

**Keywords:** baggage transfer; modal choice model; mode choice

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## HOW TO FACILITATE THE MOVEMENT OF PASSENGERS BY INTRODUCING BAGGAGE COLLECTION SYSTEMS FOR TRAVEL FROM NORTH SHIELDS TO NEWCASTLE INTERNATIONAL AIRPORT

**Summary.** This paper reviews current systems that either transport baggage or have the potential to transport baggage, as well as proposed systems, before modelling some of them in a modal choice model to examine how effective they would be if implemented. It was hoped that 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. The system proposed is compared to an existing systems known as InPost and Virgin Bag Magic. It was found that for the average passenger in North Shields, a system based on the way InPost operates would offer the greatest utility. However, 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 more 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 much more expensive to introduce compared to the InPost system as the infrastructure to run the InPost system is already in place, however, the ridership of the newly proposed system would be much larger therefore it could potentially recoup the development costs.

## JAK UŁATWIĆ PRZEPLYW PASAŻERÓW WPROWADZAJĄC SYSTEMY KOLEKCJONOWANIA BAGAŻY OSÓB PODRÓŻUJĄCYCH Z NORTH SHIELDS DO MIĘDZYNARODOWEGO PORTU LOTNICZEGO W NEWCASTLE

**Streszczenie.** W artykule dokonano przeglądu bieżących systemów stosowanych do transportu bagaży, lub mających taki potencjał, oraz proponowanych systemów. Spodziewano się, że wprowadzenie systemu zbierania bagażu zwiększy liczbę pasażerów korzystających z transportu publicznego. Takie rozwiązanie byłoby dobre dla środowiska. Miejscem wykorzystanym do analizy był obszar pomiędzy Tyne i Wear, podróż z międzynarodowego lotniska North Shields w Newcastle. Zaproponowany system został porównany do istniejących systemów znanych jako InPost oraz Virgin Bag Magic. Stwierdzono, że dla przeciętnego pasażera z North Shields, system oparty na działaniach InPost jest najbardziej użyteczny. Jednak wraz z wprowadzeniem nowego systemu, który może analizować podróże w trybie mieszanym, skoncentrowanie

zbierania bagażu z siedzibą w Newcastle dałoby dostęp znacznie większej liczbie uczestników, pod warunkiem że koszt systemu zostałby zawarty w bilecie podróży lub podróż z lotniska oferowana byłaby bezpłatnie. Wprowadzenie dedykowanego systemu kolekcjonowania bagażu byłoby znacznie droższe w porównaniu z systemem InPost, jednak biorąc pod uwagę to, że liczba przejazdów korzystających z zaproponowanego systemu byłaby znacznie większa, koszty poniesione na wprowadzenie systemu mogłyby zostać zwrócone w niedługim czasie.

## **1. INTRODUCTION**

### **1.1. Motivation**

In 2014, in the UK, car traffic increased by 1.5 percent and total traffic increased by 2.1 percent, compared with 2013 [19]. This increase in traffic causes a decrease in average speed, and thus makes journeys longer. This not only makes travelling less enjoyable, but it can also have a negative effect on the economy. If passengers chose to travel on public transport rather than in private cars, congestion would decrease. It is, therefore, desirable for people to take public transport instead of driving.

This increase in traffic also causes a significant increase in carbon emissions, and with sustainable private transport modes still in relatively early development, a way to reduce these carbon emissions would be for people to use public transport. One way that this can be done is to allow passengers to have their baggage transported separately so they no longer have to carry it while travelling.

Daniel Brice, another student from Newcastle University, has 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 [3]. This system involves transportation of the baggage via Metro (light rail system) to the airport. It was hoped that this would encourage passengers to also travel via public transport. The problem with this system is that there is only one location for passengers to drop their baggage off, and this may be in a different direction to the airport, so it does not facilitate the movement of all passengers. It may be of more use to have a system that could be located closer to people's homes.

### **1.2. Objectives**

The objective of this paper was to identify why passengers travel on specific transport modes and then identify how public transport's modal share can be maximised through use of a system that would facilitate the movement of these passengers as close to the start point of their journey as necessary. The location of the system would very much depend on what system was being analysed. It was hoped that the 'best' system would be found that both increased passenger numbers on public transport and reduced emissions.

### **1.3. Expected Outcomes**

It is expected that: the most suitable type of collection system will be found based on the affect the system has on public transport ridership; that public transport modal share will increase with the introduction of a collection point meaning that the system is beneficial; and that from the modal choice models, limitations will be found and the passenger type that is most likely to use the system will be found.

## **2. LITERATURE REVIEW**

Transport choice is dependent on the 'utility' of a transport mode and a passenger will choose the mode that gives the highest utility. Utility is a function dependant on the transport mode (for example:

travel time and the cost of travel), and the individual (sometimes called random utility; it is called this due to the fact that some of these factors are unknown or unaccounted for, and errors are also accounted for) [20].

Utility of a transport mode is given by the following equation:

$$U_{1n} = V_{1n} + \varepsilon_{1n} = \beta'_{1n} x_{1n} + \varepsilon_{1n} \quad (1)$$

U = the utility of transport mode 1; V = the 'systematic' component of utility for transport mode 1;  $\varepsilon$  = the random utility (comprises of error as well as unmeasured factors) for transport mode 1;  $\beta$  = vector of unknown parameters related to transport mode 1; x = vector of attributes related to transport mode 1

The subscript 'n' refers to the individual [8].

The main, measurable factors that many models are based on are travel time as well as transport cost. It is sometimes appropriate to convert everything to a cost, so to convert travel time to a cost by multiplying it by a unit salary. This is mainly useful when dealing with simplistic models that do not account for socio-economic characteristics.

There are a number of reasons why these models are developed, though typically models are used to predict the impact a new system will have on the overall demand on transport services [20].

There is also much work carried out in modelling how passengers travel to airports. Jehanfo and Dissanayake (2009) developed a disaggregate model of transport modal choice for travel to Newcastle International Airport. A disaggregate model was used to "give a better behavioural interpretation for passengers' mode choices" by creating new variables [8]. One such variable was baggage count. It was found that variables such as the amount of baggage, as well as the typical variables like cost and time, have a significant impact on transport mode chosen for a journey to the airport.

Disaggregated data is when data is placed into groups. Examples of groups include gender, socio-economic status and reason for travel (business or leisure). Disaggregated data will then show where there are patterns of behaviour – which therefore means that transport modal choice models are best off being made with disaggregated data.

A paper from the International conference on Travel Behaviour Research states that different people have different ideas of what factors drive modal choice, but that the factors can be split down to three categories: system, situation and person [9]. System refers to the mode of transport and refers to its accessibility, price and frequency amongst other things. Situation refers to the journey and encompasses the purpose of the trip, the distance, whether the passenger has any baggage as well as many other factors that could affect their choice of transport. Person refers to the behaviour of the person and why they make their choice – these are often hard to quantify.

When factors like baggage are taken into consideration they are significant factors in modal choice [2]. Although it is desirable to account for baggage in a modal choice model, the ability to move baggage has improved since the first models were made, due to wheeled suit cases and the like, so historic models may not be appropriate.

A modal choice model that does not account for factors that are hard to quantify (specifically comfort, safety and reliability) will not be valid if one of these factors were to change [6]. This can be furthered to include baggage; therefore, a model that accounts for baggage is necessary if that is what is going to change if a new system is introduced.

### 3. CHOSEN MODAL CHOICE MODEL

The creation of a bespoke modal choice model was unlikely to be successful due to time constraints therefore an existing model would be used. The model presented in [8] was chosen as it was developed for the area surrounding Newcastle International Airport. Although the model is from 2009, it is still fairly representative of modal choice in 2015 due to the fact that none of the systems have significantly changed in that time.

The data gained in [8] found that both travel cost and travel time are the best variables that explain a passenger's modal choice to an airport, however, it was found that travel time was a more sensitive variable so that is the only variable of the two to feature in the model. Variables for baggage count, household car ownership and size of access group were also included as they improved the model.

The model considers five different ways of travelling to the airport (four different modes):

- Taxi;
- Car (drop off) – Dropped at the airport by somebody else driving a car;
- Car (long stay) – Leave the car at the airport car park;
- Metro;
- Bus.

Multiple models were developed in [8] to describe different market segments:

- **Basic model** – This model describes all of the data that was taken from the survey.
- **Leisure models** – This model describes the modal choice behaviour of a passenger travelling for leisure.
- **Domestic passenger or international passenger** – These models describe the modal choice behaviour of a passenger travelling within the UK or travelling internationally. Both models have a variable for baggage so both were used further.
- **Income group 1 (<£20 000)** – This model describes the modal choice behaviour of people with an income less than £20 000.

Table 1 shows all of the values of the variables for each model. All variables are given the symbol  $\beta$  as seen in equation 1, however, all have a different subscript according to what variable they are and what mode of transport they represent.

List of subscripts used:

- 0 – Refers to alternative specific constants.
- TT – Refers to travel time.
- LUGG – Refers to number of bags the passenger is carrying.
- HHC – Refers to household car ownership.
- GRP – Refers to access group size.
- Car do – Refers to car (drop off).
- Car ls – Refers to car (long stay).
- Metro – Refers to metro.
- Taxi – Refers to taxi.

There are no subscripts that refer to bus. This is due to the fact that all beta-values (named so due to their symbol) for bus were set to zero. This means that bus was taken as the reference mode of transport for which every other modes utilities and probability of use would be compared to.

In the domestic passenger model, car (drop off) and car (long stay) are combined to 'ensure sufficient statistical responses'.

When the model was developed, the travel time,  $x_{TT}$ , was calculated via AutoRoute (discontinued mapping service) for either car or taxi. For public transport, however, the travel time was taken as the perceived time it took the passenger to travel to the airport, including walk and wait time. This was gained within the survey that gave the data to create the models. The other x values are just the relative numbers of that variable. For example, if there is one piece of baggage,  $x_{LUGG} = 1$ .

The individual being modelled is always assumed to choose the utility that is highest, however, there are uncertainties involved in the calculation, as seen in equation 1. If it is assumed that the difference between these uncertainties is logistically distributed then the following equation, proposed by Ben-Akiva and Lerman (1985), can be used [1]:

$$P_{1n} = \frac{e^{V_{1n}}}{\sum_j^n e^{V_{jn}}}, e \approx 2.718 \quad (2)$$

$V_{1n}$  = the 'systematic' component of utility for transport mode 1;  $P_{1n}$  = the probability of choosing transport mode 1; The subscript 'j' refers to all modes of transport; The subscript 'n' refers to the individual.

Table 1

Value of each variable within each modal choice model

|  | Variable                   | Basic model | Leisure model | Domestic passengers model | International passengers model | <£200 00 model |
|--|----------------------------|-------------|---------------|---------------------------|--------------------------------|----------------|
| Alternative specific constants         | $\beta_{0\text{cardo}}$    | 1.8         | 1.82          | 2.64                      | 2.15                           | 1.02           |
|  | $\beta_{0\text{carls}}$    | -1.83       | -1.91         |                           | -1.05                          | -2.79          |
|  | $\beta_{0\text{taxi}}$     | 1.4         | 0.91          | 3.14                      | 1.59                           | 0.28           |
|  | $\beta_{0\text{metro}}$    | 4.01        | 4.05          | 5.34                      | 3.9                            | 3.54           |
| Travel time service variable           | $\beta_{\text{TTcardo}}$   | -0.09       | -0.08         | -0.08                     | -0.08                          | -0.1           |
|  | $\beta_{\text{TTcarls}}$   | -0.04       | -0.03         |                           | -0.05                          | -0.04          |
|  | $\beta_{\text{TTtaxi}}$    | -0.06       | -0.04         | -0.12                     | -0.06                          | -0.05          |
|  | $\beta_{\text{TTmetro}}$   | -0.05       | -0.03         | -0.1                      | -0.04                          | -0.04          |
| Baggage dummy variable                 | $\beta_{\text{LUGGcardo}}$ | 0.58        | -0.12         | 0.84                      | 0.21                           | 1.05           |
|  | $\beta_{\text{LUGGcarls}}$ | 1.03        | 0.67          |                           | 1.08                           | 1.5            |
|  | $\beta_{\text{LUGGtaxi}}$  | 1.01        | 0.5           | 0.83                      | 0.95                           | 1.41           |
|  | $\beta_{\text{LUGGmetr}}$  | -0.93       | -1.48         | -1.29                     | -0.99                          | -0.72          |
| Household Car Ownership dummy variable | $\beta_{\text{HHCcardo}}$  | 1.58        | 1.29          | 0                         | 2.05                           | 1.67           |
|  | $\beta_{\text{HHCcarls}}$  | 1.73        | 1.28          |                           | 2.17                           | 1.56           |
|  | $\beta_{\text{HHCtaxi}}$   | 0.9         | 0.58          | 0                         | 1.39                           | 0.87           |
|  | $\beta_{\text{HHCmetro}}$  | 0.55        | 0.49          | 0                         | 1.29                           | 0.79           |
| Access group size dummy variable       | $\beta_{\text{GRPcardo}}$  | -1          | 0             | -0.52                     | -1.15                          | -0.99          |
|  | $\beta_{\text{GRPcarls}}$  | -0.64       | 0             |                           | -1.01                          | -0.45          |
|  | $\beta_{\text{GRPtaxi}}$   | -0.79       | 0             | -0.54                     | -1.04                          | -0.73          |
|  | $\beta_{\text{GRPmetro}}$  | -0.52       | 0             | -0.18                     | -0.84                          | -0.68          |

When these probabilities are worked out for both before and after the system has been implemented, they can be compared to examine what impact the system has on public transport use.

#### 4. MODES OF TRANSPORT

To take a bus from North Shields to the Airport requires a transfer in Newcastle city centre. The 306 was chosen for the first leg because the vehicles used are Wright Streetlite Micro-Hybrids buses which are said to be 8% more efficient than their closest rivals in class [10]. As one of the motivations for this report is to decrease carbon emissions, this bus is the best out of the three. The X77/X78 bus service was chosen for the second leg to the airport.

Table 2

Summary of bus travel times and headways

| Bus     | Travel time | Headway                      |
|---------|-------------|------------------------------|
| 306     | 37          | 15 (for majority of the day) |
| X77/X78 | 17          | 30                           |

According to Google Maps, to travel via car from North Shields town centre to Newcastle International Airport takes around 26 minutes although this does fluctuate according to the time of

day. This value of travel time is the same for car (long stay), car (drop off) and taxi, although a taxi would also incur a nominal five minute wait.

The Tyne and Wear Metro is the North East’s light rail system. The system has 2 lines and has 60 stations [18]. Both North Shields and Newcastle International Airport have a metro station, however, they are not directly connected (on different lines; see Figure 2). This means that a passenger can either travel from North Shields to Monument on the yellow line and then transfer onto the green line and travel to the airport or they can travel from North Shields to South Gosforth on the yellow line and then travel to the airport on the green line.

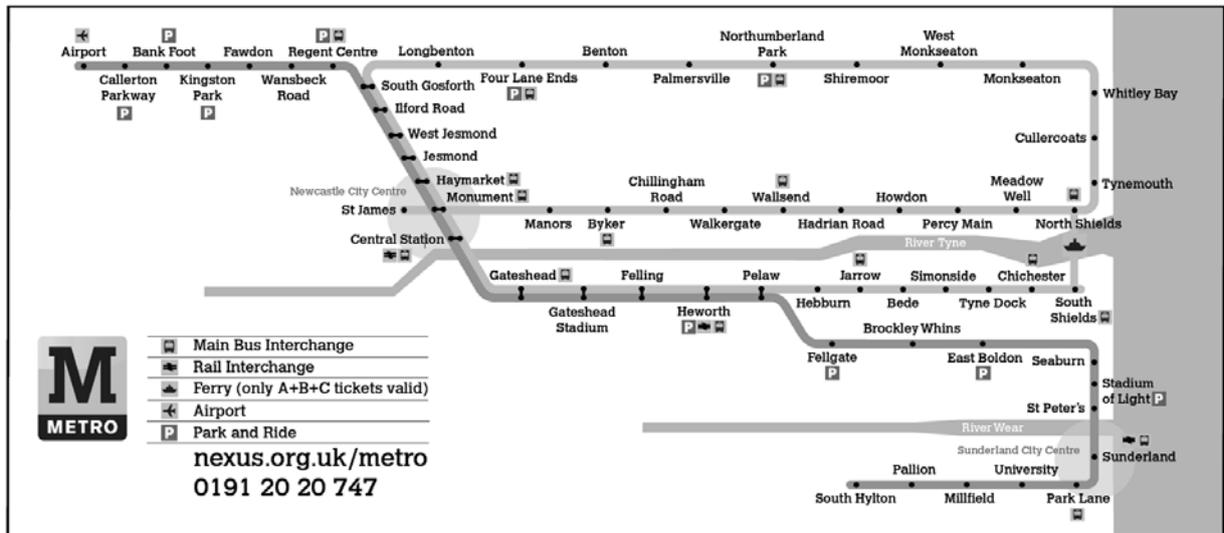


Fig. 1. Map of Tyne and Wear Metro system [17]

Rys. 1. Mapa systemu metra: Tyne i Wear [17]

Table 3

Summary of metro travel times and headways

| Metro  | Travel time | Headway                      |
|--|-------------|------------------------------|
| North Shields – South Gosforth – Newcastle International Airport     | 42          | 12 (for majority of the day) |
| North Shields – Newcastle Monument – Newcastle International Airport | 42          | 12 (for majority of the day) |

Data collected by Wales and Marinov (2015) presented in [7] as well as data collected by Montraghi and Marinov, presented in [5] has been used. This data showed that the average journey time for either route was 42 minutes, hence it does not really matter which way a passenger travels (Table 3).

## 5. BAGGAGE ‘CHECK IN’ AND/OR BAGGAGE TRANSPORT SYSTEMS

### 5.1. Existing systems

There are multiple different systems by which it would be possible to ‘check in’ baggage and meet it at the destination. One such system is a system run by Virgin called ‘Virgin Bag Magic’ [12]. This system involves a courier which picks up the baggage the day before travel so the baggage is delivered to meet the passenger at the destination. The cost for this system during the week is £10. Another similar system called ‘InPost’ works in the same way except a courier can pick it up at an InPost locker upon arrival. This system currently has restrictions on baggage size but if there was demand it may be possible to expand the size limits. The costs for InPost vary according to size but for the largest size (41x38x64cm) it costs £6.50 [22]. This system is also currently only for domestic use.

## 5.2. Systems to analyse

The best systems to analyse for this study would be the following:

- An InPost system using a courier for the pickup;
- The Virgin system already available.

## 6. MODELLING THE SYSTEMS

### 6.1. Value of Time

Before modelling the systems it was necessary to try and account for the disutility associated with the cost of the system itself. Although it is stated in [8] that cost and time could not be modelled together in the model – this is the cost of the transport itself. Clearly the introduction of the system will cause a change in the model.

Clearly there will be an associated wait with any of the systems; however, it was believed that the disutility was far greater than this wait. The main way to account for this was to incorporate the cost of the system into the model. It is said in a document published by the National Institute of Justice that a time difference can be converted into a cost by multiplying it by a function of hourly wage/price [16]. This model is based on time rather than cost, so it is possible to multiply the cost of the system by a function of wage/time to obtain the same effect.

Lioukas (1982) found that passengers in Greece valued time up to a value of 97% of the wage rate for business travel versus up to 26% of the wage rate for non-business travel [4]. It was confirmed in [23] that non-work time is viewed around the same value in the UK as it is in Greece. For a minimum approach, non-working time is valued at 0.3 x Household income (per head) – which is very similar to what Lioukas (1982) found [23].

It was also stated in [23] that consideration should be given to the journey purpose. It is logical to assume that somebody travelling to the airport to catch a flight will value time more than somebody going shopping. To account for this a value of 0.3 x wage rate was used.

To convert the cost of the system to an equivalent ‘system time’ requires use of the following equation:

$$EquivalentSystemTime = \frac{CostOfSystem}{\frac{YearlyIncome * 0.3}{37.5 * 52}} * 60 \quad (3)$$

The denominator in Equation 3 converts yearly income into an hourly time value. When the system time has been calculated it should be added to the total travel time in the model.

### 6.2. InPost System

The current InPost system needs to be altered slightly for it to work with a passenger’s baggage - an InPost locker would need to be placed at Newcastle International Airport so that the passenger could pick up their baggage before check-in. The benefit of using this system would not be that the passenger could check in early, but it would be that the passenger could travel freely without their baggage. The InPost locker would also need to be changed slightly to accommodate a suitcase. Given current InPost locker sizes, and average suitcase sizes, the size of locker would be 80x38x64cm and given the relationship between size and cost for the existing lockers, to use this size locker would cost around £7.80.

A passenger would only use this system in combination with the metro because this is the mode with the largest negative value for the  $\beta_{LUGG}$ . It would also be possible to use this system with the bus but there would be no increase in utility because bus is the reference mode. The system increases

utility by removing baggage from the passenger, hence if the  $\beta_{LUGG}$  value is negative, one less piece of baggage would increase the utility of that mode by an amount equivalent to  $\beta_{LUGG}$ .

Because a passenger can travel via metro both with the system and without the system, the model requires the addition of a new mode. Because the model is a logit model it is easy to introduce a new mode provided that all of the  $\beta$  values are easy to estimate which they are here as the transport mode remains identical. This means that all that is required to introduce the new mode is to include the utility for the new mode in the probability equation [13].

Quite often in modal choice modelling, the introduction of a new mode introduces a problem involving the 'Independence of Irrelevant Alternatives (IIA)' property of logit models. A basic explanation of this property says that the odds of an individual choosing mode 1 over mode 2 are independent of the characteristics of any other modes [14]. An example of this property is the 'Red Bus / Blue Bus' scenario which seems to be not logical as the company may decide to paint one of its buses blue to attract more passengers. The IIA property is not a negative thing in this case, however, as when the system is introduced it will likely take passengers from all other modes and keep the probability ratios (or odds) roughly the same.

### 6.2.1. InPost Model Inputs

The inputs for the model which modelled a passenger's choice before the system was introduced were the following:

Table 4

Inputs for the model

|                        | Travel time (on transport) | Wait time | Walk time   | Baggage count         | Household car ownership | Group size |
|------------------------|----------------------------|-----------|-------------|-----------------------|-------------------------|------------|
| <b>Car (drop off)</b>  | 26                         | 0         | 0           | Depends on group size | 0 or 1                  | 1 or 2     |
| <b>Car (long stay)</b> | 26                         | 0         | 0           |                       |                         |            |
| <b>Taxi</b>            | 26                         | 5         | 0           |                       |                         |            |
| <b>Metro</b>           | 42                         | 6         | 0, 10 or 20 |                       |                         |            |

The travel time (on transport) are the values found in Section 4. The total travel time,  $x_{TT}$ , is the on board travel time added to the wait and walk time. The wait time for metro was taken as half of the headway. The models for public transport were developed using perceived journey times while these inputs are actual journey times but there is no obvious way to account for this difference.

The walk time to the metro station was taken as 0 minutes, 10 minutes or 20 minutes to give a range. It was thought that the maximum time a passenger would walk would be approximately 20 minutes – any greater and the passenger would use a different station or different transport mode.

Household car ownership was taken as either 0 cars or 1 car as this covers over 85% of the population of Tyne and Wear.

Group size was taken as either one person or two people as information from the UK Civil Aviation Authority says that this range covers over 80% of all journeys from Newcastle International Airport [11]. The group size also determined the baggage count as it is assumed in this case that each passenger carries one item of baggage. The walk time, household car ownership and group size were varied to provide a 12 different 'passenger profiles' – and then the results from these were to be averaged to attempt to represent an average passenger.

It would be of interest to do a range of incomes to examine what difference the system would make to public transport use for passengers with average incomes compared to people with higher incomes. The model was applied to 5 different incomes between £15000 and £70000 in the increments given by Her Majesty's Revenue and Customs. This range represents almost 70% of the population of the North East of England [21].

The model was applied to study the system having no time cost which implies there is no disutility associated with using the system at all. The model was also applied to study the system having

a 5 minute time cost as the only disutility – where the five minutes is the total time it takes to use the system.

The inputs for the model which modelled a passenger's choice after the system was introduced are shown in Table 5 and are a combination of Table 4 plus an extra mode.

Table 5

Extra mode showing the inputs to model the system

|                          | Travel time (on transport) | Wait time | Walk time   | Baggage count | Household car ownership | Group size | System time    |
|--------------------------|----------------------------|-----------|-------------|---------------|-------------------------|------------|----------------|
| <b>Metro with system</b> | 42                         | 6         | 0, 10 or 20 | 0             | 0 or 1                  | 1 or 2     | See equation 3 |

The total travel time,  $x_{TT}$ , is the 'on-board' travel time added to the wait time, walk time and system time. Note that the baggage count is 0 as the system has taken the baggage from the passenger.

### 6.2.2. InPost Model Results

After all of these inputs were modelled, the results shown in Table 6 were gained when the new mode was introduced.

Table 6

Results for modelling the InPost system

| Input into the model  | Average change in probability of using public transport | Max change in probability of using public transport | Model   |
|-----------------------|---|---|---------|
| £15000 Income         | 0.26%   | 0.43%   | Leisure |
| £20000 Income         | 1.18%   | 1.94%   | Leisure |
| £30000 Income         | 5.59%   | 10.05%  | Leisure |
| £50000 Income         | 13.96%  | 21.87%  | Leisure |
| £70000 Income         | 20.12%  | 30.74%  | Leisure |
| No time penalty       | 45.50%  | 62.76%  | Leisure |
| 5 Minute time penalty | 44.58%  | 61.96%  | Leisure |

The whole of public transport was taken into account as the objective is to increase public transport ridership. The average change shown is the average of the 12 different combinations of inputs for that specific income/penalty. The max change shown is the maximum change of those 12 combinations of inputs. The model associated with those values is shown in the model column. 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. Values from the £20000 income are further analysed due to the fact that the average income in the North East of England is around this value [21]. The results are shown in Table 7. These values were to then be used to find an approximate number of users for the system which is shown in Section 7.

Table 7

Results for an income of £20000 for the InPost system

|  |                 |
|--|-----------------|
| Average metro users before system is implemented (leisure model) | 0.2605 (26.05%) |
| Average uptake of the system (leisure model)                     | 0.0203 (2.03%)  |

### 6.3. Virgin Bag Magic System

The Virgin system modelling is almost identical to the InPost modelling except that the cost of the system, and hence system time cost, is calculated a little differently. This system would require a baggage storage area to be placed at Newcastle International Airport so a passenger could pick up their baggage before check in. Like the InPost model, the Virgin Bag Magic system will only be used in combination with metro for the reasons given in section 6.2. This does require the addition of a new mode to the model which is not a problem due to the reasons given in section 6.1.

The cost of using this system is £10 for one bag, or £17 for two bags. This means that for a group size of 1, equation 3 is used to work out the system time. For a group size of two the following equation must be used:

$$\text{EquivalentSystemTime} = \frac{1.7 * \text{CostOfSystem}}{\text{GroupSize} * \frac{\text{YearlyIncome} * 0.3}{37.5 * 52}} * 60 \quad (4)$$

This equation is used as the cost of the system for a group size of two goes from £10 to £8.50 (per passenger) – and due to the assumption that each passenger has the same value of time, this new equation applies.

#### 6.3.1. Virgin Bag Magic Results

The inputs for this model are shown in Table 4 and Table 5. After all of these inputs were modelled, the results shown in Table 8 were gained:

Table 8

Results for modelling the Virgin Bag Magic system

| Input into the model  | Average change in probability of using public transport | Max change in probability of using public transport | Model   |
|-----------------------|---|---|---------|
| £15000 Income         | 0.12%   | 0.25%   | Leisure |
| £20000 Income         | 0.63%   | 1.30%   | Leisure |
| £30000 Income         | 3.33%   | 6.35%   | Leisure |
| £50000 Income         | 11.23%  | 19.41%  | Leisure |
| £70000 Income         | 17.53%  | 28.63%  | Leisure |
| No time penalty       | 45.50%  | 62.76%  | Leisure |
| 5 Minute time penalty | 44.58%  | 61.96%  | Leisure |

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. The further analysis of £20000 income gave the results shown in Table 9.

Table 9

Results for an income of £20000 for the Virgin Bag Magic system

|  |                 |
|--|-----------------|
| Average metro users before system is implemented (leisure model) | 0.2605 (26.05%) |
| Average uptake of the system (leisure model)                     | 0.00998 (1.00%) |

## 7. ANALYSIS

### 7.1. InPost System analysis

For all incomes used in the model, the leisure passenger model always gave the highest probability of using public transport when the system was introduced. This is due to the fact that when a piece of baggage is removed, the utility of the transport mode goes up by that transport modes'  $\beta_{LUGG}$  value. When the system time is introduced, it reduces the utility. So it is possible to say what the system time would actually have to be to offset the utility gain:

$$\text{SystemTimeToDecreaseOverallUtility} = \frac{\beta_{LUGG}}{\beta_{TT}} \quad (5)$$

The system times were found for metro (the only mode for which the system could be used with) for each model using the  $\beta$  values from Table 1:

- Basic model system time = 18.6 mins
- Leisure model system time = 49.3 mins
- Domestic passenger model system time = 12.9 mins
- International passenger model system time = 24.75 mins
- <20000 Income model system time = 18 mins

These results show that it would clearly be leisure passengers who would make use of the system as the relative time gain of dispatching one piece of baggage in advance is so large compared to other types of passengers, and so the actual system cost can be higher. This could be because, say, compared to strictly domestic passengers, a leisure passenger is in less of a rush as their flight check in window may be larger.

It is clear from Table 6 that as a passengers income increases, their likelihood of making use of the system also increases. This is due to the system time introduced in section 6.1. One problem with this is that the model itself does not account for income. A passenger with a higher income may be less inclined to travel on public transport and the model does not account for this.

The zero cost system time output gives the highest likelihood of making use of the system. Zero cost represents: infinite income or the system is free to use or the system is 'psychologically free' to use. The first two are self-explanatory, however, the system being 'psychologically free' requires more thought. If the system is 'psychologically free' it means that the passenger does not think of the cost when travelling. One way that this may be so is if the system cost is included in an airline ticket. The passenger does not individually pay for both services, so may not think of the baggage system as a cost. This outcome is unlikely to happen with InPost as it is a separate entity with no ties to an airline, so it is likely a passenger would account for the cost in full when choosing their transport mode.

The inputs that were placed into the modal choice model that caused the largest change in the probability of using public transport were:

- Walk time = 0 mins
- Group size = 2
- Household car ownership = 1

The walk time should be minimal as increased journey time decreases utility, so the lowest walk time will give the highest utility.

As household car ownership increases, utility increases for all modes except bus which has a fixed utility of 0. When the system is introduced, the total probability increase is larger for a household car ownership of 1 because, although the actual probability of using public transport is lower, the probability increase of using the metro with the system relative to using the bus is larger than with a household car ownership of 0.

Group size does not influence the leisure model directly as shown in Table 1, however, it does influence the baggage count. Although a higher baggage count does decrease the overall probability of using public transport, the total increase in probability of using public transport is higher for a higher

baggage count. This is because the system removes more baggage, so the utility of travelling via metro with the system increases relative to the other modes. This increase is larger for higher baggage counts.

To try to understand the scale of the system, passenger numbers were estimated based on North Shields's population, passengers heading to the airport from South Hylton, and South Hylton's population. South Hylton has around 1750 passengers that travel to the airport each year and has a population of approximately 10000 people compared to North Shields which has a population of approximately 40000. This implies that North Shields could have four times the amount of passengers travelling to the airport each year; approximately 7000. The value of 7000 passengers can then be used to estimate how many would use the system if it was introduced. At about 64.4% of journeys are made for leisure purposes while another 21.3% of journeys are made visiting friends or family. If it is assumed that the leisure model presented in [8] includes both of these journey types, then the leisure model covers 85.7% of journeys. This equates to approximately 6000 passengers that would travel from North Shields to Newcastle International Airport.

The results given for passengers with an income of £20000 in Table 7 show that as a ratio, the probability of using the system to the probability of using metro before the system is introduced is equal to:

$$\text{RatioOf Probabilities} = \frac{0.0203}{0.2605} = 0.0779 \equiv 7.79\% \quad (6)$$

As the probabilities are averages out of all of the twelve different sets of inputs, then the probabilities can be said to approximately represent passenger numbers. This implies that the number of people that will use the system is 7.79% of the number of passengers that use metro to travel from North Shields to Newcastle International Airport, or 467 passengers per year.

This value is a fairly low value given that it is just over 1 passenger per day on average. To run a dedicated system with a value like this would not work, as discovered in Bangkok (see section 5.1). InPost, however, is not a dedicated system and already does work to InPost boxes around Tyne and Wear. The added cost to the couriers would be minimal due to route optimisation used by them, so this extra business would come at minimal cost due to the bulk of the infrastructure already existing.

The weakness of this model is that it assumes that the passenger in question knows about every single system which is not true in the majority of cases. Probabilities are therefore used to indicate if it is likely for a person to choose the system with the highest utility.

## 7.2. Virgin Bag Magic System analysis

The Virgin Bag Magic model is basically identical to the InPost system except that the cost is different and is applied slightly differently. The similarities mean that the comments made about InPost also apply to Virgin. Because of the similarities, the leisure model again gives the largest increases in probability of travelling by public transport. The inputs into the model that cause the maximum increase are also the same, however, because of the different way that cost is applied to a group of 2, an increase in group size influences the model more for Virgin Bag Magic compared to InPost. Comparing the two, with a walk time of 0 minutes and a household car ownership value of 0, the following results are gained:

- InPost: use of metro + system probabilities
  - Group size of 1 = 0.0268
  - Group size of 2 = 0.0360
- Virgin: use of metro + system probabilities
  - Group size of 1 = 0.00123
  - Group size of 2 = 0.00509

It is clear then that ratio of group size 2 to group size 1 is much higher for the Virgin Bag Magic system than it is for the InPost system. This means that the system would appeal more to a larger group size.

Overall, compared to InPost, the probability of travelling by public transport is much reduced for the Virgin model due to the fact that the system cost is higher. It is worth mentioning that this system is already running and already has the capability of transporting baggage whereas InPost does not, so the cost associated with the Virgin model is not an estimation but is one that Virgin actually use – this implies that the estimation for the InPost cost may be an underestimation.

The Virgin system cost could be included in the cost of a flight ticket at some airports as Virgin Atlantic is a part of the ‘Virgin Group’. This is not the case at Newcastle International Airport as no Virgin Atlantic flights run from this airport.

Both models are correct as the results for ‘no time cost’ are identical for both InPost and Virgin models (Table 6 and Table 8).

Passenger numbers can be estimated like they were for InPost. Taking the values from Table 9 and applying equation 9 to them then the following ratio of probabilities is gained:

$$\text{RatioOf Probabilities} = \frac{0.00998}{0.2605} = 0.0383 \equiv 3.83\% \quad (7)$$

This puts the number of passengers using the system per year at 229. This number is less than half of the number of users of the InPost system meaning that if both systems were introduced at the same time, Virgin would be far less competitive. This system does, however, operate virtually identically to the InPost system, so it could still be introduced as all that would be required is storage space and the courier could quite easily absorb this business with minimal cost implications.

The results with both InPost and Virgin systems suggest that there is a disutility associated with having to pack their baggage early and to get it to a courier. This disutility was not accounted for in the model; instead it is done in terms of cost.

## 8. CONCLUSION

This paper looks at existing and proposed systems for baggage collection and transport systems and at the possibility to then model them using a modal choice model. The results of this paper suggest that baggage collection systems are already operating globally and, although they do not yet exist in the UK, there would be passengers willing to use them. Passengers with an income of £20000, which is the average income per person in Tyne and Wear, are shown to make use of both systems in study; InPost and Virgin Bag Magic, suggesting that these systems are both viable.

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Received 23.11.2014; accepted in revised form 26.11.2015