TRANSPORT PROBLEMS 2015 Volume 10 Issue 4
PROBLEMY TRANSPORTU DOI: 10.21307/tp-2015-056

Keywords: baggage transfer, modal choice model, mode choice, mixed-mode travel

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MODELLING THE IMPLEMENTATION OF A BAGGAGE TRANSPORT SYSTEM IN NEWCASTLE UPON TYNE FOR PASSENGERS USING MIXED-MODE TRAVEL

Summary. This paper models a proposed system that has the potential to transport baggage. It makes use of a modal choice model to examine how effective the system would be if implemented. The introduction of a baggage collection system would increase the number of passengers using public transport which would be good for the environment. The specific location of the study was Tyne and Wear and a journey from North Shields to Newcastle International Airport was chosen for the analysis. With the introduction of a new utility equation that could analyse mixed-mode travel, a baggage collection hub based in Newcastle upon Tyne city centre offered a significant number of users provided that the cost of the system was either covered in the travel ticket or provided by the airport or airline free of charge. This dedicated baggage collection system would be very expensive to introduce due to the massive amounts of work that would be required to set up the system, however, its ridership would be large therefore it could potentially recoup the development costs.

MODELOWANIE WDROŻENIA SYSTEMU TRANSPORTU BAGAŻY DLA PASAŻERÓW KORZYSTAJĄCYCH Z MIESZANEGO SYSTEMU PODRÓŻY W NEWCASTLE

Streszczenie. W artykule przedstawiony został proponowany model transportu bagażowego. Wprowadzenie systemu zbierania bagażu zwiększy liczbę pasażerów korzystających z transportu publicznego, co w efekcie przyniesie dobre skutki dla środowiska. Do analizy wybrana została lokalizacja pomiędzy Tyne i Wear oraz podróż z North Shields do Newcastle International Airport. Analizowany system zbierania bagażu byłby bardzo kosztowny do wprowadzenia ze względu na ogromne ilości pracy, która jest niezbędna do prawidłowej konfiguracji systemu. Jeśli jednak liczba przejazdów byłaby duża, możliwe jest potencjalne odzyskanie kosztów rozwoju systemu.

1. INTRODUCTION

This report builds on the work done previously titled “How to facilitate the movement of passengers by introducing baggage collection systems for travel from North Shields to Newcastle International Airport” and is a follow on to that work [2]. The motivations and literature to support this paper are contained in the previous work. The modal choice model as well as all supporting equations are introduced in the above paper. The transport systems used are also introduced in the above paper.

Brice et al [1] have done work to design a way to facilitate the movement of passengers from Newcastle city centre to Newcastle International Airport by the way of a baggage transfer system. This system involves transportation of the baggage via Metro (light rail system) to the airport. This would encourage passengers to also travel via public transport.

1.1. Objectives

The objective of this paper is to create a model that could model mixed-mode travel for passengers using a baggage transport system.

2. CHOSEN MODAL CHOICE MODEL

Let us be reminded that the modal choice model developed by Jehanfo and Dissanayake [3] was chosen for this study as it was developed for the area surrounding Newcastle International Airport. For further information and the calculated value of each variable within each modal choice model the interested reader is referred to [2].

3. BAGGAGE ‘CHECK IN’ AND/OR BAGGAGE TRANSPORT SYSTEMS

3.1. Existing systems

Swiss Federal Railways offer multiple domestics services including one similar to the Virgin system mentioned in [2]. The most interesting service they offer is to check in baggage (for certain airlines only) the day before a flight at a rail station. The passenger receives their boarding pass with this service and the cost of this system is CHF 22 which is approximately £15 [8].

Hong Kong Mass Transit Railway also has a system in which baggage can be checked in between 90 minutes and one day before the flight is due to depart [6]. The cost of this system is included in the cost of the train ticket which is HK$100 which makes it approximately £8.50 [7]. There was also a similar system operating on the Bangkok Airport Rail Link in which two airlines offered check in of baggage in Bangkok City Centre between 3 and 12 hours before the scheduled flight departure. This system began in 2011 but was closed in 2014 due to poor user numbers [5]. According to The Nation, this lack of customers was due to a number of reasons including bad accessibility of the stations and the fact that taxis were similarly priced [4].

There are currently no check-in systems of this type available in the UK. For existing systems though it seems that none of them are said to help decrease emissions. They all appear to be focused on increasing passenger convenience, mostly in busy cities. With this observation it is likely fair to conclude that the positive impact on the environment is negligible for these systems if there is one at all.

3.2. Systems to analyse

The system presented in [1] is to be analysed as it was developed for Newcastle upon Tyne. This system is mentioned in Section 1.

4. BRICE’S SYSTEM

4.1. Mixed-mode modelling

As Brice’s system is located in Newcastle Haymarket metro station, to model the system is more complex than the systems modelled previously. It involves a ‘Multi-stage’ trip in which not only can the passenger change modes, but can also make use of the system and change other values within the model. The previous method of modelling is therefore not sufficient so requires some alterations.

'Activity-based modelling', in which linked trips (trips that are linked but not necessarily part of one journey, and the needs of the passenger can change over the different parts of the journey) can be used to model multi-stage trips. Unfortunately, the model in [3], which is used for this study, was not developed for this modelling but instead it was developed for independent trips rather than linked trips. Activity-based modelling prevents unrealistic possibilities from being suggested by the model and shows utilities based on all of the linked journeys. Principles from this can be used with the model in [3] – for example the removal of certain transport modes from the model at certain stages. An example of this is not allowing people to travel from North Shields to Newcastle Haymarket via metro and then from Newcastle Haymarket to Newcastle International Airport via car as this simply does not seem to be how people travel. Therefore a new method of modelling multi-stage trips was needed which could incorporate mixed-mode travel.

A passenger takes the metro from North Shields to Newcastle and on their journey, while stopped at another metro station, they check-in their luggage.

Using the inputs of 20 minutes for travel time, a baggage count of 1 and a household car ownership value of 1, the leisure model gives the following utility for the full journey (without getting rid of baggage mid journey) (using values from Table 1 in particular and using equation 1 from [2]):

$$Utility = 4.05 - 0.03 * 20 - 1.48 * 1 + 0.49 * 1 = 2.46 \tag{1}$$

To gain the total utility for the journey with two legs, the utilities for each leg are not added together as this would give a total utility much higher than the utility for the direct journey. The correct way to do this is to take account for the ratio of time travelled for each leg to the total travel time and multiply the utility values calculated by these ratios.

This gives the following equation:

$$\begin{aligned} TotalUtility = {} & \frac{x_{TT1}}{x_{TT1} + x_{TT2}}(\beta_{01} + \beta_{LUGG1} * x_{LUGG1} + \beta_{HHC1} * x_{HHC1}) \\ & + \frac{x_{TT2}}{x_{TT1} + x_{TT2}}(\beta_{02} + \beta_{LUGG2} * x_{LUGG2} + \beta_{HHC2} * x_{HHC2}) + \beta_{TT1} * x_{TT1} + \beta_{TT2} * x_{TT2} \end{aligned} \tag{2}$$

Applying equation 2 to the problem of travelling with baggage for only one quarter of the journey gives the following result:

$$\begin{aligned} TotalUtility = {} & \frac{5}{15+5}(4.05 - 1.48 * 1 + 0.49 * 1) + \frac{15}{5+15}(4.05 - 1.48 * 0 + 0.49 * 1) \\ & - 0.03 * 5 - 0.03 * 15 = 4.05 - 0.37 * 1 + 0.49 * 1 - 0.03 * 20 = 3.57 \end{aligned} \tag{3}$$

The result from equation 3 shows that the disutility for baggage is one quarter of what it was in equation 1 while everything else is the same which is the result expected – the only change in the two equations is the fact that the person checked-in their baggage. This means that the equation is validated for this case.

This equation does not account for transfers between different transport modes as this requires extra variables which were not added by [3]. This equation will, however, account for travel on two or more modes, often referred to as 'mixed-mode travel'.

One test of this equation is to say there are two transport modes, metro and bus (with different journey times), from point A to point B, and one point half way through the journey where a passenger can transfer between modes. Applying equation 2 to this problem gives a result that is expected – the fastest journeys have the highest utility values.

4.2. System Inputs

As the baggage collection hub is located in the Haymarket metro station, the system could only be used if the metro was used for the second leg of the journey.

For the first leg of the journey a passenger could travel via metro or bus because car (drop off and long stay parking) and taxi would just travel directly to the airport. This is using the principles of activity-based modelling where transport modes that are not sensible are unlikely to be used.

For the second leg of the journey it was decided that a passenger could travel via bus, metro and metro while using the system.

It was decided to treat people who only use a single mode of transport as travelling directly to the airport as there would be no change to any of the inputs into the model. The travel time used in these cases would be the total travel time including any walk time, wait time and any transfer times.

The inputs for the model which modelled a passenger's choice before the system was introduced are presented in Table 1.

The journey times for all modes have been mentioned in previous sections. The added time to the 17 minutes on board travel time for the metro is to account for the walk/metro ride from Newcastle Monument to Newcastle Haymarket metro station as this is where the system is located. This time must be included on the first leg of the journey as the passenger still has their baggage. The walk time for both the bus and the metro for the first leg of the journey were taken as 0, 10 or 20 minutes. This variation was done to attempt to model a range of passengers. The wait times for all public transport modes were taken as half of the headway.

Table 1

Model inputs before the system is introduced

	Travel time	**Wait time**	**Walk time**	**Baggage count**	**Household car ownership**	**Group size**
Car (drop off)	26	0	0	Depends on group size	0 or 1	1 or 2
Car (longstay)	26	0	0			
Taxi	26	5	0			
Metro	42	6	0, 10 or 20			
Leg 1						
Bus (leg 1)	37	7.5	0, 10 or 20			
Metro (leg 1)	25	6	0, 10 or 20			
Leg 2						
Bus (leg 2)	17	15	0			
Metro (leg 2)	19	6	0			

The walk times for both bus and metro for leg 2 were taken as 0 minutes due to the fact that the end point of leg 1 is very close to the start point of leg 2.

The model inputs for for the implementation of the system which modelled a passenger's choice after the system was introduced are shown in Table 2.

Table 2

Model inputs for the implementation of the system

	Travel time	**Wait time**	**Walk time**	**Baggage count**	**Household car ownership**	**Group size**
Metro with system (leg 2)	19	6	0	0	0 or 1	1 or 2

The only difference between the metro with the system and the metro without the system for leg 2 is that the system removes the baggage from the passenger so their baggage count is 0.

The cost of using the system is not given by [1] therefore a nominal cost of £10 was used. This cost would make the system competitive with the preexisting system run by Virgin.

4.3. System Results

The inputs associated with the max change were a walk time of 0, a household car ownership value of 1 and a group size of 2, just as they were for InPost and the Virgin system.

Table 3

Results for modelling the baggage collection hub proposed in [1]

Input into the model	**Average change in probability of using public transport**	**Max change in probability of using public transport**	**Model**
£15000 Income	0.01%	0.01%	Leisure
£20000 Income	0.07%	0.10%	Leisure
£30000 Income	0.48%	0.70%	Leisure
£50000 Income	2.18%	3.21%	Leisure
£70000 Income	4.06%	5.98%	Leisure
No time penalty	15.46%	22.59%	Leisure
5 Minute time penalty	13.98%	20.46%	Leisure

Values from the £20000 income are further analysed as it is approximately the average income per *working* person of the North East. These values were to then be used to find an approximate number of users for the system which is shown in Section 5.

As the results are not as straightforward as with the other systems, the average metro users before the system is implemented will be taken as the passengers who board the metro for the first leg of the journey.

Table 4

Results for an income of £ 20000 and for zero system cost for the baggage collection hub in [1]

	Income £ 20000	Zero cost system
Average metro users before system is implemented (leisure model)	0.3094 (30.94%)	0.3094 (30.9%)
Average uptake of the system (leisure model)	0.0016 (0.16%)	0.351 (35.1%)

5. ANALYSIS

The way in which the system proposed in [1] was modelled was vastly different to how both InPost and Virgin Bag Magic were modelled [2]. However, both the inputs that cause the maximum increase in the probability of using public transport, and the model that this was for, were identical to the InPost and Virgin models.

It is unlikely, however, that the metro would run a dedicated system without the support of Newcastle International Airport. If this system was going to offer the opportunity for passengers to check in (this not explicitly stated by [1], however, it can be assumed that this would be one of the benefits of using the system) then flight providers may be able to offer use of the system within their ticket price, and so the system becomes ‘psychologically free’ and the zero cost model applies.

If flight check in was offered by the system then there would be a utility gain due to the fact that the passenger would not have to wait in queues in the airport. These utility gains cannot be accounted for as they are ‘random utilities’. This does not mean they are not significant as the main reason for using this system would be because of them – this means that the models results for system use are likely underestimates.

The fact that a passenger could travel via metro for the first leg and then transfer to the bus, while being an actual possibility, it is highly unlikely in reality. The model, however, does imply that it is not a bad choice. This is due to the fact that the utility of bus relative to other modes increases as journey time increases. This is simply how the model was designed on the data that was gained by [3]; it does give a large overestimation in bus use.

It is again possible to estimate passenger numbers by taking the values from Table 5 and applying equation 9 from [2] to them then the following ratio of probabilities is gained:

$$RatioOf\ \Pr obabilities = \frac{0.0016}{0.3094} = 0.0041 \equiv 0.41\% \tag{4}$$

This means 24 passengers per year will use the system (based on a current metro ridership to the airport from North Shields of 6000, as worked out in [2]). This is a much smaller number than what was found for both the InPost and Virgin system because the journey takes significantly more time as the passenger not only has to transfer at monument but then has to reach Newcastle Haymarket before getting back on to the metro. Another reason that the value is low is because the baggage is removed part way through the journey so the utility benefit of this is only realised for a minor portion of the trip.

Just because the passenger value of using the system is low for North Shields, this does not mean it would be so low for stations closer to the system location – and especially for the city centre stations which experience both the highest volume of passenger traffic and much lower travel times.

If the passenger numbers are analysed relating to the system cost being set to zero, then the passenger numbers are:

$$RatioOf\ \Pr obabilities = \frac{0.351}{0.3094} = 1.134 \equiv 113.4\% \tag{5}$$

This means 6804 passengers will use the system per year. This value of passengers is certainly significant and equates to approximately 18 passengers per day. As this value is for one station and there are many more stations much closer to the system, then the zero cost results suggest that there could be demand for a dedicated system.

Compared to both the InPost and Virgin systems, implementing this dedicated system comes at a large cost. It would involve work on Haymarket metro station and Newcastle International Airport station to accommodate the trains that would carry the baggage and accommodate the system that would handle the baggage. This increased cost however would be offset by the larger user base. The fact that it is a centrally located hub introduces the notion of economies of scale – and so transport costs per bag would be much lower for Brice's system than for both courier systems.

6. CONCLUSION

Passengers with an income of £20000, which is the average income per working person in Tyne and Wear, were shown to make use of both courier based systems, and were shown to favour these systems much more than a dedicated baggage collection system based in Newcastle upon Tyne if the costs of using both system were similar. However, if the system cost is zero, or if the system cost is included in a travel ticket, then a passenger shows that they will use any system in much greater numbers. This was deemed unlikely for a courier based system, however, for a dedicated system it is certainly a possibility and in this case the dedicated system is the system that increases public transport ridership the most.

To analyse the dedicated baggage collection system, a new equation was proposed to calculate the utility values and this allowed multi stage trips (or mixed-mode trips) to be analysed. This new equation allowed more transport combinations to be analysed in an attempt to increase the accuracy in the estimation of the number of users of the system.

7. FURTHER WORK

The mixed-mode analysis caused a new equation to be derived. This equation could be used to analyse an ‘onboard system’ so a passenger would check in their baggage while actually on the transport. This would require changes to the rolling stock, however, this could prove to be a cheaper alternative to introducing a dedicated collection hub and would prove to be much faster than the system proposed in [1], increasing utility and thus increasing the probability that a passenger would use it. A system of this sort would be the first of its kind.

The model itself could be made more complicated by introducing all of the systems at once and even integrating them to reduce costs. The InPost and Virgin model could be made more complicated by introducing the mixed-mode equation to them.

In any new modelling, a better way to assess value of time should be sought to make the modelling more accurate. This should include increased value of time for walking, especially for baggage, as passengers tend to value travel time less than walk time.

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Received 12.02.2015; accepted in revised form 03.12.2015