for boarding and alighting were done separately and when possible split by platform/direction. Scatter graphs were used to illustrate the relationship between the proportion of passengers with luggage and the respective movement rates for each station observed. Unfortunately, whilst there appears to be some form of relationship (see Figure 1 for an example from Durham), the influence of other variables means that there are no clear correlations, at the level of individual stations.

Stations	*Alighting*	*Boarding*
Berwick	0.12	0.24
Chester	0.24	0.09
Durham (Northbound)	0.08	0.24
Durham (Southbound)	0.11	0.24
Gatwick	0.08	0.23
Grantham	0.11	0.14
Newark	0.08	0.06

Table 1. R^2 Correlation Values of Station-Level Passenger Flow Relationships with Luggage

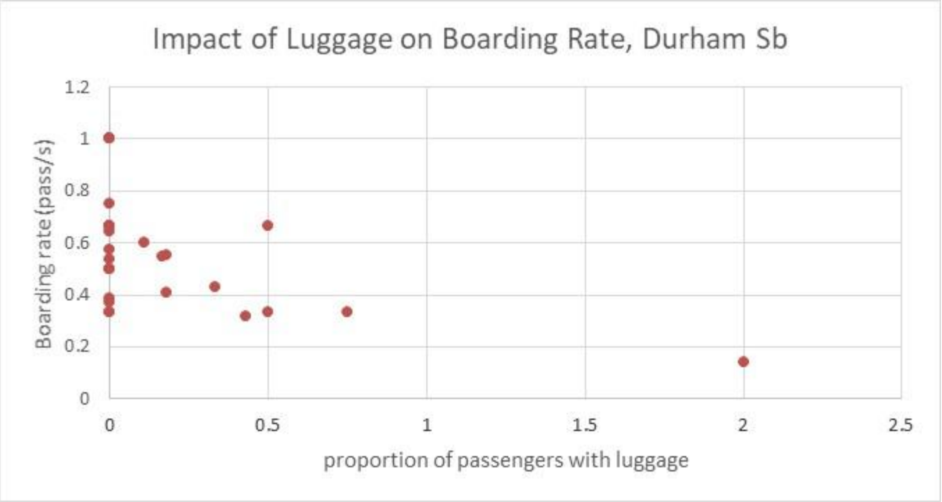

Figure 1. Impact of Luggage on the Boarding Rate at Durham (Southbound platform)

It is also important to note that, whilst most passengers have no large luggage, some of the passengers observed had more than one item of major luggage whilst boarding or alighting. Indeed, on occasions during surveys, some passengers were noted, after lifting a suitcase from train onto platform, to go back into the train to alight with their second suitcase. Individual passenger rates per train will therefore only on average reflect the number of luggage items per individual carried.

In understanding the impact of luggage, it is also important to consider the style/shape of luggage along with its size (see Figure 2), as not all large luggage will affect boarding/alighting rates in the same way. A large hiking rucksack (which is strapped across one's back) may not hinder significantly one's ability to board a train compared to the process of lifting a suitcase onto a train from the platform, since the first occurs in one motion by stepping onto train from the platform.

Figure 2. Different Luggage Types

The second stage of our work was undertaken at a more aggregate level, by comparing station-level datasets where we knew the overall proportion of encumbered passengers. Because commuting is typically the most important journey purpose for railways, and commuters generally travel fairly light, at the majority of stations the proportion of passengers with luggage is only a few %. However, our recent work for British TOCs had enabled us to observe some stations with significantly higher proportions of passengers with luggage, as set out in Table 2.

Station	*% of Encumbered Passengers*
Typical urban/metro	1
Typical suburban railway	3
Berwick	3
Newark	7
Durham	10
Grantham	13
Chester*	26
Gatwick Airport	59

Table 2. Proportion of Passengers with 'Large' Luggage

Source: RCL database *: inter-urban services only

5 Results

Against typical passenger movement rates of around 1 passenger/second, our results suggest that a near-doubling of time may be required to accommodate passengers with ‘large’ luggage, an outcome which has direct relevance to the timetabling of relevant (including airport link) rail services.

	Observed	
Station	*Alighting rate (pass/sec)*	*Boarding rate (pass/sec)*
Berwick	0.55	0.40
Chester	0.45	0.33
Durham (Northbound)	0.72	0.66
Durham (Southbound)	0.60	0.46
Gatwick	0.71	0.62
Grantham	0.50	0.47
Newark	0.42	0.44
Typical British suburban	0.7	0.8
Typical London Underground	0.8	0.9
Typical international metro	1.2	1.2

Table 3. Average Observed Passenger Movement Rates

From Berwick and Durham, our regression of passenger movement rates against the proportion of passengers with heavy luggage showed a very significant relationship of around -0.81; in other words, the rate at which passengers board trains falls by 81% for each item of large luggage they are carrying. However, the reductions in rates at other stations (see Table 4) are somewhat less, which we do not yet understand. Nnevertheless, one hypothesis is that East Coast trains at these locations have considerable space, so the impact of slower passengers is more obvious: at Grantham and Newark (which are much nearer London), most trains are pretty full anyway, so there will be other factors reducing free-flow speeds (e.g. passengers standing in the vestibules).

Stations	Flow rate reduction per large item of luggage		Increase in station stop time per stop (secs)	
	Alighting	Boarding	Alighting	Boarding
Berwick	-34%	-82%	0.1	0.1
Chester	-53%	-37%	2.4	2.8
Durham (N)	-27%	-80%	0.0	0.4
Durham (S)	-33%	-83%	0.2	1.5
Gatwick	-12%	-37%	0.1	3.7
Grantham	-31%	-42%	0.2	0.5
Newark	-11%	-10%	0.1	0.1

Table 4. Impact of Luggage by Station

These highest results are, at first sight, inconsistent with those found by Heinz in Sweden (2003). However, her analysis divided passengers into those with no luggage, and everyone else, whereas ours divided passengers into those with no significant luggage, and those with. It is therefore not surprising that our results show the impact of (large) luggage to be almost twice the impacts she found, since her work included smaller items of luggage.

However, as well as changes in movement rates, the sheer quantity of encumbered passengers also needs to be taken into account. The resulting average impact on station stops here was estimated to be under one second at most stations but 1.5s at Durham Southbound, 2.4s at Chester and as much as 3.7s at Gatwick; note that these averages include observations of train stops where no passengers had luggage. Differences in these impacts related not only to the numbers of passengers involved, but also to the relative difficulty of boarding with luggage, as opposed to alighting with it. Whilst the impact per stop may be small, it should be remembered that the effect of these on the train service is cumulative: even at only 8 trains per hour, the expected total loss of time at Gatwick is half a minute per hour. Such losses are noteworthy in busy railways which are timed to the half-minute (or less), especially as we now have the ability to forecast them.

6 Conclusions

The rising demand for rail services means that railway operators increasingly need to plan station stop times carefully, and this no longer just applies to congested urban environments. The operational research reported here shows that merely acknowledging the expected numbers of passengers is likely to be inadequate, as the impact of their luggage appears to be significant. Passengers with heavy luggage were found to take as much as 83% longer than those without, when boarding or alighting from trains. The effect of the luggage alone can amount to several seconds per train stop, which cumulatively can give problems on busy rail lines, problems which can now be taken into account in advance.

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