A Study by Product Design into the Potential for a Check-In and Bag Drop Service On-board Light Rail Vehicles for Passengers Travelling to the Airport

Abstract

It appears that nowadays rail vehicles are not the primary choice of transportation for people going to the airport. The inconvenience of carrying luggage on railways deters passengers, who look for alternatives. Attempts have been made to encourage passengers to travel to the airport by rail. However major limitations in these existing systems suggest a need for extensive work and alterations. This would increase the price, discourage passengers.

This study investigates the potential for implementing an on-board check-in and bag drop system onto rail vehicles. By observing the Tyne and Wear Metro, the benefits and limitations of installing such a facility have been explored, by the development of suitable operations and interior designs.

Four designs which meet the design criteria were produced and their limitations considered. This study concludes in that the potential for an on-board check-in and bag drop facility is realistic. Each design brings key benefits and limitations, and all meet security, and health and safety criteria. A feature incorporated into all designs allows for the equipment to be removed easily and stored away helps in a low cost and versatile approach.

Key words: Metro, Rail vehicles, Check in desk, Passengers, Baggage

1. Introduction

With the growing problems of increasing congestion on the roads and carbon emissions, new ways to travel are being investigated which are more efficient, environmentally friendly, and economical. Metro railway services are a viable solution to this problem. However, the majority of the public currently take a preference for travelling by car [or road] [1] and it is therefore the aim to encourage people to use the metro services more by offering a genuine incentive.

In busy cities, light rail can provide a reliable and direct service to airports. In 2015, the UK saw an estimated 250 million passengers arriving and departing the national airports per day [2]. These figures highlight a key factor causing congestion on the roads. It is therefore important to address this issue by looking into new ways in which passengers can be transferred. Most established airports are served by a rail facility. However, these rail facilities are not fully utilised, particularly by passengers carrying luggage. An extract from a recent presentation on the logistics of baggageless transportation quoted ‘as long as the railway system is not able to replace the car boot, it will not be as successful’ [3]. The difficulty of carrying luggage on public rail services deters people from using this form of public transport [4] and therefore it is common for passengers to opt for an alternative where baggage is able to be stowed away allowing the passengers to travel more easily. It is therefore important to investigate the potential for new rail facilities which offer improved incentives for passengers travelling in and out of the airport.

The Tyne and Wear Metro is a light rail service, operated by Nexus, which serves much of the population of the North East. There are over 70 stations, including one at Newcastle International Airport. The vehicles are poorly equipped for passengers travelling to the airport with luggage. It provides no storage for baggage and has an internal layout which is difficult to navigate with luggage. This results in passengers opting for alternative modes of transport when travelling to the airport. As a result the Metro is poorly utilised, and a significant revenue generating opportunity is lost.

Using Tyne and Wear Metro as a case study, this study looks into solving the inconvenience of carrying luggage on rail vehicles. It will do this by investigating the potential for implementing an on-board check-in and bag drop facility. This study focusses on the interior product design needed to operate such a service on-board a rail vehicle, and the various designs and equipment that would be required. Requirements for safety and security are considered within this study. The external operations, technology and other facilities needed have also been evaluated and are introduced in this report. This facility is a new concept, and therefore this study is intended to develop a major breakthrough in the understanding of whether this idea could be both beneficial and feasible.

Through the production of visual 3D digital models and investigations into the way the Tyne and Wear Metro vehicles would need to operate, the objective for this study is to investigate whether a luggage drop off facility could be implemented on a light rail vehicle without major changes to the pre-existing construction. By considering the key benefits and limitations highlighted by this study, conclusions have been drawn about the potential of this new and innovative idea and hence whether the introduction of this facility could be feasible in Newcastle and elsewhere.

2. Motivation

In this current age, alternative options for transport are being explored to counteract the increasing production of carbon emissions through excessive use of petrol and diesel powered vehicles. In 2015, car traffic grew by a further 1.1% from 2014, reaching the highest levels since 2007 [5]. This continuous increase in car traffic is a significant contributor to the high concentration of carbon emissions, particularly with in city centres, whilst also creating major congestion on the roads. Travelling by road is becoming extremely unreliable due to the unpredictability of journey and arrival times due to excessive traffic. A mode of transport which provides solutions to these issues is electric powered trains and metro vehicles. Whilst road users account for 71% of transport carbon emissions, railway companies account for less than 1.8% [6]. Railway vehicles are able to transport several passengers per single journey during which the vehicle produces a negligible amount of carbon. This mode of transport removes vehicles from the road and contributes to the reduction of carbon emissions and road congestion. Particularly during peak times of travel, many commuters resort to travelling by rail out of choice. Rail provides an extremely reliable service, as the trains are efficiently organised to operate so that traffic is non-existent and therefore actual journey times are more predictable. This provides assurance to the passenger that destination times will be met and thus is a more suitable mode of transport when punctuality is vital.

Following the opening of the Tyne and Wear Metro in 1980, further extensions were made to the line and in 1991 the service was extended to Newcastle International Airport [7]. The Tyne and Wear Metro now provides a rail service for an expansive population in the North East of the United Kingdom, with stations located in Newcastle upon Tyne, Sunderland, North Shields and Newcastle International Airport. Despite this, full utilisation of this facility was not made. Since the introduction of the Tyne and Wear Metro operations, a decline in passenger flows has been observed with the metro scores being amongst the lowest in terms of operated passenger capacity in relation to network size [8]. Increasing the number of passengers that use the Tyne and

Wear Metro would have a positive impact on the requirement to reduce both carbon emissions and road congestion. One suitable way to do this would be to encourage passengers to use the metro when travelling to and from the airport. It is thought that whilst the current metro provides a service to Newcastle International Airport, the operations and interior design of the airport metro cars is not suitable or convenient for those passengers travelling with luggage. This therefore deters people from using the service and instead resorts to automotive transport.

Travelling to the airport can be a stressful and expensive experience. For most people, the preferred mode of transport for airport transfer is automotive by use of car or taxi. This is particularly typical for those passengers travelling with luggage. The ability to travel hands free is the main reason for the preference to travel by car or taxi as large suitcases can be stored in the boot of the vehicle and handling of the luggage is kept to a minimum. These modes of transport can be costly. Travelling by car can result in paying for the long stay car park facility provided by most airports. In the case of Newcastle International Airport, using such a facility can cost in excess of £80 per week. Travelling by taxi can also be associated with extremely high costs, particularly for those that live further away from the airport. In the case of someone living in Sunderland, a return taxi journey to Newcastle International Airport can exceed £100. It is to those passengers wishing to travel to the airport but wanting to avoid these high transfer costs that a more affordable but still convenient option may appeal to. The Tyne and Wear Metro can provide a suitable mode of transport for people travelling to the airport as it is both cheap and reliable. Despite this, the use of the metro is avoided due to the inconvenience of having to carry large luggage on a public transport service. Travelling to Newcastle International Airport by road can be unreliable due to excessive congestion, particularly during peak times of rush hour. Although the metro avoids this issue, overcrowded metro carriages is another factor that discourages passengers to use this facility as boarding the metro with baggage is currently impractical, particularly in the case of a family with several suitcases.

3. Existing Systems

3.1.Virgin Bag Magic

Virgin Bag Magic is a service introduced by Virgin Trains. From £31.67, a courier can collect a passenger’s suitcase from their house and deliver it to any UK destination. This service removes the need for passengers to carry a heavy suitcase with them and provides for more pleasant travel. Knowing that the train journey can be made without luggage; that they will not have to struggle to store it or worry about leaving it out of sight, provides peace of mind and reduces concerns for the customer. By using this facility, passengers can leave their house, travel by public transport and arrive at their destination without their suitcase. This offers the added benefit for more opportunities such as upon arrival heading straight to a business meeting or restaurant without the need to drop off any luggage at the hotel beforehand. Such a system could be adapted to the Tyne and Wear Metro to help encourage passengers to use the metro service by removing the issue of passengers being hindered by their luggage.

Whilst this service seems an adequate solution to the issues raised, it does have some major drawbacks. In the case of people travelling unexpectedly last minute, this service would not be available as suitcases are required to be collected from the person’s home one day in advance. There is a disutility associated with passengers having to pack their luggage early and therefore this makes this service unsuitable. Another limitation with this service is that it cannot be used when travelling abroad. Therefore those passengers that are flying to a destination outside of the UK, this service is not suitable and is currently therefore extremely limited in terms of its global availability. Finally, the most important restriction with this facility is the cost. With this provision costing over £30, in some instances, the fee matches that of the train ticket and therefore result in a 100%

increase in the cost of the journey rendering the Bag Magic facility less of a prudent choice. In a study conducted by Daniel Reece, Virgin Bag Magic was seen as a facility which would be better utilised providing the costing was reduced or even free [9].

3.2.InPost

Inpost is a service in which people can send a parcel and have it delivered to one of many national global lockers positioned across Europe. A postage stamp can be printed online and attached to the parcel before either being handed to the courier or by placing the parcel in one of the available lockers. The parcel is then transported to the required destination in which it is then stored in a locker, ready for the recipient to collect. The use of this facility can be related to that of a baggage handling system. Passengers travelling to destinations abroad can use the facility to post items to a location near to their hotel to therefore remove or reduce the number of items they are to carry and thus allow them to travel light [10].

The InPost service works similar to that of Virgin Bag Magic however it has the added benefit of the delivered item being collected at an InPost locker at any time. Issues arise in that the maximum dimensions for the parcel are limited at 38cm x 38cm x 60cm which equates to a small suitcase. Such a facility can therefore not be used for large heavy luggage which is the main issue when it comes to the impracticality of carrying luggage on public transport. Furthermore, when posting abroad, the minimum number of days to deliver is on average 6 days which would require advance preparation in sending an item. As stated in Daniel Reece's study of Virgin Bag Magic, such a system which requires early packaging is not advocated by most passengers and therefore the InPost service would be highly impractical.

3.3.Hong Kong in town check-in

Several baggage handling services have been erected in different cities across the world in the attempt to encourage people to use public transport when travelling to the airport. An example of a system like this is the Hong Kong in town check-in. Passengers are able to check in their luggage in the city centre before then being able to travel hands free for the remainder of the day leading up to the departure of the flight. The checked in luggage is then transported as freight via a separate train which carries the luggage to the airport to be loaded onto the aircraft. Passengers can then spend the day exploring the city and then continue to the airport without luggage and proceed straight through to security thus avoiding excessive queues to check in bags. This facility offers a great incentive to use public transport as, it minimises the time required by the passenger to be at the airport before flight departure whilst also allowing passengers the freedom to travel without baggage. Though people, particularly those with higher incomes, may have insisted on using a taxi or car to travel to the airport, they are now provided with a viable option to use public transport that provides benefits that taxis and cars cannot offer. By encouraging more people to travel by public transport, the stress of being stuck in traffic against time constraints and the costly fees for parking and taxi fares are removed. In addition to the physically demanding task of manoeuvring bags through turnstiles, up and down stairs and between crowds of fellow passengers is eliminated [11]. Furthermore, this facility costs just $13 U.S which is cheaper than other forms of transport and to many may seem financially viable.

An initial downfall with this facility is the issue that passengers are required to travel to the city centre with their luggage. This would therefore necessitate passengers to travel, for part of the journey, with a form of luggage and thus the inconvenience of carrying a suitcase on public transport has not been entirely removed. There is also the potential for extended travel time in that passengers would be required to depart via the city centre public transport service in order to check in their bags. The reality is that it may have been quicker and more direct to travel straight to the airport. For people that are located closer to the airport than that of the city centre station, there exists the possibility that they would have to travel away from the airport and into the city centre in order to first check in their bags which would seem counterproductive and add more time to the journey.

3.4. Baggage Collection Hub at Haymarket Station

A study was conducted at Newcastle University in which a baggage collection system was modelled to observe whether such a system, similar to that of the Hong Kong in town check-in facility, could be implemented with the Tyne and Wear Metro. The idea was that a baggage collection hub would be located in the Haymarket metro station [9] [12] in which passengers could check in and drop off their luggage before proceeding to Newcastle International Airport.

When analysing this model, an estimate of just 24 passengers per year travelling from North Shields were calculated to use this facility out of a current metro ridership of 6000 [12]. This value is extremely low and shows a much lower utilisation of the facility than that estimated for Virgin Bag Magic or the Inpost service. The main reason for this low estimation of passengers was found to be due to the need for passengers travelling from North Shields to transfer metro line at Monument station and then depart at the following station (Haymarket station) in order to check in their luggage. The need for multiple alights is incredibly inconvenient for passengers, it adds to the journey time, it is awkward with heavy and multiple baggage and is not a relaxing way to travel. It would appear that, direct travel on the metro to the airport station, being able to avoid multiple manoeuvres of luggage on and off the vehicle would lend itself better to customer convenience. Cost is another factor highlighted that contributed to the low utilisation of the facility by the passengers. The study found that when setting the cost to zero, the number of passengers that would use the baggage collection hub out of the 6000 metro riders increased by 113.4% [12]. This shows that there is a demand for such a system; however, it would require to be considered low cost to the user or deemed as psychologically free by including the price within the flight or metro ticket. This challenge may be difficult as such a facility would be extremely expensive to provide, with major works being required on the infrastructure of the metro at both Haymarket and the Airport station. Changes to the current signalling would have to take place and several new employees would be required which would all contribute to the need for a significant financial investment. With a small number of passengers estimated to use this facility, the price to use such a system would have to be considerably high in order to fund this concept.

3.5. Baggage Transfer System using Tyne and Wear Metro

The potential into the possibility of the Tyne and Wear Metro being used to transfer baggage by running a pendulum freight train system between the Haymarket and Newcastle Airport was investigated by event based simulation in a study that took place at Newcastle International Airport [13].

The results of this study stated that the metro vehicles could be used with a capacity of 9750 bags across 26 freight train journeys. This gave a potential for the metro to transfer 61,125 bags per day and thus it was concluded that the metro had the potential to be enabled to transfer freight. This study supports the opportunity for the metro to carry large quantities of luggage and therefore installing an on-board bag drop facility, in which luggage could be stored on the metro, has the possibility to be created into a working and successful facility.

3.6. Melbourne Airport Monorail Interior Design

Whilst new external facilities which help remove any luggage from a passenger is beneficial in encouraging the use of public transport services, having an interior design on board the metro which is suitable for accommodating passengers carrying large bags is also fundamental. Currently the Tyne and Wear Metro is inappropriately designed for passengers travelling to the airport with luggage. The metro contains no storage on board and narrow walk ways, which make carrying luggage through the metro a daunting task. This in itself could be a major factor that contributes to why passengers prefer to travel to the airport by taxi or car. Therefore the interior design of the metro must also be addressed.

Figure 1: Proposal for the Interior Design for the Melbourne Airport Monorail [14]

An example where the interior design has been considered is in the proposal for a high-capacity automated monorail to Melbourne Airport, Australia [14]. The design produced for the internal layout of the monorail has considered the high capacity for passengers with baggage, as seen in Figure 1. The use of longitudinal seats have been integrated in the design which provides open space and makes it easier to manoeuvre luggage through the vehicle and creates space in front of seated passengers making it possible to place any luggage by their feet. Hanging straps and vertical rails have also been used to provide safety for passengers that are standing. This internal design would encourage people to use this rail service as a means of travelling to the airport and therefore these design features should be carried forward into the Tyne and Wear Metro.

If considered in isolation, upgrading the internal design may not be sufficient to see a significant increase in the utilisation of the Tyne and Wear Metro, when traveling to Newcastle International Airport. There remains the inconvenience of having to handle and maneuverer a suitcase on public transport. It should therefore be considered to combine a baggage collection facility with an upgraded internal design within the metro.

3.7.Tyne and Wear Metro

The metro is made up of two services called the Yellow Line and the Green Line. The Yellow Line operates a service from St. James to South Shield Station whilst the Green Line operates from South Hylton to the Airport Station, as seen in Figure 2. For this study, the Green Line service will be observed. A metro vehicle leaves from South Hylton every 12-15 minutes depending on the time of day [15]. Nexus stated the turnaround time at both South Hylton and the Airport Station should not exceed 10 minutes.

Figure 2: Map of Tyne and Wear Metro Rail Service [36]

The main factors that influence the demand for the metro are the population, GVA (Gross Value Added), road fuel costs and impacts on congestion. Currently, the North East has a growing population with an increase of 2.2% from 2001 [16]. The GVA has seen a massive 90.8% increase in the North East since 1997 [17] whilst petrol has gone from 28.2p per litre since 1980 (when the metro operations began) to over 110p per litre [8] and congestion, as discussed earlier in the report, is increasingly becoming an issue particularly in the city centre. Based on these facts there should be an increasing demand for the metro, however, the utilisation of the metro is not maximised and therefore has the potential for a greater ridership. Further incentives should be made to encourage the use of the Tyne and Wear Metro which can be done by installing facilities for passengers travelling to the airport to accommodate those carrying luggage.

In the document Metro Strategy for 2030 [8], it states that there is a continued growth in passenger numbers forecasted by the airport operator with the number of passengers travelling to the airport being the highest growth in percentage terms. This passenger growth supports the concept that there is a necessity to consider the upgrade required to better accommodate those travelling to the airport. It is clear that people are already willing to use the service to travel to the airport; therefore incorporating more facilities to incentivise passengers travelling with baggage would greatly increase the ridership of the Airport metro.

Compared to other light rail services within Europe, the Tyne and Wear Metro has one of the highest seating densities. This does not reflect the fact that in the Nexus study, most passengers travel on the metro for a total of 10 minutes and therefore do not necessarily require a seat. This therefore demonstrates the potential to remove seats within the carriages to better accommodate passengers travelling to the airport with luggage. In the case of the Edinburgh Tram, the seat density was dropped to just 1.8 (compared to the Tyne and Wear Metro's of 2.3) to accommodate for storage space required for Airport traffic [8]. This is something which should be considered for the Tyne and Wear Metro as doing so would encourage airport passengers to use the metro service whilst also offering an increased capacity.

By 2025, Nexus is aiming to have produced major upgrades and modifications to the existing metro rail service currently in place. The regeneration process for the metro has been called 'The Metro Reinvigoration' programme which has been sectioned into three phases.

Phase one involved upgrades into the ticketing and gating programme surrounding the metro. This phase has been completed. Meanwhile, Phase 2 is currently in process and aims to complete modifications to the track, building, systems and stations. Refurbishment of the tracks is focused around the city centre, the refurbishment of 45 station is in process and upgrades in the communications and signalling systems are to be conducted. As this work has already commenced, it may not be viable to look at installing baggage collection schemes at stations in Newcastle city centre. Such a system would require further upgrades to the infrastructure and signalling which would be difficult to fund at this late stage. Within Phase 2 a significant condition assessment has been conducted on all 90 of the metro cars which determine them suitable for continued operation into the 2020s. By this time new considerations will need to be have been made for a new fleet and improved capacity.

Phase 3 of the programme will consider the renewal of the fleet. The aim for Nexus is to have the new fleet operating by 2025. It therefore seems appropriate for any new systems, relating to passenger travel to the airport, be commissioned and installed in line with this major upgrade [8].

Currently the metro is a fully driver-operated vehicle with automatic train protection in which emergency brakes are applied if a signal is passed at red. Feasibility studies have been carried out by Nexus regarding the potential to implement a driverless system for the Tyne and Wear Metro [8]. These investigations concluded that a driverless system would not currently be viable. The facility currently operating is reliant on extensive signalling, which supports only fully driver-operated vehicles.

3.8.Newcastle International Airport

Newcastle International Airport is the largest airport in the North East. It operates out of one terminal building and operates with 20 different airlines. Since 2010, the number of passengers that utilise the airport has grown from 4.34 million to 4.54 million per year [18]. This statistic also shows that there can be as many as 12,500 passengers per day using the airport which contributes to road traffic and therefore the need for an incentive for these passengers, to use the metro service, should be provided. This volume of air traffic passengers is not insignificant and demonstrates that there should be greater numbers of passengers utilising the metro service than currently exists. Therefore a need to support adaptation of the metro to accommodate passengers travelling to and from the airport, which would significantly increase the ridership and generate more money towards the facility, is clearly demonstrable. The increasing number of passengers shows the need for change to the metro to facilitate better transportation for these passengers. If the metro fails to meet these needs, then the service to the airport will not be fully utilised and will waste potential.

The metro station located at Newcastle International Airport provides stair free access into the airport terminal thus making transporting luggage from the platform a simple task. The station is also equipped with a sheltered roof top which can help protect luggage from bad weather conditions.

4. New Service

Through the review of the systems already in existence and the analysis of the data collected from studies, a new service has been considered that could apply to the Tyne and Wear Metro. This proposal is believed to solve the issue of poor public transport utilisation when travelling to the airport, whilst addressing the limitations of the existing solutions discussed. The solution is to investigate the potential of implementing an on-board check-in and bag drop facility for passengers travelling with luggage to the airport. Specifically for this study, the ways in which a light rail service would be required to operate to facilitate this new concept will be stated, whilst the necessary equipment and the functionality and layout of the interior of the railway vehicle will be assessed through the study of the current Tyne and Wear Metro vehicles and operation. Such a facility would allow passengers to check in their luggage upon boarding and therefore enjoy the majority of the journey without any baggage. This study will specifically look at the interior product design of the on-board check-in and bag drop facility and investigate how such a facility could be retrofitted into the existing Tyne and Wear metro cars using a variety of unique designs displayed as visual 3D digital models.

This new idea offers many incentives that other modes of transport and existing facilities cannot provide. A great deal of time is saved due to the fact that the time taken to travel to the airport and check in luggage is combined into one journey hence making the time required for the mundane procedures prior to the departure of the flight minimal. Any anxieties of excessive queues at the check in desks inside the airport terminal are also eliminated as passengers that use the on-board check-in and bag drop facility are able to proceed straight through to security upon arrival and so offering an appealing incentive to passengers of all incomes.

Major regeneration to the infrastructure and stations is avoided by locating the check-in and bag drop facilities inside the metro vehicle. Initial scoping suggests this option to be low cost in terms of installation and hence the service offered to passengers could be competitively priced to make it a financially viable option for customers.

Furthermore, the on board check in service would allow passengers to immediately check in their baggage upon boarding the metro vehicle and hence remove the need to depart mid-way to check in luggage, in the case of bag drops located at one specific station, and allowing passengers to travel without luggage on their person.

This study aims to test the true capabilities of this facility and assess whether these initial beneficial factors could be viable options that could be put into practice depending on the discoveries made through the development of this study.

5. Methodology

The identification of the requirements, characteristics, market research and facilities available for this study was conducted using a road mapping technique. This provides a framework to help tackle the fundamental questions that apply to this study [19] thus clearly demonstrating the aims.

By observing the design and operations of the current Tyne and Wear Metro vehicles through both desk top research and first hand visits to Nexus metro depot, and through the exploration into the existing facilities in place and technology available, several design solutions for the interior of the Tyne and Wear Metro cars have been developed. This has been done using both new and existing equipment and alternative methods of operation to facilitate the on-board check in and bag drop system.

Various equipment, operations and interior layouts were considered before then producing a selection of sketches displaying alternative designs. Following evaluation of these designs, a selection of final designs, which were deemed as reaching the criteria set, were selected to be modelled and analysed.

The final designs selected have been created as a 3D digital model using Autodesk Inventor to give a visual display of the unique on-board check-in and bag drop systems. An accurate original 3D model of the existing design of the metro to be modified was produced before the new designs were implemented into this model. These 3D digital models can then be used to give a clear and realistic picture of the setup of the facility on the metro. This helps to provide a reliable report which offers assurance in the functionality of the design idea.

Through using design evaluation techniques and considering public opinion surrounding the designs produced, the potential of an on-board check-in and bag drop facility have been discussed to provide valid conclusions for the designs and to obtain the benefits and limitations of this concept.

Mechanical validation has been conducted to show that the metro has the capability to facilitate the designs produced in terms of their functionality, layout, size and weight to provide further evidence that such a facility could be installed and to provide support to the conclusions of this study.

6. New Service Development

6.1. Design Criteria

In order to produce a set of suitable solutions as to how an on-board check-in and bag drop facility could successfully function, a collection of key criteria were acquired through the literature reviewed and experts contacted over the course of the study. The design criteria had a clear objective about the important factors in the development of the design solutions and thus ideas could be produced around this criteria set and the importance presented within the study. By taking the sum of the scores, a percentage weight for each design criteria could be produced based on the importance given. This provides a clear display of the level of consideration each criterion should be given towards the designs and operations, and assists with final evaluations of the products. Table 1 shows the key criteria and the influential importance they acquired.

Design Criterion	Importance (1 low, 5 high)	Weight (%)
Performance	5	14.7
Economical	5	14.7
Versatile	5	14.7
Safe	5	14.7
Secure	5	14.7
User Friendly	4	11.8
Robust	3	8.8
Aesthetically Pleasing	2	5.9

Table 1: A table showing the design criterion set for this study

Performance (5) - It is vital for the designs to provide maximum performance in the facility provided. This included optimising the volume of luggage which the designs can accommodate, providing a wide range of facilities for passengers to utilise and operating in an efficient manner.

Economical (5) - The solutions produced must have a heavy weighting for the costs required to implement an on-board check-in and bag drop facility for rail vehicles. Designs should be realistic in relation to the technology and equipment required whilst the more economical options should be favourably considered. The lower the cost of installing this facility onto rail vehicles, the cheaper the service can be provided to the customers. This subsequently attracts more users of this service and overall will generate greater revenue for the operators which will enable the check-in service to be subsidised.

Versatile (5) - Cognisant of the current Metro Strategy, the designs must be developed in conjunction with the current infrastructure, systems and vehicles in place. By developing solutions which can be adapted to the existing operations and vehicle designs, a more valid, assured and cheaper design will be produced. The designs should attempt to minimise the impact on the current capacity and layout of the metro vehicle to minimise disruption to passengers and the operations and thus ensure customer acceptance of this facility and allow the metro to efficiently operate as usual. It is important that as many customers as is feasible are able to be comfortably accommodated within the carriages. Improved customer satisfaction will lead to an increase in public interest and further uptake of this service.

Safe (5) - Alongside any new design, safety of staff and customers are paramount if a design is to be accepted and developed. Ideas which create uncertainty surrounding the safety of any person must not be further considered.

Secure (5) - Security of the luggage is a necessity in the solutions designed for this study. Any doubt inferred from possibilities of the luggage being tampered, lost or stolen will deter passengers from using the check-in facility. Whilst extensive security checks may not be possible in the solutions produced, alternative options should be considered and attempted to aid in the assurance of both luggage and thus passenger safety.

User Friendly (4) - In terms of the customers, using this facility should be equally as straightforward as checking in luggage at an airport. The idea is to attract passengers by offering a stress free service with beneficial attributes a car or taxi provides. Consideration must also go into the ease of use of the equipment for the members of staff to retain employee satisfaction and ensure high productivity, good customer service and efficiency in the operation of the equipment. Furthermore, it is important that staff members are not required to carry out overly strenuous tasks which could result in injury; Health and Safety Regulations must be considered. Where economic viability, versatility, safety or security factors are significantly impaired due to user friendly functionality, priority should always be given to these more important criterions.

Robust (3) - Equipment which contain heavy luggage and is transported frequently must be able to withstand different environments and have the robustness to be able to withstand knocks, outdoor conditions during transportation to the metro vehicles and heavily loads. Whilst this is an important feature to be considered, a complete assessment of the robustness of such equipment cannot be completed until a prototype of the proposed solutions can be manufactured.

Aesthetically Pleasing (2) - It is required that equipment used and the setup of the facility is visually appealing to customers as it reflects a user friendly and quality service which initially attracts customers. The main focus of this study is focused on looking at the potential for a check-in and bag drop facility to function on-board a rail vehicle. Slight alterations to the presentation of the designs could be made prior to a prototype being produced. However, it is the functionality of this system which takes initial priority in the study.

6.2.Luggage Sizes

In the case of this study, the dimensions in Table 2 have been used to represent the various luggage sizes which are to be considered for the storage design. The way in which each size of luggage has been represented in the 3D model designs is displayed under 'Model Presentation'.

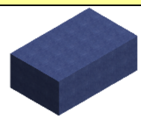
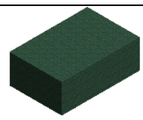
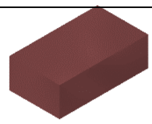
Size	Height (m)	Width (m)	Depth (m)	Volume (m^3)	Model Presentation
Large	0.76	0.48	0.29	0.11	
Medium	0.67	0.45	0.25	0.08	
Small	0.63	0.36	0.21	0.05	

Table 2 Dimensions for luggage size

6.3.Location of Check-In Desk

Two areas on the metro were initially deemed as being suitable to install a check-in desk. These areas were at location 1, approximately a quarter of the way from the front of the metro car, and location 2, at the centre of the car. It should be noted that in the case of the Tyne and Wear Metro, each metro car is numbered from one to ninety whilst the ends of the cars are labelled as A and B. Figure 3 displays the current seating arrangement for the Tyne and Wear Metro and highlights the locations considered for the check-in desk to be erected whilst also labelling end A and B for this particularly drawing of the car.

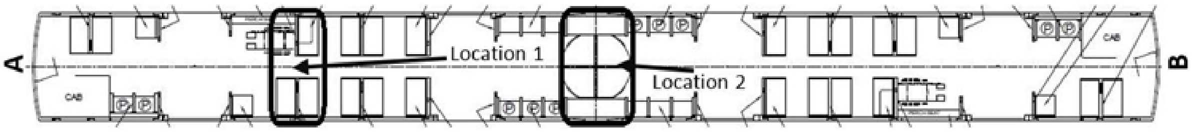


Figure 3: A caption of the current seating arrangement of the Tyne and Wear Metro which highlights location 1 & 2

Location 1 was initially analysed due to the low seat density to the front of the metro. The front end of the metro was observed as having more open space relative to the rest of the metro which therefore was ideal in terms of being able to store checked in luggage and thus minimizing the need to remove a vast number of seats to accommodate this. In order for this idea to work, it was required that the doors to the front of the metro remained closed for the duration of the journey until arriving at Newcastle International Airport as this area would accommodate the secure luggage store. Airport passengers intending to utilise the check-in desk would then be required to board the metro through the second set of doors from side A. From here, these passengers would move through the metro and towards location 1 where luggage could be checked in and removed from the passenger. Following this, the passenger would move back up through the metro, baggage free, and be seated with standard passengers at side B of the metro whilst the luggage is stored at the front end of the metro.

Figure 4: Centre area of metro vehicle where location 2 check-in desk would be installed

Location 2 was considered due to the fact that only longitudinal seats are installed at this point. This created an area which offered good floor space and seating, with a large surface area suitable for stacking luggage. This can be seen in Figure 4. For this location, it was proposed that airport passengers would board the metro through the same set of doors as with location 1 however in this instance it is required for passengers to move through to the centre of the metro. Following the check in of the luggage, passengers would then either be seated in the available longitudinal seats within the centre of the metro or move through to the standard seating area located at side A of the metro.

Comparison of these two potential locations for the check in desk and by observing the interior of the metro cars, several factors were uncovered which influenced the conclusion made for the optimum location for the check in desk. In the case of location 1, passengers are required to move up and down between the narrow aisles located in front of the check in desk. This can be very impractical particularly when moving towards the check in desk, manoeuvring luggage between the wide, obstructive seats could have a deterring and negative impact on passengers who are considering using the metro when travelling to the airport. Furthermore, congestion on-board the metro from passengers moving up and down the narrow aisles could cause overcrowding and impede the operating doors and cause concern with safety. Within location 1, there is also little room to install a check in desk that sits adjacently to the side walls of the metro as the presence of a narrow aisle still remains. Due to these factors, it would be required for all the seats from location 1 to the second set of doors, on side A of the metro, to be removed, re-designed or repositioned to create open floor space. The ability to remove these seats is not feasible as most contain equipment beneath them, such as saloon heaters, a PTI supply and a door isolator. It would therefore be necessary to either relocate this equipment or redesign the layout of the seats so that they are repositioned as longitudinal seats, a feature which the centre of the metro already has. Both of these options are costly and time consuming, particularly when it is considered that this would have to be applied to most of the fleet of vehicles. A permanent change to the seating on the metro would limit the potential for the metro to operate as usual when the check-in and bag drop facility is not in use and would therefore create dissatisfaction for regular passengers who use the metro for reasons other than travelling to the airport. It would therefore seem sensible in this instance to locate the check in facility at location 2 where the seating is already designed with open floor space in mind and therefore no change to the positioning of the seats are required.

Recently, perch seats were installed either end of the metro as to accommodate for the RVAR regulations required surrounding the accessibility for disabled passengers with wheel chairs. There are specific regulations required in assuring wheel chair passengers are able to safely board the metro vehicles. The position of this wheel chair area has also been specifically located to meet requirements for the LED metro information board to be visible from either direction [20]. Positioning the check in desk at location 1 therefore obstruct the wheel chair area and thus not meet RVAR regulations. This would therefore create another undesirable additional cost and lengthy procedure in relocating a facility which has been recently refurbished. Converting the centre of the metro into a check in area would not influence the pre-existing RVAR required facilities and therefore provide a cheaper and simpler instalment of a check-in and bag drop facility.

Nexus must follow the health and safety requirement which states that there must be at least 6 operational doors per metro car at any given point. Whilst the plan of operation, with the check-in desk positioned in location 1, does allow for 6 operational doors to be functioning at once, it does create limited resilience for the vehicle if one door were to fail during transport. If this were to occur, then the service would have to cease operating immediately and be transported to the Nexus depot workshop in order for it to be repaired. In the event of this happening, major complications can occur in relation to the logistics of luggage already checked in on the metro and ensuring passengers do not miss a flight. The need to prematurely remove luggage from the metro before arriving at the airport could create major security concerns and complications in ensuring all the luggage is safely transferred to the airport. By installing the check-in desk in location 2 of the metro, all doors can operate as usual as no part of the check-in facility would overlap any sets of doors. Not only does this not reduce the existing reliability of the metro but it also further prevents the need to apply any mechanical change to the metro car. It is important not to hinder any existing positive attributes about the metro such as its reliability, particularly when this is already a key benefit over automotive travel.

Storing luggage at the front of the metro (side A) can cause complications in terms of access and egress for the driver to the driver's cabin. A large amount of space at the front of the metro could not be utilised for storage as it would prevent the driver opening the cabin door thus the space available for luggage at the front of the metro is more limited than initially assumed. Health and safety concerns are also considered in the event of an accident in which luggage could pile up against the driver's cabin and prevent the driver's quick escape.

The centre of the metro is supported by a tractor bogie. This means the centre bogie is pulled along by an engine at the front of the metro and therefore contains no added weight in terms of an engine and gearbox. The ability to add new equipment and facilities in this area and the potential for storing large amounts of heavy luggage is therefore further assured as this is the best location to have added weight introduced.

The conclusion of this analysis to identify the optimal place to locate the check-in desk, conclusively suggests that location 2 provides a more prefabricated area which has a greater potential to be adapted to operate as a check-in and bag drop facility without the need for extensive refurbishment. This in turn allows for the possibility of a cheaper project to upgrade the metro and create an area which can be versatile in its utilisation. For these reasons, location 2 is considered as the area to be investigated for this study.

6.4. Operation of the Metro

For this study, factors supporting the requirements and operations for the metro outside of its interior design were assumed through research and the way in which the airport and metro service currently operate.

With the number of flights departing Newcastle Airport each day to various destinations, it can become a complex system in which high volumes of luggage bound for several different destinations are required to be checked in from one check-in desk on-board the metro and then accurately directed to the relevant airline. If passengers are able to board and check-in luggage on any desired metro during that day, it can become overwhelming in terms of checking in passengers and printing the correct baggage labels corresponding to the destination of the luggage from one desk, whilst also making the number of passengers expected on each metro vehicle unpredictable. Attempting to facilitate the check-in desk in this way can override the system, create longer waits to check-in luggage, lead to greater costs and complex organisation and therefore this type of operation should be avoided.

Following luggage being checked in at an airport, the baggage is transferred by a conveyer belt, passed through security checks and finally sorted and loaded to different flights [21]. The metro check-in service must therefore follow similar schedule to that used by the airport to ensure that luggage can be sorted to the correct destination along with the non-metro baggage, checked in as usual at the airport. Communication between the metro and the airport is key if this facility being a success. To assist in these factors, it was therefore concluded that for a check-in and bag drop service to operate on-board a metro, it would be a more sensible assumption for each metro to operate for different airline companies with the check in for particular flights correlating to departure times at the airport. This allows luggage to be transferred from the metro at designated times to the corresponding airline and allowing the computer used on the check-in desk to be programmed prior to the departure of the metro from the first stop (South Hylton). Through the use of a clear communication strategy between both Nexus and Newcastle International Airport, luggage can be collected from the metro at the Airport station with a prior knowledge of the airline, destination and sum of luggage expected thus ensuring exceptional levels of organisation.

For each day, a planned schedule can be produced to allocate metro cars to certain airlines and flights, depending on the flight departures that day. Not only would this organisation of the rail vehicles aid in preparing the correct equipment required on-board that specific metro, but it is fully understood by Nexus operators what airline and destination of luggage to expect thus enabling a more efficient and well managed service. This also prevents large surges of passengers during peak times as the maximum passenger expectancy can be calculated previously and managed accordingly. During off-peak times, the on-board check-in and bag drop facility can serve a wider range of flights over a broader time scale. Where there is a high density of flights set to depart or large passenger airlines are in operation, then the range of destinations the check-in desk on-board the metro serves can be limited to control the passenger flow.

It has also been considered that it would not be necessary to have the entire airport metro fleet operating the on-board check-in and bag drop system particularly if an effective schedule of the metros can be accomplished. Currently the Tyne and Wear Metro provides a service in which a vehicle departs for the airport on average every 15 minutes [15]. By confining the check-in availability on each metro relative to the airline company and the time in which flights are due to depart, this controls the number of passengers that would utilise each metro and frequency of service can be adjusted. It should be considered that the Nexus would provide this service with every other metro thus offering it twice an hour. Doing this would save money in terms of the amount of equipment that would have to be manufactured and bought in to facilitate the check-in service whilst also reducing the costs surrounding the number of staff required.

6.5.Customer Facilities

With this is extensive organisation and operation required for the metro vehicles, there must be facilities available for the passengers to help them understand how the system operates and which metro service to board. An obvious method to provide thorough information and instruction to passengers about the on-board check-in and bag drop facility is through the Nexus website. The website should provide all the facts surrounding the capability of the facility, how tickets can be bought, where passengers need to board and which metro they are required to get. Each week a schedule can be posted online as to the times at which the metro vehicles containing the on-board check-in facilities are arriving at each station and the flights that the metro vehicles will serve. The idea would be that passengers can input their flight details into a search engine on the Nexus website which can then locate the information required for the passenger as to which metro they must board and the times available to them. These functions found on the website could easily be incorporated into an app which can be downloaded onto smart phones and therefore provide live updates and information related to the airport facility. Real-time departure information available via smart phones is already considered a key facility to be introduced that could enhance the customer experience for the metro, hence the introduction of this has the potential to assist with passengers travelling to all destinations and carry several benefits [22]. To account for passengers who are not aquatinted with the use of online technology, information should be able to be provided through a help line phone number or flyers and poster which can be sited at most stations g on the airport line.

Within the stations on the airport line, copious information must be provided to ensure clarity to passengers, intending to use the on-board check-in and bag drop facility, where they must board the metro. This can be done using intelligible signs placed around the platform and markings on the floor as to where airport passengers should position themselves prior to the metro arriving. To help further clarify the correct location where passengers are required to board, bold text and images should be displayed on the outside of the doors offering instructions to the passengers.

Displayed on the front of the metro on the existing LED monitor should be the flights which that specific metro serves. This offers assurance for passengers in understanding the correct metro that must be boarded relative to the flight. Public announcements can be made at the platform ahead of the metro arriving also confirming the flights which the incoming metro serves.

6.6.Initial Design Limitations

During research into the study, several limitations were discovered which were influential in the features of the designs. Within the interior designs, these limitations were overcome to ensure realistic and functional solutions were produced.

The Green Line operates to the Newcastle International Airport station. There are issues in installing a driverless system due to the presence of pedestrian level crossings and the metro sharing the same line as Network Rail's Sunderland Line [8]. The current signalling and infrastructure of the Tyne and Wear Metro is not equipped to be able to facilitate a driverless service and therefore would require major changes. Whilst installation of a driverless system has the potential to be incorporated in the future, such a modification to the Tyne and Wear Metro would be highly expensive and time consuming. In the case of this study, a main objective is to look at the possibilities of implementing an on-board check-in and bag drop facility without the need for major change and cost. It has hence been determined that a driverless operation should not be considered in the case of this study.

The Tyne and Wear Metro currently operates with two metro cars coupled together. This is due to most platforms being unable to accommodate more than two cars [8]. In order to keep costs down and the practicality of implementing such a system into the current Tyne and Wear Metro service up, it has been concluded that the design should attempt to avoid the necessity for a third metro car and therefore remain a two car system. Hence, the aim is to minimise the amount of space required to facilitate a check-in service and so prevent the capacity of the vehicle being heavily affected for passengers not travelling to the airport.

The Tyne and Wear Metro vehicles are operated such that there is no dedicated fleet of metro cars which solely serve the Green Line. All vehicles available must have the potential to operate for both Green and Yellow Line when required. It is therefore not possible to dedicate a set number of vehicles to function as transport to Newcastle International Airport only as this would limit the available rolling stock available thus reducing the reliability of the service. This information removes the possibility of installing permanent facilities to the interior of the metro which would affect the capacity and full capability of the metro when the on-board check-in and bag drop facility is not in use. Consuming space that was available for passengers on the metro for a facility that is not currently in use will reduce capacity and possibly upset the existing customer satisfaction of the Tyne and Wear Metro and may deter regular passengers from utilising the metro as a first choice to commute. Installing the check-in facility is intended to build upon the successes which already exist from the Tyne and Wear Metro; to create a quality service suitable for passengers of all types. Consequently, a key feature for the designs has been to ensure that during the times in which the check-in desk is not in use, all equipment can be removed and stored away without obstructing large spaces and seating areas for passengers. The designs have been produced to allow the equipment to be removed conveniently and efficiently from the metro cars and transferred into other vehicles when required. Designs produced have been attempted to be modelled with respect to the equipment and layout currently utilised within the metro to limit the degree of upgrade required to all the metro vehicles and prevent equipment being required for every metro vehicle which in turn reduces the financial burden on the scheme and saves money.

Figure 5: Manual emergency door handle on-board metro car 4067

For each set of doors on-board the metro, a manual pull down handle is installed on one side of the metro. These handles are located next to the doors at around 2000mm up from the floor of the vehicle. Within the centre of the metro, two of these mechanisms are found and it is an irrefutable health and safety requirement that this remains accessible at all times. New designs therefore were required to be developed around this equipment. The location of this handle can be seen in Figure 5.

Within location 2, found at the centre of the metro, two containers extruded into the sides of the metro are present in which fire extinguishers are contained, as seen in Figure 6. These two fire extinguishers are required to be accessible at all times during transit in the case of an emergency. Therefore, designs are to accommodate this health and safety factor to assure the correct number of fire extinguishers at all times.

Figure 6: Fire extinguisher casing on-board metro

Due to the centre of the metro sitting on a pivoting bogie, slight rotation at location 2 is inhibited, as seen in Figure 7. The floor of the metro rotates relative to the rotation of the bogie and it is therefore important that equipment does not overlap between the rotating pivot and the stationary section of the metro as this can result in movement within the equipment making it unstable, unsafe and impractical.

Figure 7: Centre section of metro facilitating a pivoting bogie

For designs in which equipment is required to be transported on and off the metro car, considerations have to be made to the dimensional limitations. The maximum height equipment can be is 2016mm (the height of the doors), whilst all equipment must be able to pass around the centre vertical handrail, which gives 960mm of floor space. Equipment that exceeds these dimensions will not be able to be transferred onto the metro unless dissembled first.

It was confirmed through Nexus that the possibility of installing 240V plugs to the centre location of the metro could be possible. Currently, the metro does however utilise a considerable percentage of electricity provided due to the existing operation of the metro. Therefore, designs were contemplated based on the selection of equipment which would require a minimal power supply.

Currently no storage exists on-board the Tyne and Wear Metro. The suggestion of utilising the unused driver's cabin for storage of equipment whilst in transit was dismissed due to safety issues.

6.7. Waiting Area

Through observing the centre area of the metro, the best location to position the check-in desk was in the centre arch way of the vehicle, as seen in Figure 8 location 2b. Whilst positioning the check-in desk at the front of the centre compartment, as seen in Figure 8 location 2a, would provide a greater area behind the check-in desk allowing more room to store luggage, there would become issues in passengers queuing to use the check-in desk and thus crowding the doors.

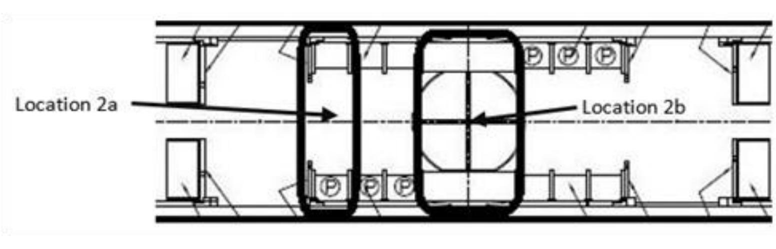


Figure 8: Areas check-in desk was considered to be installed

Using location 2a would require passengers, waiting to check-in luggage, to stand with large baggage which can impede clear access to board and exit the metro via the operating doors. Where there is a sudden surge of passengers intending to utilise the check-in and bag drop facility, a backlog of passengers can become a major issue for concern as passengers are force to move down the narrow aisles in order to fit onto the metro, which therefore fails to address the issue of passengers having to navigate luggage between closely packed seats, whilst also creating the potential for a slow boarding process. If passengers find difficulty in occupying sufficient room for them, then boarding all passengers becomes a lengthy process which in turn reduces the efficiency of the railway service. The metro cannot leave whilst a queue of people is extruding out from the metro doors. Particularly in the case of passengers travelling to the airport, being unable to board the metro will not be accepted due to the importance of punctuality in terms of arriving on time at the airport. Incorporating the system in which specific metro vehicles serve certain flights will make it more important for passengers to be able to board the required metro or face missing the opportunity to use the check-in facility and risk flights being missed. It is therefore important to not only consider sufficient room for luggage to be stored, but it is vital that room is reserved for passengers utilising the check-in facility to assist with user friendly attributes.

The solution to these issues raised was addressed by positioning the check-in desk at the centre of the metro. This allowed for priority seating and standing space for airport passengers, whilst retaining sufficient room for luggage to be stored. The basic layout incorporated into all the designs was therefore designed into three sections, as seen in Figure 9.

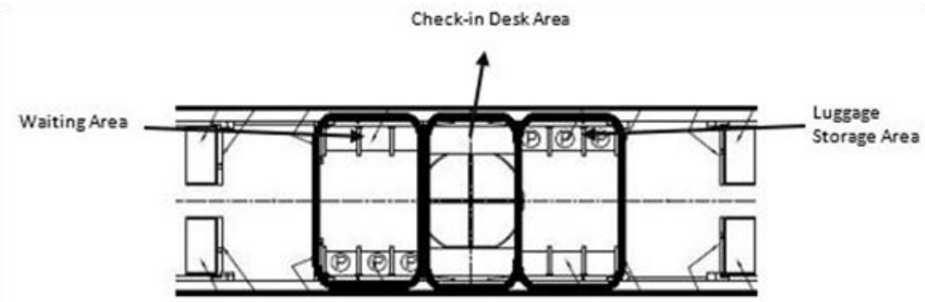


Figure 9: Layout of check-in and bag drop facility

This arrangement allows for passengers using the check-in facility to board the metro and move into the designated airport priority seating area. Passengers with luggage can then be accommodated within this area thus preventing obstruction to other passengers and reducing the potential of overcrowding around the doors. To demonstrate the design for this seating area, a representation model was developed as seen in Figure 10.

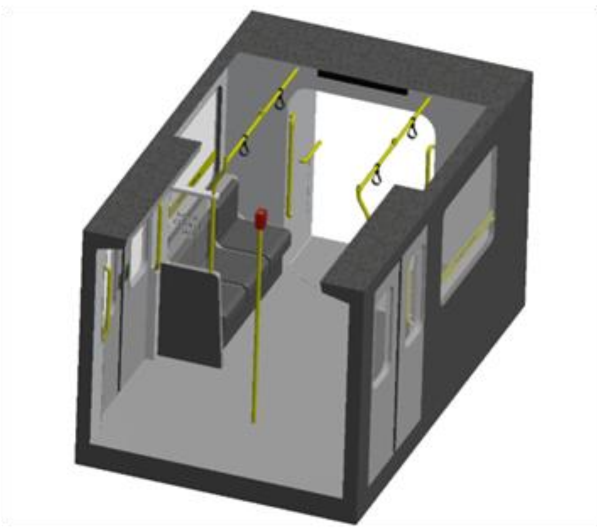


Figure 10: Autodesk Inventor Display of Design for Airport Waiting Area

The benefit with using this area of the metro for the check-in facility allows for minimal change. Passengers waiting to check-in will remain with their luggage which necessitates the need for sufficient floor space. Longitudinal seats not only open up space inside the vehicle, but are an ideal design for passengers being able to position luggage in front whilst seated.

The aisle along other seated areas on-board the metro vehicle provide a narrow width of just 600mm whilst access to the longitudinal seating area provides a wider opening with an aisle width of 1200mm, as seen in Figure 11. This wider access to the seating provides ideal conditions for passengers moving through the metro with baggage.

Figure 11: Differing width of aisles between centre of metro and standard seating

Additional features added to the waiting area are very basic and therefore cheap. Stickers will be added to the glass shields above the side boards which state 'Airport Check-In Area', as seen in Figure 12. This clearly presents the direction in which airport passengers must go upon boarding the metro which assists in efficient boarding. This feature would have to be applied to all metro cars as it is not a feature which could be removed. Doing this would be a low cost addition and would not disrupt the current operation and layout of the metro when the check-in facility is not in use.

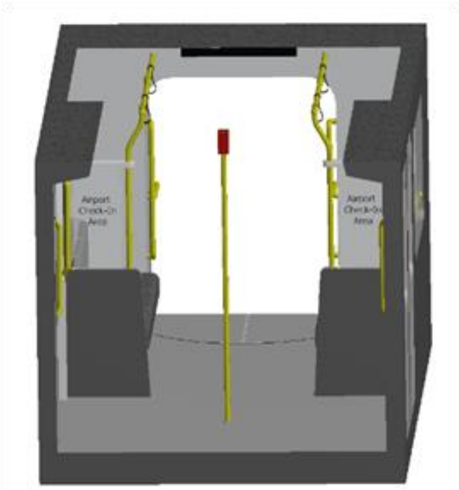


Figure 12: Airport check-in area labels above side boards

On the window above the longitudinal seats, located in the waiting area, would be a sticker labelled as 'Airport Passenger Priority Seating', as seen in Figure 13. This provides additional assurance for passengers boarding the metro with luggage that there are available seats. This feature would also be applied to all metro cars and have no effect in the operation of the metro when the check-in desk is not in use. The priority seating can remain to be used for passengers travelling back from the airport and passengers using a metro vehicle travelling to the airport but without the check-in facilities on-board. Due to this only being priority seating, where there are journeys in which there is a low number of airport passengers, other passengers may use this seating area thus assuring that there is only a small section of the metro that is temporarily occupied, for the journey to the airport, by the check-in desk and luggage storage area.

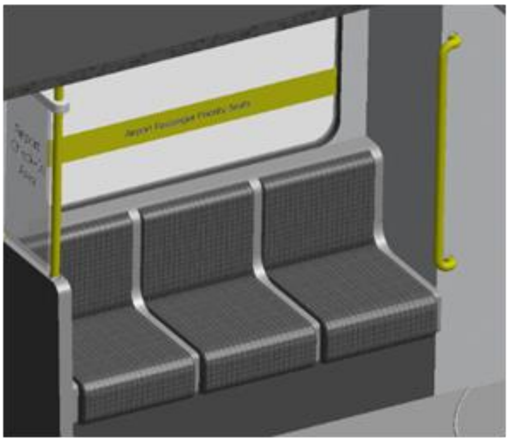


Figure 13: Airport passenger priority seating label

Currently, advertising is presented along the top corners of the metro. An idea which could aid in funding this facility would be to obtain funding from the airport. An effective way to do this would be to offer advertising instalments for Newcastle International Airport within the waiting area of the check-in facility. This assures the airport that advertising is being directed specifically to relevant customers and thus provides a genuine incentive for the airport to help in funding this project. A visual of how this advertising could be presented has been displayed in Figure 14.

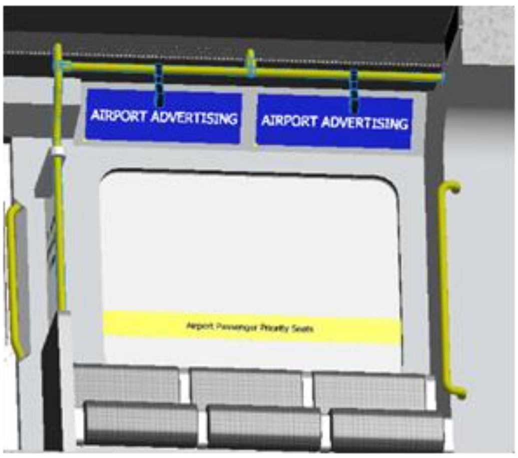


Figure 14: Airport advertising within waiting area

To further organise passengers within the waiting area, consideration must go towards utilising a ticketing system in which passengers collect a numbered ticket upon boarding. The idea would be that passengers can be seated in the waiting area and then wait for the relevant number to be called before moving to the checking desk to hand over luggage. This would prevent frantic queuing and crowding around the check-in desk thus dispersing passengers along the metro making the waiting area less crowded.

6.8. Designs

Four designs have been considered (1, 2.1, 2.2 and 3) for the check-in desk and storage area of the check-in and bag drop facility and developed as a product design. The next section discusses these designs in detail.

6.8.1 Design 1

Design 1 has been created in which small permanent changes are required to be made to the centre of the metro car, however, these features are able to be packed away and removed and thus do not affect the normal operation of the metro if the check-in facility is not being utilised. When this design is in operation, the location 2b and the rear set of seats in the centre of the metro are occupied.

A full depiction of the design when in operation can be seen in Figure 15, whilst the design when the check-in and bag drop facility is packed away can be seen in Figure 16.

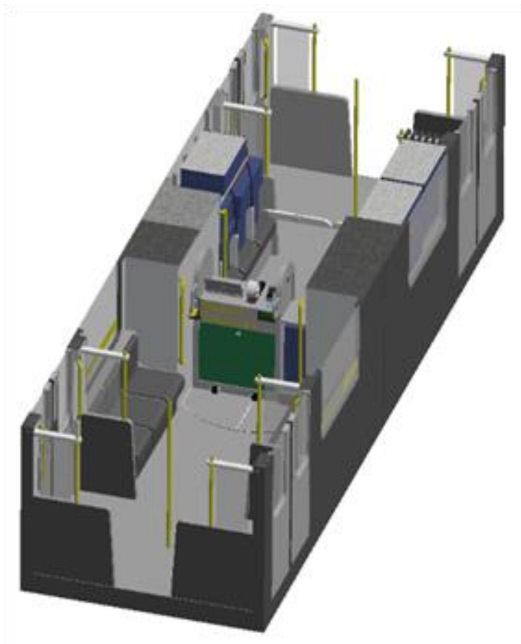


Figure 15: Full display of Design 1 when in operation

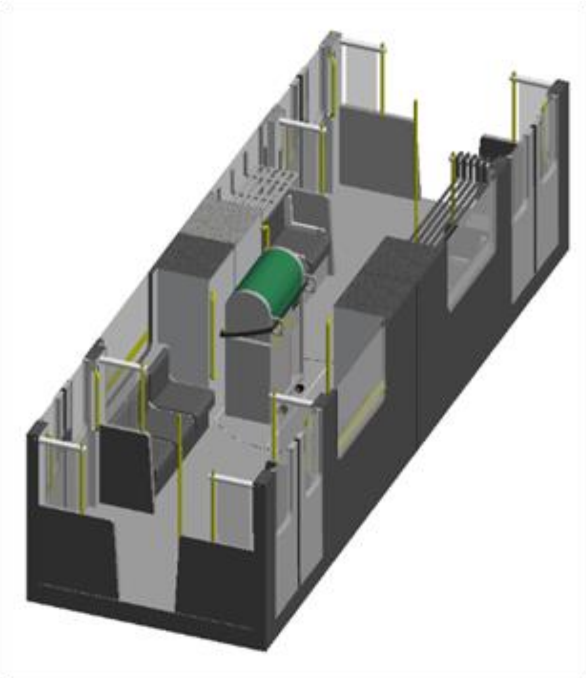


Figure 16: Full display of Design 1 when packed away

6.8.1.1 Features of Check-In Desk

The check-in desk has been designed so that it is mobile. This allows it to be easily removed and transferred to different metro vehicles when required. The desk has been made mobile by adding a set of wheels to the back of the desk. Handles are extruded from the check-in desk at either side as to assist in manoeuvring the desk conveniently. An overall display of this design can be seen in Figure 17.

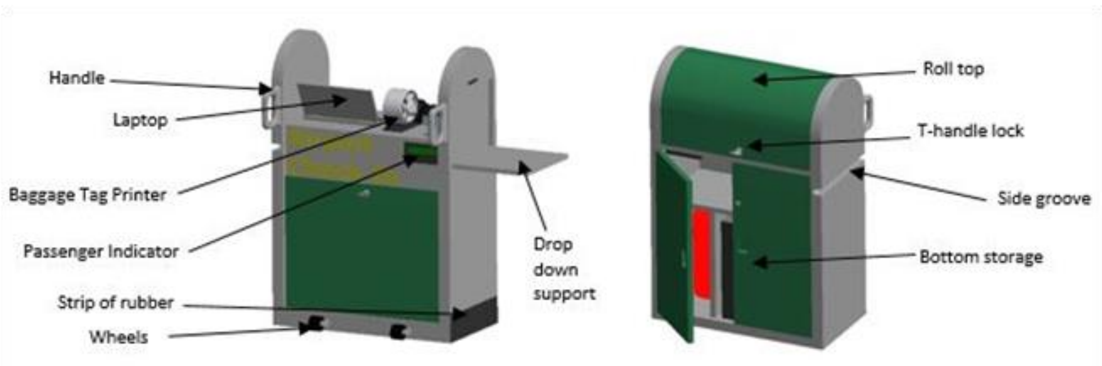


Figure 17: Design 1 check-in desk 3D model

In order for the check-in desk to be supported and stable on-board the metro, a groove, mirroring the radius of the horizontal hand rail positioned in location 2b, is found cut into the side of the check-in desk whilst a drop down support has been designed into the side of the desk. To drop the support, a knob is rotated which causes the surface of the desk to drop down. Carved into this surface is a groove with the radius of the horizontal hand rail in which the support slots onto. These features can be seen in Figure 17.

This design is able to contain all the components required to operate a check-in facility within its own storage. There are two sets of storage for this check-in desk. The top section is contained by a roll top function. Designed into the front of this is a T-handle lock which is used to provide a locking system for the check-in desk whilst also adding convenience towards lifting back the roll top and pushing it down the back of the desk. Beneath the roll top, contained are several airport equipment products. The bottom section is contained by a set of doors. Designed into these are a set of cut out handles and a cam lock used to lock the doors shut. Within the bottom storage area, there are 5 separate compartments which are used to store various larger equipment. This can be seen in Figure 18.

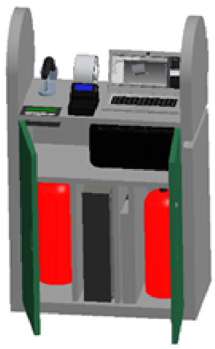


Figure 18: Model representing the equipment contained within the check-in desk

6.8.1.2.Equipment

For this design, the check-in desk has been powered without the need for an external source of power. To accommodate this, an external battery can be installed into the bottom storage section on the top compartment, as represented in Figure 18. It is this battery which powers all the equipment within the check-in desk. The equipment utilised for the check-in desk has therefore been selected partly based on the power consumption required.

A laptop has been recommended to act as the computer of the check-in desk. This allows the computer to operate without the need of an external source of power. In the event that the battery of the laptop falls low, the internal battery within the desk can then be used. This therefore condenses the time in which the battery is powering the computer. The laptop would be fitted onto a mount which is permanently fixed to the check-in desk workstation within the top storage of the desk, the location of which can be seen in Figure 17.

To scan the boarding passes of the passengers, a barcode scanner is required. For this design, the Xenon 1900 Barcode Scanner for passenger services has been selected. The Xenon 1900 is a tool used to gather data of tickets and boasts for its ability to be applied for bag drop check-in counters and boarding passes. This specific model was selected due to the compact design, low operating power requirements and basic installation of connection directly to a PC workstation via USB [23]. In conjunction with this device, the scanner will be mounted on a stand which will be fixed to the workstation as to prevent movement during transportation of the desk. This device would be stored in the top storage of the desk at the as seen in Figure 18. The recommended mount to use with this product is the Honeywell STND-22F00-001-4. The Xenon 1900 scanner would be continuously powered by the check-in desk internal battery.

Stored inside of the bottom check-in desk is a weighing scale. In the case of this design, a product known as the H305 bench scale has been used. This scale is designed for airport luggage weighing and a compact shape hence being suitable to store away inside the bottom storage of the desk, as seen in Figure 18, and also be install on the confined space of metro.

There must be an indicator display system for both the passenger and staff member. The H305 Bench Scale, used to weigh luggage for this design, is able to interface to all Avery Weigh-Tronix indicator systems [24]. Therefore, the Avery Weigh-Tronix ZM205 indictor components have been selected for use. This product comes with both an operator display and passenger display unit. These indicators can be easily connected to the weighing scale from the check-in desk, whilst both products are compact with face displays of just 200.7 x 108.7mm. Rectangular cuts have been designed into the work station and front of the check-in desk in which the indicators can be fitted in to, as seen in Figure 19. These are bolted to the desk whilst the passenger display is covered by a clear plastic screen to prevent damage, particularly when the desk is on-board the metro but not in use. Both products have a low power consumption of just 150 mA at 12 VDC and are to be powered by the check-in desk internal battery.

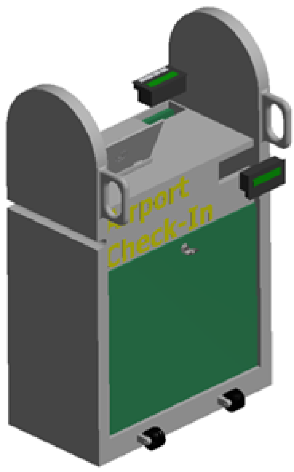


Figure 19: Indicator system in check-in desk

For this design, the TK180 Baggage Tag Printer was selected due to its extremely compact design and 200mm/sec high speed printing. A USB interface is incorporated into this product making for an easy and flexible integration thus suited to this application [25]. This product would be fitted to a fixed mount on the work station of the check-in desk within the top storage of the desk. This product has a low power requirement of just 24VDC and would be powered by the check-in desk internal battery.

Due to the positioning of the check-in desk for this design, luggage would be weighed and transferred next to the fire extinguisher container at the centre of location 2b. Constant movement of luggage at this point can cause damage over time to the screen containing the fire extinguisher. A loose strap hangs from the fire extinguisher casing and this is required to be covered to prevent it catching with luggage and pulling the casing open. Therefore, a shield was designed which fits between the weighing scale and the fire extinguisher casing. This is stored inside of the check-in desk when not in use. To be able to accommodate this however, the shield has been hinged down the middle so that it can be folded in half and packed away.

Due to the position of the check-in desk when installed, both fire extinguisher emergency containers are obstructed. To account for this, two fire extinguishers are stored within the bottom storage of the check-in desk. This retains for the required amount of fire extinguishers to be available whilst the metro is in transit thus complying with health and safety regulations.

To account for the fact that the check-in desk would obstruct access to one of the fire extinguisher cases in the centre of the metro when the desk is stored away, an emergency plastic cover was added to the back of the check-in desk to be used to access one of the fire extinguishers stored within the check-in desk. This fire extinguisher is encased within its own compartment inside the check-in desk and therefore prevents the possibility of this feature being taken advantage of for improper conduct such as to steal equipment. This design feature therefore ensures that the correct number of fire extinguishers remain accessible at all times.

Assurance is provided that the fire extinguisher casing on the back of the check-in desk is not accidently damaged when passengers are standing in front of it as when the check-in desk is open, the roll top falls down in front of the casing thus protecting it.

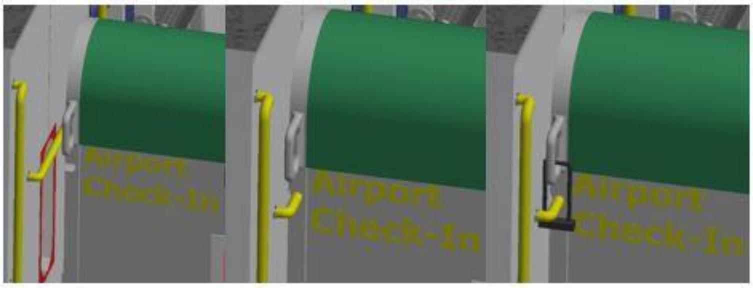


Figure 20: Initial installation of check-in desk

To add further structure to the check-in desk, the drop down support is lowered onto the opposite horizontal hand rail on-board the metro. This allows the for a secure fit, as seen in Figure 21, thus providing extra support to the opposite end of the desk. Beneath this support, the weighing scale is to be fitted and luggage passed through.

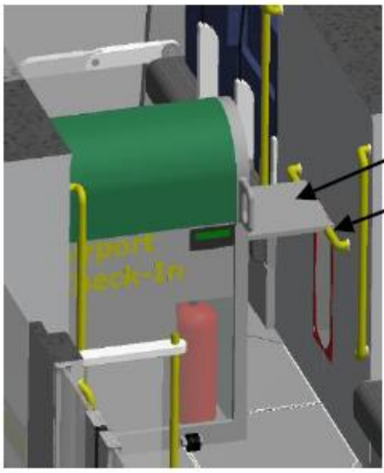


Figure 21: Check-in desk supported to horizontal hand rail

To assemble the shield protecting the fire extinguisher casing, the shield is slotted into the drop down support. At the end of the drop support, two narrow slits are machined through the surface. The shield designed has two teeth extruding from its surface which can mate with the slits in the support. By lowering the shield down through the horizontal hand rail, the teeth can slot into the slits of the support whilst the shield hangs over the fire extinguisher container whilst just coming into contact with the metro floor. This process can be seen in Figure 22.

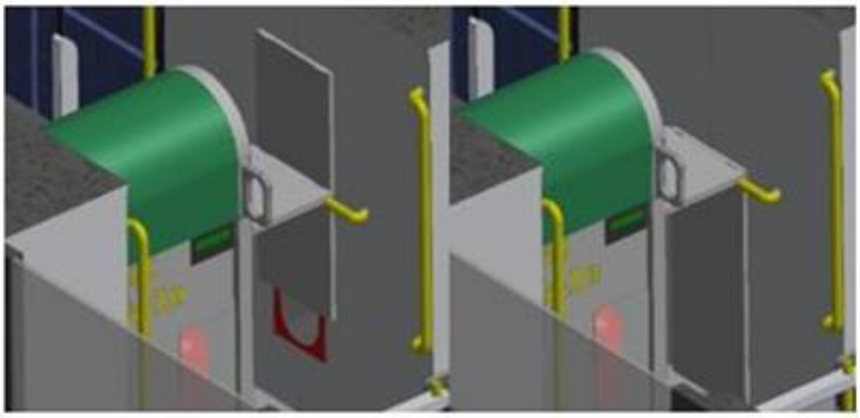


Figure 22: Fire extinguisher shield setup

The weighing scale is removed from the check-in desk and placed on the floor of the metro in-between the side of the desk and the shield covering the fire extinguisher container. The design of the desk is such that when the weighing scale is fitted, the width of the scale, shield and desk accommodates the full width of the metro at that point. This creates a compact fit which stabilises the check-in desk and tightly fits the scale in place. The visual setup of the check-in desk once successfully installed can be seen in Figure 23. Fitted to the lower side of the check-in desk and shield is a strip of rubber which sits parallel to the H305 weighing scale. This adds further assurance by increasing the friction between the components and reducing the chance of movement whilst in transit.

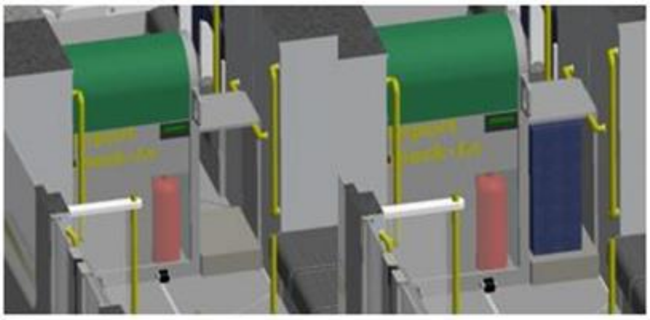


Figure 23: Complete installation of check-in desk on

When the check-in desk is required to be opened, the roll top storage can be unlocked, lifted up and pushed down the back of the desk. This then exposes a work surface, with all the equipment required to operate an airport check-in facility already available.

This check-in desk operates such that passengers are required to check-in online, prior to boarding the metro. This therefore removes the need for a printer to be present within the check-in desk which would print boarding passes. The absence of this equipment reduces costs of bought in components and saves space on an already highly condensed work surface. Checking in online is a service provided by most airlines in which passengers can print off boarding passes or download them onto smart phones. Incorporating this requirement also intends to greatly speed up the baggage drop process on-board the metro and therefore reduce the waiting time and potential for extensive queuing. Upon boarding the metro, the staff member operating the bag drop facility is just required to scan the boarding pass, check the passport details of the passenger and finally weigh the luggage.

The section between the horizontal support and the weighing scale, where luggage is weighed, is facilitated as a measurement for the maximum allowable size of luggage to use the on-board check-in and bag drop service. The design has been produced to accommodate 'large' suitcases, as represented in table 2, however this feature could be easily altered depending on the maximum dimension of luggage deemed fit through further assessment of the check-in facility. In the case of this study, luggage greater in size than a 'large' suitcase has been concluded as occupying too much space if a significant amount of luggage is wanted to be stored on-board the metro.

Upon passengers checking in baggage, the luggage is to be stored in the storage area whilst the passenger is free to be seated on the metro.

The first step in closing down the check-in desk would be to switch off all the relative airport equipment installed on the desk followed by the internal battery. The shield protecting the fire extinguisher casing would be lifted up and removed from between the metro wall and weighing scale. This would then be stored inside of the check-in desk. To be able to accommodate this, the shield has been hinged down the middle so that it can be folded in half and packed away. The H305 Bench Scale would then be detached and stored inside of the desk. The lock connecting the check-in desk to the horizontal hand rail via the handle of the desk is then to be unlocked by the member of staff and stored in the desk. Following this the doors of the storage unit within the check-in desk would then be locked shut. The fold down support, which sits on the horizontal hand rail on the side of the metro, would then be lifted up and locked in place against the side of the desk. The roll top of the desk would then be pulled over the top of the check-in desk and locked thus exposing the fire extinguishers emergency casing on the rear of the desk.

This now contains all equipment safely inside of the desk, as seen in Figure 24.

Figure 24: Check-in desk locked away

The check-in desk can then be prised away from the horizontal hand rail, sat within the side groove of the desk, and rotated so that the front of the check-in desk is facing the side of the centre compartment of the check-in and bag drop area at location 2b. A strap, which can be stored inside of the check-in desk, is then hooked onto the end of the horizontal hand rail, threaded between the handles of the desk and connected to the opposite end of the hand rail. This secures the desk in place and prevents it from tipping over in the event of emergency braking or an impact, as seen in Figure 25. With the check-in desk stored away in this way, this allows for plenty of space (965mm) for passengers to move around the desk. Following this, all equipment for the check-in and bag drop facility has then been successfully packed away. This is a quick process which does not remove any seat space on the metro whilst allowing the interior to operate in the same way where only a very small section of the metro is accommodated by the facility. Figure 25 shows the final configuration of the check-in desk when stored away.

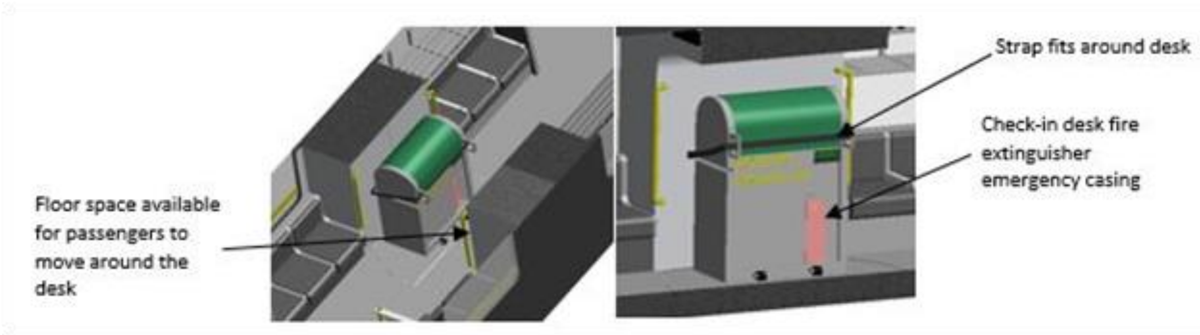


Figure 25: Check-in desk when not in use

6.8.1.3.The Storage Area

To accommodate a greater capacity for luggage to be stored in the storage area, two sets of baggage racks have been designed for the storage area above the longitudinal seats which sit opposite each other. These baggage racks would be a permanent addition to all metro vehicles. The Tyne and Wear Metro currently lacks any storage space for baggage and therefore installing this feature would help improve an all-round customer satisfaction, not just specific to airport passengers. The dimensions of the baggage racks have been designed as to fit around the current layout of the metro whilst also assuring there is sufficient room beneath for passengers to still be able to utilise the seats. Therefore, the addition of these luggage racks would have no effect on the capacity of the metro and would only improve the facilities available for all metro passengers.

The designs of the pair of baggage racks differ from each other to accommodate for the manual emergency door handle which located above one side of the storage area. The luggage rack above the longitudinal seating which does not facilitate the emergency door handle is designed to provide two levels of storage which fits across the full length of the seating of the storage area, as seen in Figure 26.

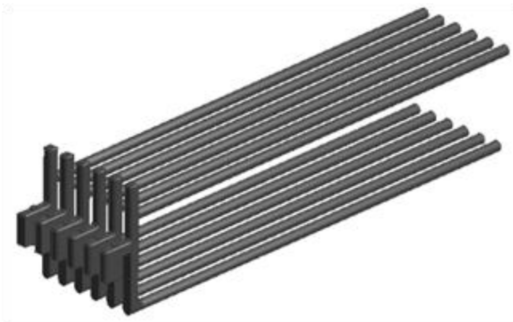


Figure 26: Baggage racks

The baggage rack is connected to the side of the centre compartment of the check-in area via two levels of six extruding rods whilst the opposite end is supported onto the horizontal structure supporting the vertical hand rail above the side board of the storage area. This provides a strong structure to support heavy luggage. The rack installed onto the metro can be seen in Figure 27.

Figure 27: Racks installed onto the metro car

The design of the baggage rack located above the longitudinal seating which facilitates the emergency door handle has been produced as to retain clear access to the handle. This can be seen in Figure 28. This reduces the capacity of luggage in which the baggage rack can accommodate however it remains to provide an increase of overall baggage capacity to the storage area whilst keeping to the health and safety requirements.

Figure 28: Design of luggage rack above longitudinal seats with emergency door handle

This baggage rack is not able to be supported on the horizontal structure supporting the vertical hand rail in order to keep the emergency door handle clear and therefore an alternative design to support the baggage rack has been considered. Like the first baggage rack design, this rack will be connected to the side of the centre compartment of the check-in area via two levels of six extruding rods. The rack will then be further supported by vertical rods extruding from the back. These rods will connect to the ceiling of the metro. The dimensions of this rack have been considered as so the rods fit behind the light casing and venting system to allow connection to the ceiling and to retain access to the lights when servicing is required. The rack installed onto the metro can be seen in Figure 29.

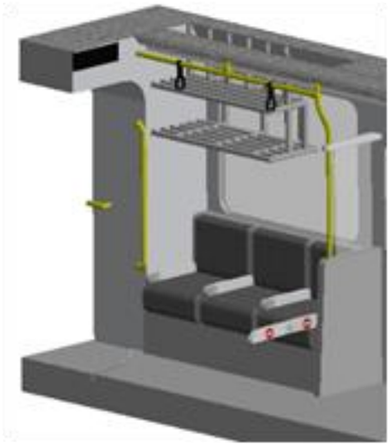


Figure 29: Luggage rack installed above longitudinal seats

Due to the location of the check-in facility, passengers could be able to access the opposite end of the check-in area by boarding side B of the metro. It is important that this area is not accessed by passengers as to assure the security of the luggage. To accommodate this requirement, it is proposed that all metro cars would be fitted with 'fold out arms' installed onto the longitudinal seats in the storage area, see Figure 30. These fold-out arms are installed on the spacing between the seats so not affect the capacity of the metro when the check-in and bag drop facility is not in use. To implement the barrier to prevent access to the storage area to passengers and make it clear to not to enter, a doubled jointed arm rest is located at the end of the longitudinal seating which is extended outwards so it lies flat and parallel to the base of the seat, as seen in Figure 31. When both double joined arms are folded out, a complete barrier falls across the width of the storage area thus denying access.

Figure 30: Set up of double jointed fold out arm to act as barrier

Designed onto the passenger side of the barriers are no entry signs which add clarity that the storage area is a restricted area and not to be accessed.

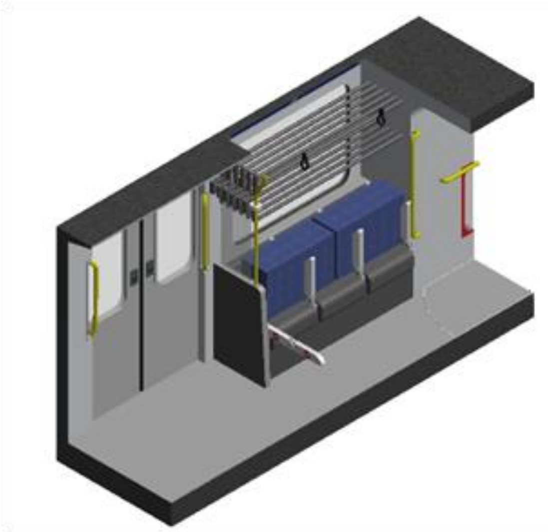


Figure 31: Fold out arms lifted up

The longitudinal seating within the storage area of the check-in and bag drop facility is to be used as storage for checked in luggage. To allow for a considerable amount of luggage to be stacked on the seats, supports have been installed to prevent the stack of luggage from collapsing. Single jointed 'fold up arms' have been installed within the spacing between the seats. These have been designed to be lifted backwards but constrained to fall back no further than 90 degrees from the face of the seats. No locking mechanism is required to retain the arms from remaining upright as it should be allowed for them to fall back onto the luggage to create a tight fit.

Stored within the 'fold up arms' are straps which can be pulled from within the arms and clipped to the luggage racks to provide further support for the stack of luggage.

On opening the check-in and bag drop facility to be utilised, the storage area must be prepared for use. This design provides a very quick and simple setup in that just the double jointed 'fold out arms' are required to be dropped down to create a barrier to prevent entry by passengers into the storage area. Subsequent to this, the on-board check-in and bag drop facility is ready for use.

Following luggage being checked in using the on-board check-in and bag drop facility, the 'fold out arms' are lifted up and the luggage is placed behind them, as seen in Figure 32. Baggage should be stacked on the seats until the luggage racks prevent room for further luggage to be stored. Once the stack of luggage exceeds the height of the folded out arms, the straps can be pulled from within the arms and clipped to the luggage racks.

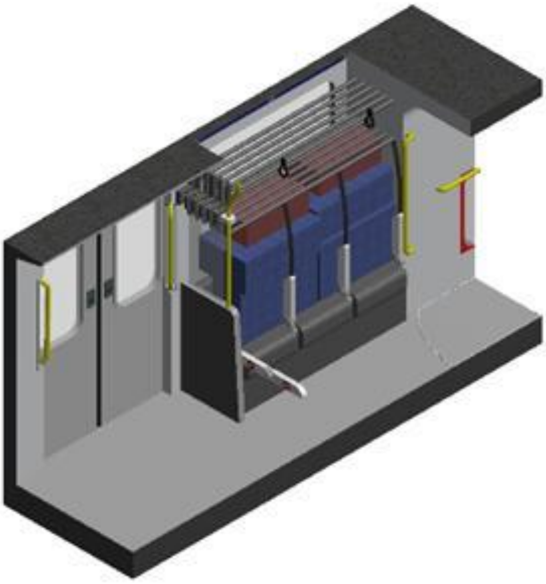


Figure 32: Straps from arms clipped to the luggage rack

Following both seats hitting the maximum capacity of luggage that can be contained, the baggage racks are then to be used. A visual of the storage area completely set up and in use can be seen in Figure 33.

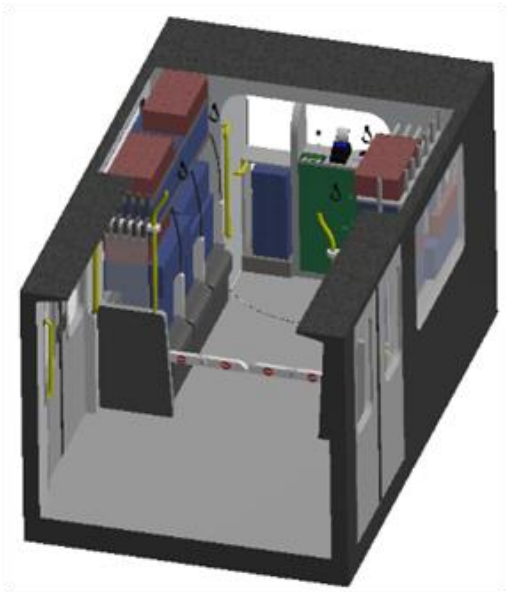


Figure 33: Storage Area setup and with full capacity of luggage

Once the metro arrives at the Airport station, it is required that all passengers are allowed to disembarking the metro vehicle. This aids in the assurance surrounding the security of the luggage whilst also allowing for an empty metro to assist in an efficient change over time. A member of staff employed by the Newcastle International Airport is required to be waiting with a baggage cart on the platform. Luggage is then unloaded off the metro and onto the cart. Access between the platform and airport terminal is wheelchair accessible and therefore transporting a cart into the airport will be achievable.

Once the equipment within the storage area is stored away, passengers travelling back from the airport can then board the metro and utilise the luggage racks installed for suitcases thus providing some assistance for a baggage free journey. A display of the storage area after luggage is offloaded and all features are packed away can be seen in Figure 34.

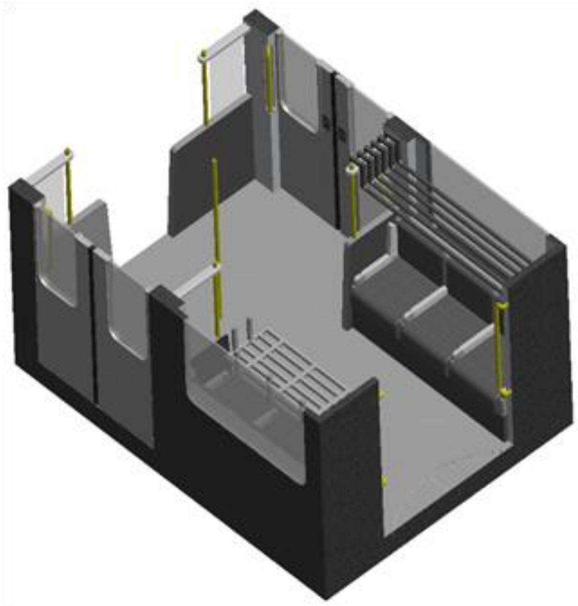


Figure 34: Storage area packed away

Based on the shape and size of the storage areas for the luggage, estimation could be made as to the baggage capacity of Design 1. The dimensions used for the purposes of this study show set dimensions for each type of luggage however the height, size, width and volume of each individual luggage used by a passenger can vary. Therefore estimation for the capacity of this design is displayed through a calculation of the volume of each section of the storage area divided by the volume of the varying luggage types used for this study. The value of luggage was in each case rounded down to zero decimal places. This is displayed in Table 3.

		Volume Capacity (m^3)	Small Luggage	Medium Luggage	Large Luggage
Storage Side without Emergency Handle	Seating Storage	0.835	17	11	7
	Lower Rack Storage	0.249	5	3	2
	Upper Rack Storage	0.186	3	2	1
	Total	**1.27**	**25**	**16**	**10**
Storage Side with Emergency Handle	Seating Storage	0.835	17	11	7
	Lower Rack Storage	0.165	3	2	1
	Upper Rack Storage	0.088	1	1	0
	Total	**1.088**	**21**	**14**	**8**
Total Capacity of Storage Area		**2.358**	**46**	**30**	**18**

Table 2: A display of the estimated baggage capacity for Design 1

Considering the worst case scenario in which all passengers' board with large luggage, this would give the facility a baggage capacity of 18 bags per journey. With the metro operating from South Hylton to the Airport for approximately 16.5 hours per day, assuming the on-board check-in and bag drop facility operates on two metro journeys per hour, this system has the potential to facilitate the movement of 594 'large' suitcases per day. Assuming the check-in service operates on every metro journey to the airport, this design could facilitate the movement of 1485 'large' suitcases per day.

6.8.2 Design 2.1

Design 2.1 has been created in which no permanent changes need to be implemented into the current design of the centre of the metro. This allows for all equipment to be removed when the check-in and bag drop facility is not utilised on-board the metro. When this design is in operation, location 2b and the storage area is occupied. This design aims to offer an alternative way of handling the luggage whilst looking at alternative equipment and operations that could be implemented. It should be noted that for this design to efficiently operate, it is recommended that two members of staff are on-board, with one operating behind the check-in desk and the other in front.

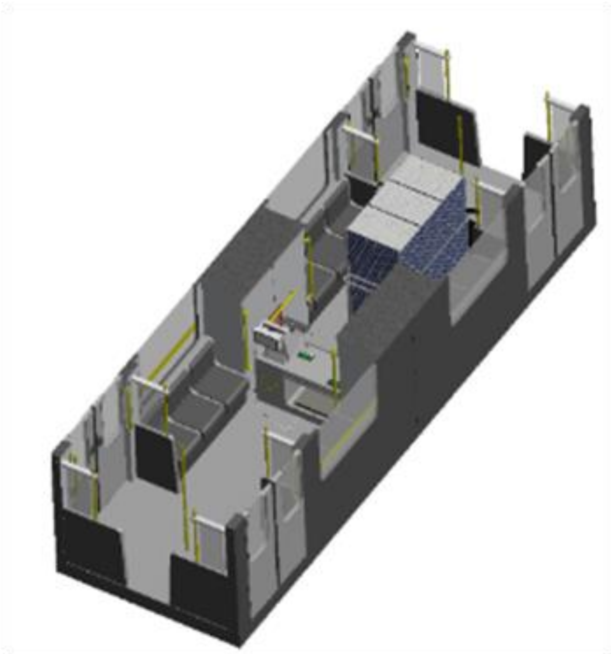


Figure 35: Design 2.1 when in operation

A full depiction of the design when in operation can be seen in Figure 35, whilst the design when the check-in and bag drop facility is not in use can be seen in Figure 36.

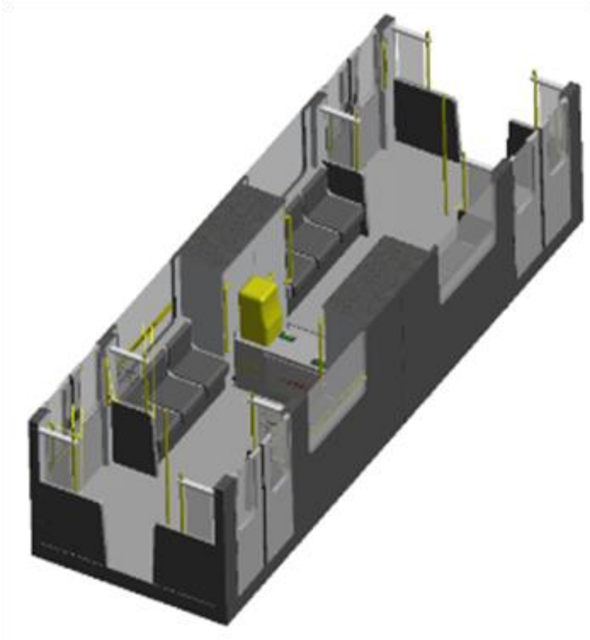


Figure 36: Design 2.1 when packed away

6.8.2.1.Features of the Check-In Desk

An alternative way of incorporating the required facilities to operate a check-in desk is to buy in a bulk amount of existing mobile check-in kiosks. The MD1 Mobile Service Desk, as seen in Figure 37, is equipped with all the capabilities of a full check-in desk, including boarding pass and bag tag printers, an adjustable passenger facing LCD screen and keyboard and monitor for the operator.

Figure 37: MD1 Service Desk

In addition to this, weighing scales can be easily connected to the MD1 through its external input panel [26]. This design therefore considers the opportunity for passengers to be able to obtain boarding passes thus expanding the customer base for passengers who can use the on-board check-in and bag drop facility. By utilising this service desk, it reduces the amount of separate components required on-board the metro and assists in a more user friendly and efficient service. Furthermore, the MD1 Mobile Service Desk contains its own battery and charging facility thus allowing it to be operated without the need for an external power source for up to 10 hours. This allows for desk to be able to operate in the event of a power malfunction from the plug of the metro which in turn offers a greater reliability of the facility.

Figure 38: Explosive view of Design 2.1 check-in desk

With the need for a weighing scale and indicators to be connected through the MD1 Mobile Service Desk, it would be a disarranged setup if equipment was not contained within one structure. This would also create a health and safety hazard with wires being exposed and difficultly in being able to lock down equipment to prevent it projecting down the aisles in the event of emergency braking or an impact. To remove these issues, a casing has been designed in which the MD1 desk can be fitted into whilst the weighing scale and indicators are also incorporated into the design. This would allow for a more efficient handling of the equipment as all the required components are contained within the desk. The MD1 desk fits into the casing as seen in Figure 38 whilst the bare casing can be seen in Figure 39. The service desk is padlocked internally to keep it fixed to the casing and prevent theft.

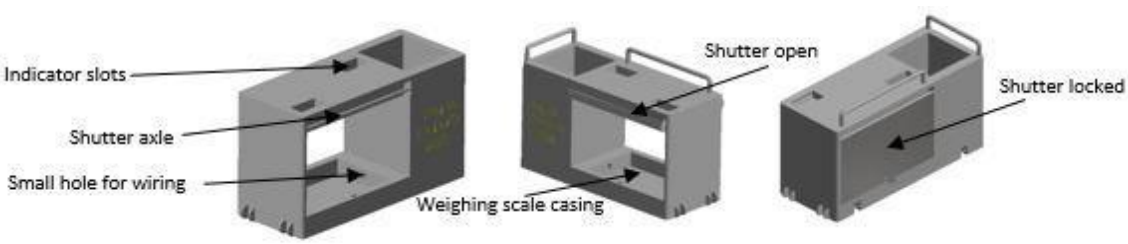


Figure 39: Check-in desk casing and shutter mechanism

Within the container for the service desk, a large opening is cut in which the H301 weighing scale sits. To accommodate this bench scale, a rectangular intrusion to the base of the opening is implemented into the design which allows the scale to sit in thus reducing the portion of the scale exposed. From here, the wiring can travel from the scale and through a small hole that passes through into the section containing the MD1 desk.

The indicators used with the H305 Bench Scale are the Avery Weigh-Tronix indicator systems. Similarly to design 1, both passenger and operator components are fitted into rectangular cuts which have been designed into the work station of the casing for the MD1 desk. These are bolted to the desk whilst both passenger and operator display are covered by a clear plastic screen to prevent damage to the indictors.

Two metal roll down shutters cover the weighing area of the check-in desk as to protect the scales and allow for a storage area to store equipment in when the desk is not in use. This is functioned by installing two horizontal axles within the weighing area of the desk. The metal shutters fit around these axles and are able to roll up and down. The base of the shutters is fitted with a small T-handle lock which can allow the shutters to lock into the inner base of the check-in desk.

The casing for this design has been produced so that it is mobile to allow it to be transferred to different metro vehicles when required. The casing creates a check-in desk which is wider than the maximum 960mm width required in order to be able to transfer the desk onto the metro. To accommodate for this, wheels have been added to the side of the desk thus allowing it to be lifted up and pulled onto the metro vehicle. A long bar handle has been added to the opposite side of the check-in desk to assist in manoeuvring it conveniently. Further to this, wheels and a long bar handle have been added to the operator side of the desk. This allows for improved manoeuvrability when on-board the metro in positioning the check-in desk.

6.8.2.2.Equipment

Using the wheels and handle on the side of the casing, the check-in desk can be transferred onto the metro. Upon the check-in desk entering the centre of the metro, the desk is then to be required to be rotated such that it is adjacent to the walls of the metro and the 'Airport Check-In Desk' text on the desk is facing towards the waiting area. From here, the desk is to then be pulled back into place within location 2b, using the wheels and handle on the operator side of the desk.

This design has been considered such that the check-in desk is able to fit in the centre compartment of the check-in and bag drop area whilst remaining in front of the fire extinguisher containers on-board the metro. This allows for clear access to the fire extinguishers at all times without the need to store extra fire extinguishers within the check-in desk which saves money and weight. To allow for sufficient space for the members of staff to operate behind the check-in desk, it has been preferred for the desk to be stored at the front end of the location 2b whilst avoiding overlapping the pivoting floor. Upon the positioning of the desk being complete, two sets of locks have been fit around the long bar handles and horizontal hand rails seen within the vehicle. This prevents the desk from projecting down the aisle of the metro in the event of emergency braking or an impact. This initial installation can be seen in Figure 40.

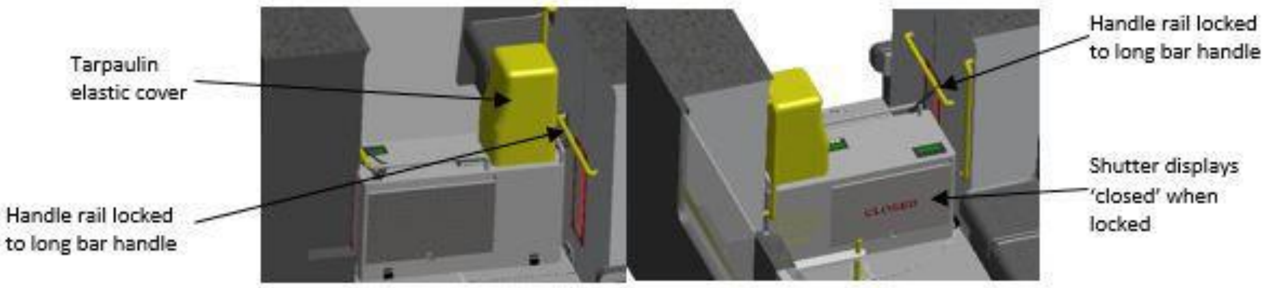


Figure 40: Check-in desk installed on metro vehicle

Covering the monitors or the check-in desk is a tarpaulin elastic cover that fits over this equipment. Upon the opening of the check-in desk, the cover is removed and placed on the seats within the storage area. The passenger monitor and operator keyboard of the MD1 Mobile Service Desk and then extended outwards ready for use.

The two metal roll down shutters cover the weighing area of the check-in desk are to be unlocked and rolled up thus exposing the H305 Bench Scale. Following the processes mentioned, the check-in desk would be successfully setup to look as seen in Figure 41.

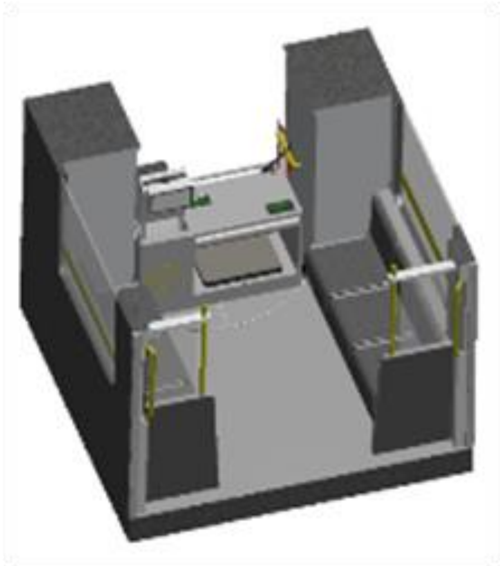


Figure 41: Check-in desk successfully setup

Upon boarding the metro, passengers would move through the waiting area and towards the front of the check-in desk. From here, boarding passes can be obtained and luggage can be weighed. The opening containing the weighing scale could act as a determinant as for whether luggage is of a suitable size to be checked-in using this facility. Alternatively, the smaller height of the work station of the check-in desk can allow for the potential of larger luggage to be passed over it. For this design however, it is assumed that baggage greater in volume than 'large' luggage is not acceptable for use. Upon luggage being approved, the baggage label and be printed and applied. From here, the luggage can be pulled through into the storage area whilst passengers are free to be seated on the metro.

When closing down the check-in desk, the desk would be unplugged from the metro power source followed by the mobile service desk being logged off and shut down. Other equipment from the check-in and bag drop facility is placed on the weighing scale within the check-in desk. Following this, the metal shutters are pulled down closed and locked shut. When this is done, the shutter displays the message 'closed' which provides a clear sign to passengers that the desk is not currently in use. The adjustable keyboard and passenger monitor of the MD1 Mobile Service Desk is then folded down and the tarpaulin elastic cover is place over the top of the service desk thus protecting it from being damaged. Once packed away, the check-in desk will look as seen in Figure 42.

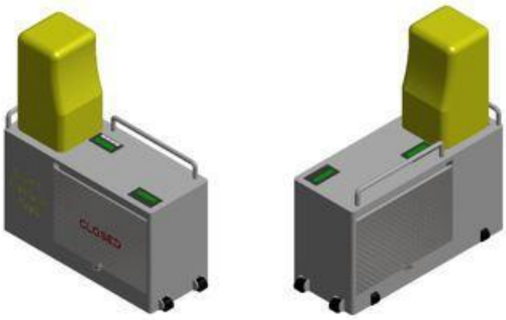


Figure 42: Check-in desk when closed down

The desk is to remain in the position it is initially installed as. This allows the fire extinguishers on-board the metro to remain accessible to passengers. No seating is accommodated in this storage of the desk, however, a small section of the metro floor space is occupied by the desk (around 0.65m^2) whilst the internal operation of the metro must be altered slightly. With this design, passengers are not able to pass through from side A to B of the metro vehicle. This would not be perceived as much of an inconvenience as clear access to a set of doors is still available to all passengers. In the event that passengers want to move to the opposite end of the metro, access can be simply achieved though departing the metro and walking to the next set of doors on the opposite side of the metro.

6.8.2.3. The Storage Area

To prevent passengers being able to access the storage area via the opposite side from the waiting area, an expandable safety barrier has been designed. The barrier can be collapsed to be stored within the weighing section of the check-in desk when not in use whilst being able to be expanded an utilised as a barrier. The end support of the barrier has been designed such that it can slot onto the end of the side board at the edge of the storage area, strapped to the vertical hand rail and then expanded outwards to be connect the end of the opposite side board. This design was inspired by the Titan Expanding Barrier [27], as seen in Figure 43. The design produced for this product can be seen in Figure 44.

Figure 43: Titan expanding safety barrier [27]

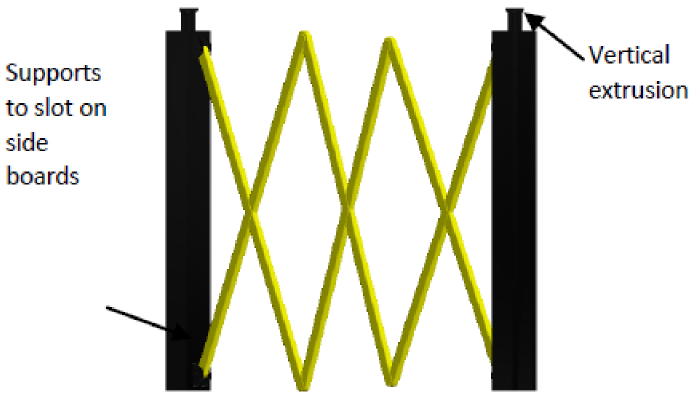


Figure 44: Model produced of expanding safety barrier

For this design, a roll container is used to store the luggage. This utilises the vast floor space within the centre of the metro, due to the use of the longitudinal seating, and therefore avoids the need for any adaptations to the current components on-board the metro. Luggage is able to be safely and securely stacked up within the container and hence made for more efficient handling of the luggage.

The initial dimensions of the roll container were designed to be able to transfer and manoeuvre the container on and off the metro vehicle. To accommodate this, the depth was assured to be no greater than 960mm whilst the height of the container was based less than the height of the doors of the metro vehicle (2016mm). The length of the container was then judged by the length of the length of the longitudinal seats within the storage area (1710mm), such that it was of a similar length to this, as to assure the roll container did not interfere with the staff member operating the check-in desk and to avoid the wheels overlapping onto the pivoting floor. This therefore created the maximum storage capacity of the check-in desk whilst retaining functionality for it being operable for the Tyne and Wear Metro.

With the roll container being designed at just under two meters tall, access to the storage within the container would be required via a door on the side. With this considered, it would not be safe to stack several loads of luggage on top of each other at two meters in height as the baggage can become unstable within the roll container. This could then lead to luggage falling out from the container upon opening the door. Furthermore, customers may be dissatisfied as luggage checked in first would be put under an intense amount of weight, from a high stack of heavy luggage being stored on top of it, which could lead to damaged goods within the baggage. To account for this, the roll container has been split into two sections.

The bottom half facilitates no doors on the side of it. Luggage is stored here by lowering the luggage down into the bottom section. The middle section of the container then has a flat extrusion round the inner perimeter half way up, as seen in Figure 46. A board sits on this extrusion and acts as a shelf within the container. This board is hinged down the middle as so it can be folded up to allow luggage to be dropped into the bottom storage.

The top half of the roll container facilitates a double door at the front side which provides access to luggage stored at the top section. At this section, luggage can be stacked on the shelf of the container. The doors accommodate a T-handle lock which provides an ergonomic feature help in opening the door whilst providing a locking system to safely contain the luggage within the roll container. The roll container designed can be seen in Figure 45.

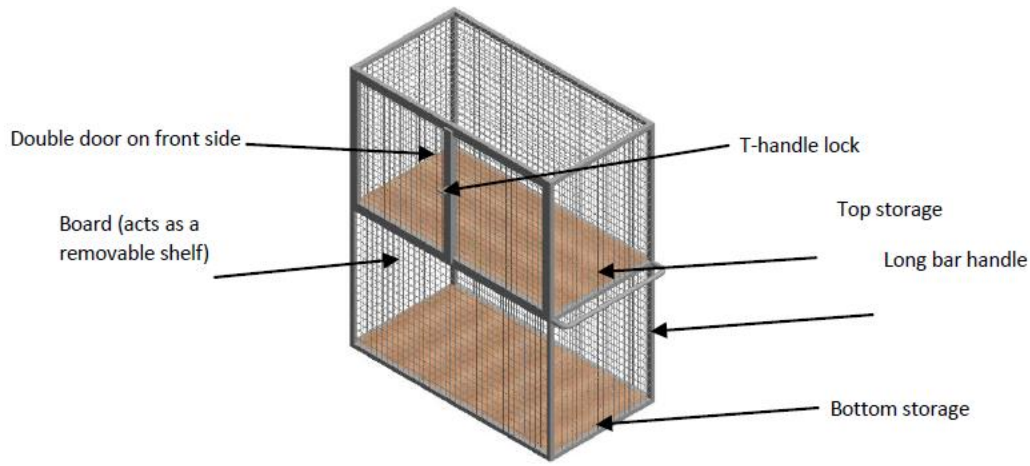


Figure 45: Design 2.1 roll container

This roll container has been designed so that it is mobile and can therefore be easily transferred on and off the metro vehicle. To accommodate this, four heavy duty of swivel castors have been implemented to the base of the container. Integrated into the wheels of the roll container are brakes which can be applied when on-board the metro, as to prevent the container from moving whilst in transit. A long bar handle has been fitted at the end of the container to provide a suitable grip whilst manoeuvring it, as seen in Figure 46.

Figure 46: Design 2.1 roll container base

The walls of the container are caged, as seen in Figure 46, to ensure it is light weight thus easy to move and to provide the staff on-board the metro with a clear vision of the luggage at all times. The use of minimal material for this design also reduces the cost of manufacturing the product.

At the first station of travel to the airport, this being South Hylton, an empty roll container is to be transferred onto the metro vehicle. The container is positioned flat against the left hand side of the longitudinal seating such that the longer side of the container sits parallel to the seating. It must be assured that the double doors of the container are facing away from the longitudinal seats in which the container is positioned against as to facilitate clear access to the storage by the member of staff operating the check-in service. Once the container is correctly positioned, as seen in Figure 47, the brakes of the swivel wheels are applied thus locking the roll container in place.

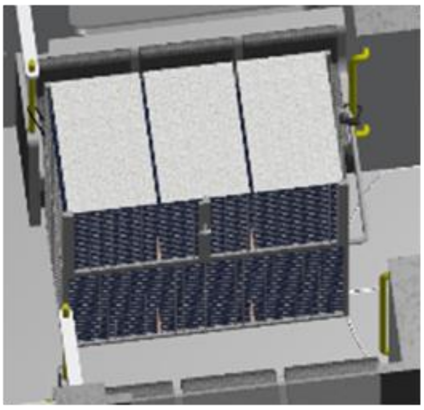


Figure 47: Roll container locked up in position during operation

A lock is then applied to the long bar handle of the roll container and the vertical hand rail positioned on the edge of the centre compartment of the check-in and bag drop facility. A strap is also fitted around the vertical hand rail positioned above the side board adjacent to the longitudinal seating and passed through the caging of the roll container, as seen in Figure 47. These added features provide additional safety and stability to the container as to prevent it projecting down the aisle in the event of emergency braking or an impact. It is particularly important for this to be considered for this design as when the container is full of luggage, it becomes a heavily condensed weight on a set of wheels. The brakes and locks therefore account for this.

From within the check-in desk, the expandable safety barrier is removed and installed. The end support is slotted down the side of the side board. Present on top of the support is a vertical extrusion in which an adjustable strap is fixed to it. This strap is tied around the vertical hand rail above the side board and tightened as to fix the support of the barrier. The opposite support is then pulled out and fitted into the end of the opposite side board. A strap is attached to this support as well which can be tightly fitted around the vertical hand rail. The straps prevent the barrier from pulling out from the side board whilst the ingrained slot of the supports which fit around the side boards provides a casing either side to prevent the barrier from falling forwards or backwards. This set up can be seen in Figure 48.

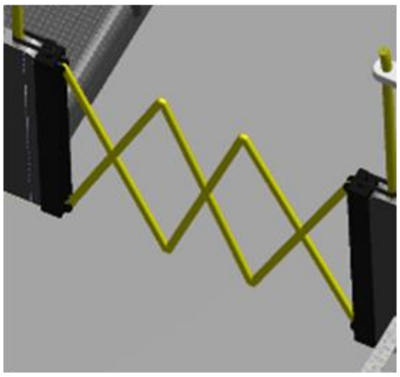


Figure 48: Expandable barrier set up

Following these installation processes, the storage area setup is complete which is displayed as seen in Figure 49.

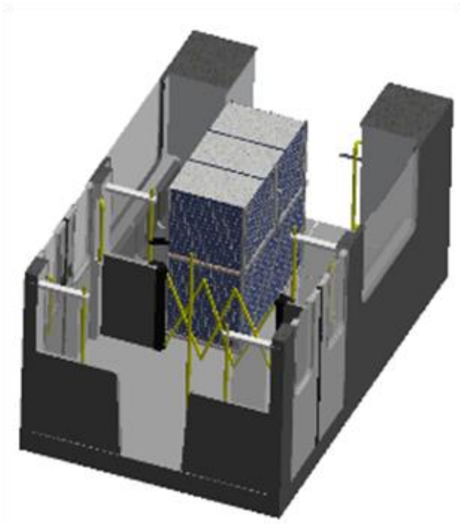


Figure 49: Design 2.1 storage area in

Once an item of baggage has been checked in, the luggage would be placed on the seating opposite the roll containers. The staff member would then open the double set of doors of the container and lift back the board enclosing the bottom section of the storage. From here, the luggage can be lifted up and lowered into the roll container. Following the maximum capacity of the bottom storage being accommodated, luggage would then be stacked on top of the board. Once the maximum capacity of the roll container has been reached or the final station prior to the airport has been passed, the doubled doors are locked shut to safely secure the luggage in place.

On arrival at the airport, all passengers depart the metro first. Following this, the barrier is removed by disconnecting the straps from the vertical hand rails and pulling the supports together thus collapsing the barrier. It can then be stored within the check-in desk. The lock and strap are removed from the roll container and the brakes on the wheels are removed. A member of staff, employed by the airport, waits for the roll container at the Airport Station. This staff member is required to board the metro and manoeuvre the roll container off the vehicle and onto the platform. From here, the roll container is wheeled away into the airport. The metro can then travel away from the airport without a roll container on-board which therefore prevents the container occupying valuable passenger space and thus this area of the metro can operate as usual.

With this design, a separate mode of transport would be required to transfer the roll containers back to South Hylton. If a sufficient number of the roll containers are bought in by Nexus, these containers can be accumulated at the airport and transferred via a heavy goods vehicle back to South Hylton by the end of the day. This would maximise capacity for passengers whilst the metro is operating.

In the case of this design, the safety barrier is simply collapsed down and stored within the check-in desk. The roll container is then removed from the metro vehicle. This therefore leaves the storage area in the same setup as the current metro design, as seen in Figure 50.

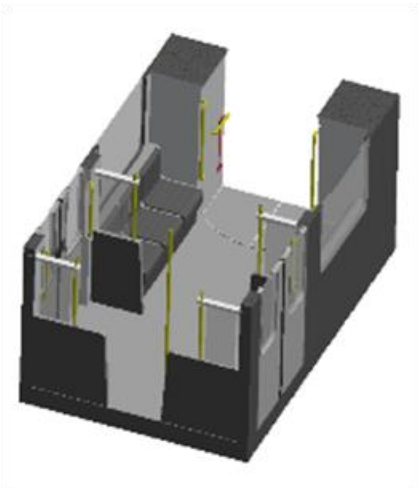


Figure 50: Display of the same metro layout left when Design 2.1 storage away is packed away

As for Design 1, based on the shape and size of the roll container, estimation could be made as to the baggage capacity of Design 2.1. The dimensions used show set dimensions for each type of luggage however the height, size, width and volume of each individual luggage used by a passenger can vary. Therefore, an estimation for the capacity of this design is obtained through a calculation of the volume of each section of the storage area divided by the volume of the varying luggage types used for this study. The value of luggage was in each case rounded down to zero decimal places. This is displayed in Table 4.

	Volume Capacity (m^3)	Small Luggage	Medium Luggage	Large Luggage
Bottom Storage of Roll Container	1.035	21	13	9
Top Storage of Roll Container	1.017	21	13	9
Total Capacity of Roll Container	2.052	42	26	18

Table 3: A display of the estimated baggage capacity for Design 1

Considering the worst case scenario in which all passengers' board with large luggage, this would give the facility a baggage capacity of 18 bags per journey. This therefore provides a capacity similar to that of Design 1, however, this design requires less components and no permanent additions to the facilities on-board the metro. This therefore means this system has the potential to facilitate the movement of 594 'large' suitcases per day. Assuming the check-in service operates on every metro journey to the airport, this design could facilitate the movement of 1485 'large' suitcases per day.

6.8.3. Design 2.2

An alternative way of operating and storing the equipment for Design 2.1 was considered in which the roll container could be transferred back on the metro from the Airport Station. This would therefore cut out the need for alternative transportation being required to transfer the container back to South Hylton thus saving money. This design would retain the same design for the check-in desk and foldable barrier but observe a new design to the roll container in which the check-in desk can be stored within the roll container.

6.8.3.1.Features of the Roll Container

The general design of the roll container is kept the same, however, the dimensions of the container has been altered slightly as so the container can fit into the centre compartment of the check-in and bag drop area. This centre compartment has a lower ceiling height of 1940mm and therefore the height of the container would be required to be reduced. The width and depth of the container remains the same. This reduces the luggage capacity that the roll container can store, nonetheless, the features of the board that sits within the container and the double door remain the same.

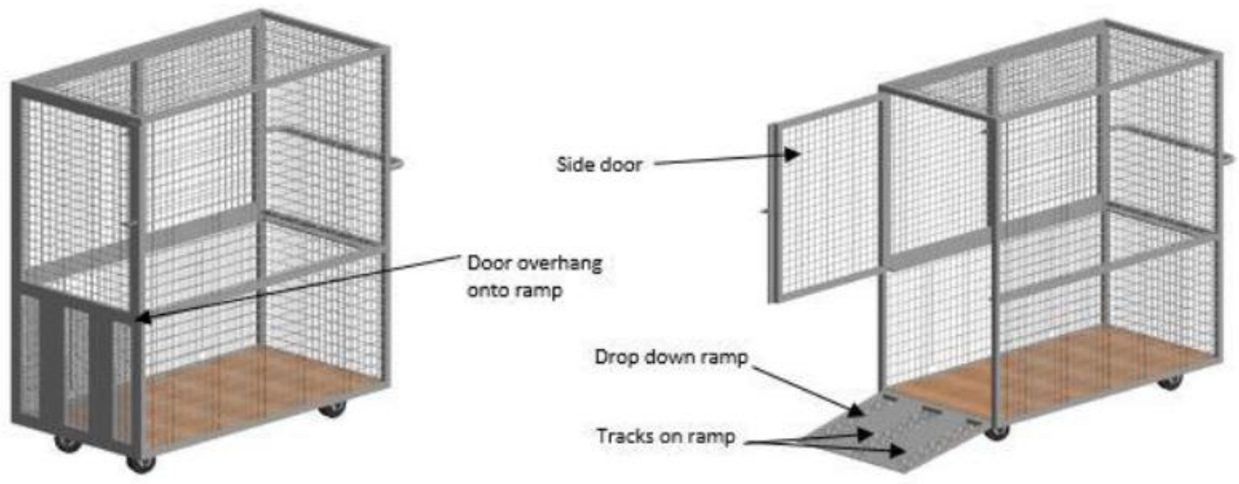


Figure 51: Design 2.2 roll container with drop down ramp

An added feature to this design of the roll container is that the side can drop down to act as a ramp. Upon the check-in equipment being packed away, the ramp would be dropped down and then check-in desk can be pulled onto the roll container. Due to the height of the frame of the container being almost two metres in height, being able to drop down the whole side of the roll container would be impractical as there would not be sufficient room on-board the metro to be able to do this. Furthermore, a ramp as long as this would undergo intense forces, due to large moments acting on it, when the check-in desk is being pulled along the ramp and therefore make it susceptible to failure. To account for this, the side of the roll container is designed into two parts. The top section of the roll container contains a door, equipped with a T-handle lock, which can open up. The bottom section has been reduced in height for this design and is hinged at the base and therefore able to drop down as to act as a ramp. The door at the side is able to be locked through the use of the T-handle lock. This door overhangs the bottom half of the roll container and thus when the door is shut, the ramp remains in place. Upon opening the door, the ramp is then able to be dropped down. The functionality of this feature can be seen in Figure 51. By reducing the height of the bottom section of the roll container and creating two openings to the side of the container, a ramp of just 600mm in length is able to be utilised thus making it sturdy and more compact, whilst improved access of the luggage for staff members is achieved.

The ramp of the container has been designed so that the tip is narrow in an attempt to allow the ramp to be as flush to the floor of the metro as possible when dropped down which in turn creates convenience in being able to pull the check-in desk onto the ramp. The ramp has a similar caged design to the rest of the roll container; however, designed into the cage are two tracks to create a smooth surface for the wheels of the check-in desk to be able to follow. The design of the ramp can be seen in Figure 51.

The extrusion around the inner perimeter of the roll container, in which the hinged board sits, does not exist at the side of the container in which the ramp is equipped with, as seen in Figure 51. This allows the board to operate in the same way but allows open access at the side of the container for the check-in desk.

The same mobility features are present for this design of the roll container; however, the long bare handle has been switched to the opposite side as to accommodate the ramp.

Due to the position in which the roll container is stored on-board the metro, new locations will need to be considered for the emergency fire extinguishers. It is suggested that these are located with one at the front end of the metro, at side A, and the other at the opposite end, at side B.

6.8.3.2. The Storage Area

Installing this design of the roll container involves exactly the same processes. The container is positioned at the same place, however, with the handle being on the opposite side of the container, the lock is fixed around the handle and attached to the vertical hand rail above the side board whilst the strap is fixed around the vertical hand rail at the edge of location 2b and passed through the caging of the container. This can be seen in Figure 52.

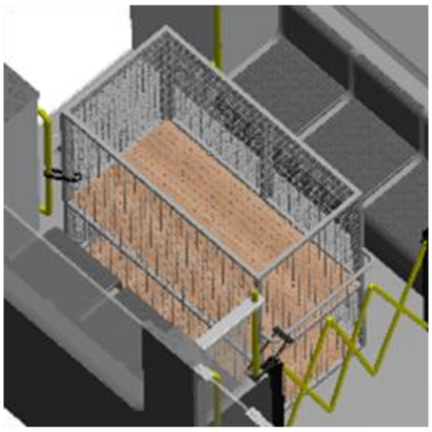


Figure 52: Installation of the roll container for Design 2.2

The way in which the roll container is operated when the metro is in transit does not differ to Design 2.1. The side door and ramp should remain closed as to not disrupt the stack of luggage. The way in which luggage is stored onto the container is the same.

Following the arrival at Newcastle International Airport, the roll container is to be transferred off the metro and into the airport in the same way as described in Design 2.1. The difference is, however, that the staff member employed by the airport that is required to wait at the platform to transfer the luggage, would also be required to wait at the platform with an empty roll container ready. Upon the arrival of the metro, the roll container on-board, which contains the checked in luggage, can then be transferred into the airport whilst the empty roll container is transferred onto the metro. This empty roll container is then stored in the centre compartment and all equipment from the check-in and bag drop facility is loaded onto it. Subsequently to the checked in luggage within the container being unloaded and passed to airport security, the now empty roll container would be transferred back to the Airport Station to await loading onto the next metro service accommodating the check-in and bag drop facility.

Figure 53: Roll container with equipment stored within it

On arriving at the Airport Station, the barrier would be collapsed down followed by the roll container being transferred off the metro and the new empty container being transferred on. The new roll container would then be positioned in the centre of the storage area of the metro. Firstly, the hinged board separating the top and bottom storage of the container is folded back and lifted up and out from the extrusion it is sat on and positioned on the floor container to the side so that it is stood up right. The side door of the container would be unlocked and opened up thus allowing for the ramp to drop down to the floor. The check-in desk is rotated 90°, such that the desk is aligned with the side entry of the container, and pulled onto the roll container via the drop down ramp. Following this, the barrier is then stored within the roll container and the ramp is raised up and the door closed and locked shut. By avoiding the barrier being stored within the check-in desk, it removes the chance of the barrier damaging and scuffing the weighing scale. The roll container with all equipment stored inside can be seen in Figure 53.

The roll container, containing the check-in equipment, would then be transferred into the centre compartment of the check-in and bag drop area of the metro at location 2b. It is assured that the wheels of the roll container do not overlap the pivoting floor. Once correctly positioned, the brakes on the wheels are applied to fix the container in place. Due to the size of the roll container, complete accommodation of location 2b, on the pivoting floor, is occupied by the container. To assure passengers are not tempted to attempt to move between the metro and the roll container, two panels have been designed which sit within the vertical hand rails positioned at the ends of location 2b. These panels also provide a barrier as to prevent the container moving down the metro in the event of emergency braking or an impact.

The barriers are designed around the shape and positioning of the roll container. The first barrier is a flat rectangular shape. One end is curved such that it can be clipped around vertical hand rail. At either end of the barrier, a cut is implemented into the base as so the barrier can then be pushed down and slotted onto the bottom section of the hand rail. The second barrier is of a unique shape. Due to the size of the roll container, although the wheels are contained within the pivoting floor, a section of container structure over hangs. Therefore, this barrier has been shaped such that it curves outwards to tightly fit around the side of the roll container. The ends of the barrier are then equipped in the same way as the first thus allowing it to be fitted onto the vertical hand rails. Displayed on the front of these barriers is the message 'Keep Out' which provides clear instructions to the passengers that this section of the metro is not available for use. These designs can be seen in Figure 54. This figure also displays the final setup of the check-in and bag drop equipment when stored away.

Figure 54: The check-in and bag drop facility packed away for Design 2.2

This design would not reduce the seating capacity of the metro, however, location 2b would be completely out of bounds for passengers to stand and move through. With this section facilitating the pivoting tractor bogie, and therefore obtaining slight rotation of the floor, and being of a smaller height without any windows, it would be seen as the most unpopular place to stand and therefore the unavailability of this area won't greatly affect customer satisfaction negatively.

As previously considered, based on the shape and size of the roll container, estimation could be made as to the baggage capacity of Design 2.2. The same method is used to measure the capacity of this design, as in Design 1 and 2.1, as to create an estimation for the capacity of this design. The results are shown in Table 5.

	Volume Capacity (m^3)	Small Luggage	Medium Luggage	Large Luggage
Bottom Storage of Roll Container	0.696	14	9	6
Top Storage of Roll Container	1.017	21	13	9
Total Capacity of Roll Container	1.713	35	22	15

Table 4: A display of the estimated baggage capacity for Design 2.2

Considering the worst case scenario in which all passengers' board with large luggage, this would give the facility a baggage capacity of 15 bags per journey. This therefore gives a capacity smaller than Design 1 and 2.1, however, this design avoids the need to operate a separate mode of transport to transfer the roll containers back to South Hylton Station. This system has the potential to facilitate the movement of 495 'large' suitcases per day. Assuming the check-in service operates on every metro journey to the airport, this design could facilitate the movement of 1237 'large' suitcases per day. Despite this design being unable to accommodate as much baggage as Design 1 and 2.1, it still has the potential to transfer a substantial number of luggage per day whilst offering an alternative method of operating an on-board check-in and bag drop facility.

6.8.4.Design 3

Design 3 briefly looks at the possibility of combining features from Design 1, 2.1 and 2.2 to create a storage area of maximum capacity and a service which provides the greatest amount of facilities for passengers. This design shows the maximum potential of baggage that an on-board check-in and bag drop facility could operate for the Tyne and Wear Metro. The newly considered concept for this design is only considered within the storage area. The idea for this design would be to have the storage area for Design 1 incorporated onto all metro cars. In the event that there is an expected passenger increase due to a large passenger flight departing or a high density of flights during a particular time of the day, the roll container could be incorporated with this design to temporarily increase the capacity of the service. This design also shows the potential to be able to further modify and develop the metro to increase its capacity in the event that the on-board check-in and bag drop facility increases in popularity over time.

6.8.4.1.Check-In Desk

The check-in desk used would be the same design used in Design 2.1 and 2.2. This allows for the desk to be stored within the roll container and for the availability of printing boarding passes.

6.8.4.2. The Storage Area

For this design, all the facilities within the Design 1 storage area would be available apart from the double jointed drop down arm, which acts as a barrier, which would be replaced as another single jointed 'fold out arm' which contains a pull out strap within it. The extra arm would provide added support for safely stacking the luggage. For this design, the safety barrier used for Design 2.1 and 2.2 would be used.

Design 3 incorporates the roll container from Design 2.2 within the storage area whilst additionally containing the features from Design 1. Within Design 2.1 and 2.2, the seating space within the storage area is not occupied and therefore there is potential for this area to be accommodated for further storage for baggage.

The aim of this design is that luggage can be stored in the roll container whilst also being stored on the seats and on the luggage racks. The luggage racks are an instalment that would benefit all metro passengers and therefore should be utilised whilst the fold out arms to do not accommodate any capacity of the metro vehicle.

The roll container is transferred onto the metro and positioned and installed in the same way as in Design 2.2. The 'fold out arms' on the seating of the storage area remain untouched. This would complete the instalment of the storage area.

For this design to work, a specific order in the way the storage area and luggage is managed whilst the check-in desk is in operation is required. Firstly, luggage would be loaded onto the roll container as seen in Design 2.2.

Following the maximum capacity of the roll container being reached, luggage would be stored on the seating and luggage racks positioned on the opposite side to the roll container. The operation of this storage for the seats and luggage rack would be the same as seen in Design 1 however with the addition of an extra arm to raise up and a strap to connect to the luggage rack.

If further storage is still needed to store more baggage, it would be possible to unlock the roll container from the hand rails and push it to sit against the opposite longitudinal seats. This would prevent access to the luggage already stored on the seats, luggage rack and front access to the roll container; however, this luggage should not be accessible once checked in. Upon transferring the roll container to the opposite side, luggage can then be stored on the available seats and luggage rack exposed. This design of operation can be seen in Figure 55. For this design to operate, it would be highly recommended for at least 2 members of staff to be on-board the metro at all times.

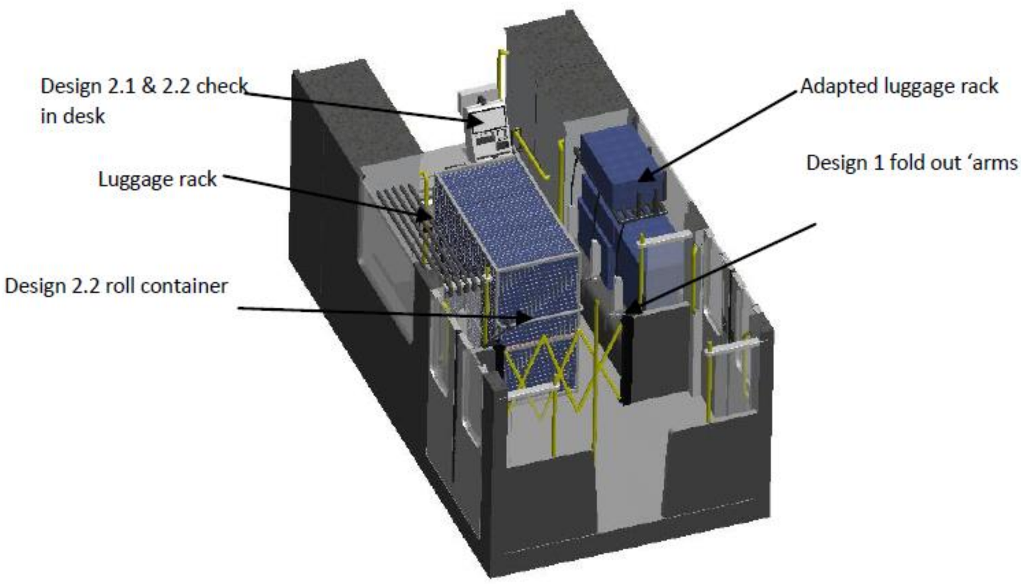


Figure 55: Design 3 when in operation at full capacity

Upon arriving at the airport, two members of staff, employed by Newcastle International Airport, would be required to be waiting with two roll containers. One roll container would be of the design of the container seen in Design 2.1 whilst the other would be of the design from 2.2. Luggage stored on the metro on the seating and baggage racks would be transferred from the metro, onto the platform and into the roll container from Design 2.1. This roll container was found to have a luggage capacity equal to Design 1 and therefore it would be guaranteed that the entire luggage from the seating and baggage racks could be loaded onto the roll container. The container on-board the metro would then be unlocked and transferred off the metro. The empty container on the platform of the Airport Station would then be loaded onto the metro. The two roll containers present on the platform, containing luggage, can then be transferred into the airport.

This design would require the airport to stock a small number of roll containers from Design 2.1 whilst the roll containers from Design 2.2 would operate in the same way.

Following the luggage being off-loaded from the metro vehicle and the new empty container being transferred on-board, the whole of the check-in and bag drop area would be stored away in the same way as seen in Design 2.2.

This design aims to show the how much baggage an on-board check-in and bag drop facility could accommodate and therefore provide an idea on the potential of such a service and show the possibilities in which a facility like this could be developed.

To calculate the luggage capacity of this Design, the values calculated from Design 1 and 2.2 were combined. These values can be seen in Table 6.

	Volume Capacity (m^3)	Small Luggage	Medium Luggage	Large Luggage
Total Capacity of Design 1	2.358	46	30	18
Total Capacity of Design 2.2	1.713	35	22	15
Total Capacity of Design 3	1.713	81	52	33

Table 5: A display of the estimated baggage capacity for Design 3

And again considering the worst case scenario in which all passengers' board with large luggage, this would give the facility a baggage capacity of 33 bags per journey. This therefore gives a capacity over twice that of Design 2.2. This system has the potential to facilitate the movement of 1089 'large' suitcases per day. Assuming the check-in service operates on every metro journey to the airport, this design could facilitate the movement of 2722 'large' suitcases per day.

This design would be a more expensive option however it still delivers the key features and specifications required for the check-in and bag drop facility to be a success whilst producing an impressive volume of baggage movement. This shows there is great potential for this facility to operate at a remarkable scale whilst still only occupying a small area of the metro and allowing for a similar level of operation for the Tyne and Wear Metro.

6.9. Staff

For Design 1, 2.1, 2.2 and 3 to operate, at least one member of staff is required. This would be the cheapest option, however, for an efficient operation of this service, two members of staff are recommended. An on-board check-in and bag drop facility is a brand new concept which has not been implemented anywhere in the world. The functionality of the service may therefore be confusing to many, particularly during the early days of opening.

It is therefore recommended that one member of staff would operate behind the desk whilst the other would operate outside of it and manage the passengers. This would allow a member of staff to provide clear instructions to passengers and aid with sufficient organisation thus preventing queuing and a more efficient service. The member of staff outside of the check-in desk can operate with a tablet device and provide live information to passengers regarding flight information. Whilst the member of staff behind the check-in desk is serving customers and handling luggage, the other member of staff can answer any queries passengers have and provide sound advice. Further to this, this staff member can assist in the handling of luggage and storing away of the check-in equipment during peak times.

The staff member outside of the check-in desk can also provide assistance to non-airport passengers. Based on customer service attributes between 2009 and 2012, customer service factors which are consistently rated highly are staff availability, train cleanliness and passenger behaviour [8]. These factors can be addressed with the introduction of this member of staff. With currently, just an occupied driver on-board the Tyne and Wear metro, there is a poor staff availability and therefore this additional staff member can provide greater availability to all passengers. With the presence of a second staff member, passenger behaviour is likely to improve due to the fear of being removed from the metro and reported to the authorities. The cleanliness of the train can also be addressed as a quick clean can be conducted by the staff member at both South Hylton and the Airport Station.

6.10.Security

Security is extremely important for this concept. Whilst the installation of an X-ray machine is not practical, certain protocols and features can be implemented to account for this. A major assistance of the security for this concept would be to have a second member of staff that could provide additional surveillance to potential threats.

A quote from the Tyne and Wear public transport users group states, ‘we believe safety and security on the Metro should be a major priority, with steps taken to improve this where possible. On-train staff presence is essential for security. We would strongly welcome proposals that would increase staffing for passenger assistance in passenger areas of trains and in stations’ [22]. Without passengers being assured that the baggage is safe and, most importantly, the passengers themselves are safe, customers of the Tyne and Wear Metro would be deterred from using the on-board check-in and bag drop facility. By introducing two members of staff on-board the metro whilst the check-in desk is in operation, this provides physiological and psychological assurance for passengers regarding safety. Further to this, the staff member outside of the check-in desk would be able to provide improved vigilance to threats and security breaches.

Specific practices based around the security for light rail vehicles can introduced into the operation of the Tyne and Wear Metro. These include the development of operations for agency staff and employees to implement such as screening of passengers by observation techniques (SPOT) [28] and baggage reconciliation techniques to prevent a disembarking passenger leaving baggage behind [29].

Passengers can act as public surveillance in observing threats on-board the metro. A public awareness campaign of ‘if you see something, say something’ can be heavily incorporated into the metro vehicles to raise public awareness of indicators of terrorism and violent crime [28]. This can be done by the use of posters fitted within the metro vehicle and on the station platforms. If a passenger develops suspicion, a member of staff would be available on-board to then deal with this concern in a proper manner.

Currently, CCTV cameras are positioned by each set of doors on-board the metro. This allows for a clear capture of every passenger that boards the metro. For these designs, a CCTV camera is recommended to be positioned to face the check-in desk and the storage area of the luggage. This provides constant surveillance of the luggage and check-in area at all times. These cameras provide a valuable source of evidence for use in the detection and investigation of a crime thus act as a useful deterrent value [29].

PSIs are believed to both deter and detect terrorist activity and are suspicion-less inspections of transit passengers by staff members [28]. This technique is a quick process in which passengers can be randomly searched. This may involve luggage being randomly hand search after every set amount of luggage that has been checked in. The unpredictability of whether luggage will be searched is an effective deterrent for terrorist activity whilst also not producing a major change to the efficiency of the check-in service.

Attempting to implement on-board security equipment which airports facilitate, such as X-ray machines, to provide sufficient security checks to luggage before being loaded onto the aeroplane would be impossible due to the amount of power that would be consumed by the metro, the significant additional weight, the large capacity of the metro it would require and the predicable extensive reduction in the efficiency of the check-in facility. Complications would arise in transferring luggage directly from the metro onto the aeroplane, as sufficient security checks would want to be conducted by the airport rather than leaving it accountable to the Tyne and Wear Metro. Therefore, an effective way of assuring the luggage checked in on the metro undergoes sufficient security checks before being loaded onto the aeroplane is to simply transfer the luggage from the platform and into the terminal where the baggage can then be loaded via the bag drop desk utilised for extra-large baggage. This bag drop area is used as a neutral dropping point for awkwardly sized and extra-large which has already been checked in and thus contains a baggage label, similarly to the baggage checked in on the metro. Luggage that is passed through here undergoes all the required security checks of the airport and is arranged into the corresponding destination of flight. By operating the on-board check-in and bag drop service such that each metro serves a set number of flights, this method of transferring the luggage through airport security has the potential to successfully operate. Once the entire luggage checked in on the metro is passed through the airport bag drop desk, the usual security checks and handling of the luggage can be implemented thus providing the same assurance for the safety of passengers on-board the flight.

7. Evaluation

7.1. Design Evaluation

To initially evaluate the alternative interior designs produced the design criteria, set prior to the development of the designs (see 5.1), have been based on the quality of the design. By weighting the design criteria based on the importance each contributes to the design, an overall weighted score could be produced to provide a ranking of the preferred designs for this study. The design criteria and weighting was developed through observations made during the study, review of the research and literature and discussions with experts from Nexus. Each design has been produced to meet the criteria; however, to obtain the optimum design, the ratings produced are relative to each other. Ratings follow a scale of 5 (very good) to 1 (very poor). The results for this evaluation can be seen in Table 7.

Criteria	Weight (%)	Design 1		Design 2.1		Design 2.2		Design 3	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Performance	14.7	4	0.588	5	0.735	4	0.588	4	0.588
Cost	14.7	3	0.441	3.5	0.5145	5	0.735	2	0.294
Versatility	14.7	5	0.735	4	0.588	5	0.735	4	0.588
Safety	14.7	5	0.735	5	0.735	5	0.735	3	0.441
Security	14.7	4	0.588	5	0.735	5	0.735	4	0.588
Usability	11.8	4	0.472	5	0.59	3.5	0.413	3	0.354
Robustness	8.8	2.5	0.22	4	0.352	3	0.264	3	0.264
Aesthetics	5.9	3.5	0.2065	4	0.236	4	0.236	3	0.177
Total Weighted Score		3.99		4.49		4.44		3.29	
Rank		3		1		2		4	

Table 6: A table displaying the weighted scores for the design criteria for each design

Based on this evaluation, the optimum design which best considers the criteria set at the start of this study have been determined as Design 2.1. This was due to its simplistic design which allowed for an exceptional performance, usability, robustness and aesthetics. Design 3 provides impressive potential for the number of luggage it could accommodate in a single journey, however, this evaluation table highlights that in order for Design 3 to successfully operate, further considerations must be made to comply with the design criteria for safety and cost. A brief discussion behind the reasoning for the ratings given for each criterion can be seen below.

Performance - Design 2.1 scored the best for this criterion. This was due to the ability of being able to store a high volume of luggage whilst providing the ability for passengers to print boarding passes. This design can be operationally turned around at the airport in the most efficient and simplistic way and with minimal handling of equipment. This design exceeded that of Design 2.2 and 3 due to the operation being the simplest and having the ability to be installed and packed away efficiently. Design 1 storage area provided high capacity for the storage for luggage whilst providing sufficient floor space for the staff to work, however, due to the more complex setup of the check-in desk, it was deemed below the performance Design 2.1 provides.

Cost - Design 2.2 scored the best for this criterion. This design required small permanent upgrades to the interior of the current metro vehicles. This avoids the need for all the vehicles to undergo extensive modifications. Instead, a specified amount of the equipment can be bought in and adapted to each metro as required. The check-in is composed of less components as the MD1 Service Desk incorporates most of the required facilities. A bulk order of one component from the same company results in cheaper costs overall. Design 2.1 required separate transportation for the transfer of the roll containers, which adds further employment and expense. Design 1 requires the purchase and manufacturing of several individual components, including an internal battery for each check-in desk, the addition of two fire extinguishers and new designs manufactured specifically for the metro in the case of the check-in desk, luggage racks and 'fold out arm' supports. Design 3 combines features from Design 1 and 2.1 and is therefore the most expensive.

Versatility - Design 2.2 and Design 1 scored best for this criterion. Compared with Design 2.1, 2.2 is able to retain the exact operation of the metro, by transferring the roll container back to South Hylton via the metro, whilst occupying no seating space. Whilst design 1 limits the number of passengers it can provide a service to due to the inability to obtain a boarding pass on-board, this design provides the best design in which the smallest area is permanently accommodated and thus minimises the change of the internal operation of the metro and its capacity. Passengers are able to pass internally through the metro vehicle from side A to side B and this allows for complete access and the same internal operation. By the utilisation of the internal battery, installation of plugs is avoided. Design 3 provides a similar operation as Design 2.2, however, an additional operation of roll containers within the airport is required.

Safety - All designs ensure that components are locked down during transit. This removes the potential for equipment to be projected down the aisles in the event of emergency braking or an impact. All designs ensure wires are encased by an enclosure for check-in desk equipment. The utilisation of the waiting area removes luggage from being a tripping hazard for non-airport passengers and more efficient boarding reducing the chance of crushing. Each design considers the availability of fire extinguishers remaining available at all times. Design 3 scores lower due to the need to transfer a full capacity roll container from one side of the storage area to the other. This involves temporarily unlocking the container. Therefore, comprehensive communication between the driver and the staff member operating the desk must be implemented to prevent the metro departing whilst the container is unlocked. The roll container used for Design 2.1 minimised the number of time the luggage is moved by the train staff and prevents over overexertion.

Security - All designs incorporate storage areas equipped with locks to contain expensive equipment within the desk. Security procedures and equipment (see 5.7) would be implemented to all designs. The security of Design 2.1 and 2.2 exceeds that of Design 1 and 3 however as luggage is locked and stored away in an enclosed container during transit making unauthorised access to luggage highly improbable. Furthermore, the safety barrier used would provide a more extensive prevention into the storage area due to the larger area it barricades and greater difficulty in dissembling.

Usability - Design 2.1 provides the simplest operation in terms of storing the equipment away. Handling of the luggage is minimal whilst the check-in desk does not require to be repositioned. This gives for a quick turnaround time. The MD1 Service Desk offers the widest range of facilities whilst providing an LCD screen for passengers thus making the facility more 'user friendly'. Design 2.1 and 3 require the check-in desk and barrier to be detached and loaded onto a roll container which is then locked into position. This creates a more complicated storing process and is a more strenuous task. Design 3 scores worse here, however due to the requirement of staff managing more extensive and complex operation of the storage area. Design 1 induces a simple setup of the storage area however the installation and packing away of the check-in desk requires a more convoluted process than Design 2.1. However, Design 1 scores higher than Design 2.2 and 3 as the check-in desk for this design is a more compact and light weight design thus making manoeuvring it more easier.

Robustness - Whilst this area will be consider more thoroughly following the production of prototypes of the proposed designs, an initial estimation can be made as to the robustness of the designs. Design 1 scores low relative to the other designs due to the frequency of demand and use of the components; constantly building and deconstructing the check-in desk can lead to wear over time. The more components, the greater chance there is of damage to the facility. The roll top mechanism could be susceptible to grit and dirt contamination that would cause damage over time. Design 2.1 scores the highest in this criterion as the equipment is subject to the least handling and therefore less likely to be damaged. The check-in desk used for Design 2.1, 2.2 and 3 contains a casing for the weighing scale and thereby removes the need to handle the weighing scale. The robustness rating for Design 2.2 and 3 is lower than that of 2.1 due to the drop down ramp within rolling container which can be compromised by regular heavy loads thus inducing repetitive strain on the hinges of the ramp.

Aesthetics - The check-in desk of Design 2.1, 2.2 and 3 sits within the width of the aisle whilst being composed of only one part. This gives a more complete, sturdy and professional finish to the product. With the MD1 Service Desk providing LCD screens for the passengers, this provides a modern and technologically advanced service which would appeal to the modern passengers. The storage area of Design 1 provides a more subtle facility and gives a neater finish with floor space being retained. Despite this benefit of Design 1, the passengers will be more enticed by the aesthetics of the waiting area and check-in desk utilised by passengers and therefore Design 2.1 and 2.2 were scored higher. Design 3 was scored the lowest as it contains a very packed storage area which may not look aesthetically pleasing. Further to prototypes being produced, the aesthetics of each proposed design can be modified as this was not prioritised for this study.

7.2. Customer Opinion

Through research of a National Rail Passenger Survey [30], the key factors which influence customer satisfaction on a rail vehicle were observed. Factors which were applicable in terms of them being affected by the on-board check-in and bag drop facility were evaluated and scored based on the influence the designs and operations proposed would have on each area of customer satisfaction relating to passengers travelling to the airport. The scoring system used can be seen in Table 8.

Customer Satisfaction Scoring System	
1	Highly Positively Effected
2	Positively Effected
3	No Effect
4	Negatively Effected
5	Highly Negatively Effected

Table 7: Display of the scoring system used for the customer opinion evaluation

The averages of the scores were deduced for each design. The results of this evaluation can be seen in Table 9.

Customer Satisfaction	Design 1	Design 2.1	Design 2.2	Design 3
Passengers always able to get a seat on the train	4	4	4	4
Journey time reduced	4	4	4	4
Punctuality/Reliabiliy	4	4	4	2
Inside of train is maintained and cleaned to high standard	4	4	4	3
Accurate and timely information provided on trains	5	5	5	5
Personal security on trains	4	4	4	4
Sufficient space on train for passenger luggage	5	5	5	5
More staff available on trains to help passengers	5	5	5	5
Ease of getting on and off	4	4	4	4
Navigating the station	4	4	4	4
Boarding quickly and easily	5	5	5	5
High level of technology expected	4	5	5	5
Clear gangways	5	5	5	5
Total	**4.38**	**4.46**	**4.46**	**4.23**

Table 8: A display of the results regarding the customer satisfaction obtained from the proposed designs

Table 9 highlights the positive consideration each design has towards customer satisfaction. There is an extensive range of customer satisfaction considerations that are improved for airport passengers by the installation of this facility. This evaluation therefore shows that the end user would be excited by the designs proposed and opportunities provided. Design 2.1 and 2.2 would provide a service that would provide the highest customer satisfaction, however, due to similar operations for the internal designs being similar, the choice of design should not heavily impact the customer satisfaction, providing the operations proposed in this study are followed.

Passengers always able to get a seat on the train - Sufficient room being available for passengers to sit/stand is highlighted as currently one of the biggest impacts on overall dissatisfaction [30]. For airport bound passengers, this satisfaction is positively affected for all designs as the waiting area would provide priority seating. This waiting area provides six seats; however, this wouldn't be enough to guarantee airport passengers a seat, particularly during busy periods. The designs do provide a move toward improving this consideration. Furthermore, once the luggage is checked in, access to other seating down the narrow aisles of the carriages would be more accessible.

Journey time reduced - By combining the check-in process and the journey to the airport into one transaction, the overall time a person would spend prior to passing through security would be reduced.

Punctuality/Reliability - The punctuality and reliability of a rail service is the biggest impact on the overall satisfaction of the public service transport. It is therefore important that this satisfaction is retained to not disrupt the positive reputation of rail services. This is maintained by ensuring there are no delays due to the check-in and bag drop facility. To aid in this, the equipment must be able to be installed and packed away within the current operative time scale. Design 1, 2.1 and 2.2 could be installed and packed away within the 10 minute turnaround time at the Airport and South Hylton Station. This therefore provides the most reliable transport to the airport when compared to road transportation. Design 3 would require additional time to handle the extensive amount of equipment and operations contained within it and thus reduce the punctuality and regularity of the metro.

Inside of train is maintained and cleaned - With the addition of extra staff on-board the metro service, there is an opportunity for staff to conduct a quick clean of the vehicle during turnaround when arriving at the Airport and South Hylton Station. Design 3 would find difficulty in adding this requirement to the already extensive tasks required from the staff on-board at turnaround.

Accurate and timely information provided on trains - With a member of staff operating outside of the check-in area, this staff member will provide live information through the use of a smart phone/tablet device.

Personal security on trains - There will always be concern from some passengers regarding the storage of luggage on trains. Each design has considered the optimal solution to maintain safety and assure passengers. The additional staff provided also helps with personal security.

Sufficient space on train for passenger luggage - With airport passengers being able to check-in and drop off luggage on-board the metro, this customer satisfaction area has been completely resolved.

More staff available on trains to help passengers - The purpose of the extra staff member operating outside of the check-in area is to provide assistance for passengers. This is a feature which currently is not present on the Tyne and Wear Metro.

Ease of getting on and off - Departing the metro at the airport station is easier with no luggage to have to carry. There still remains a difficulty for passengers boarding the metro when travelling to the airport and when boarding and departing on the return journey from the airport. These designs provide some improvement to this area of satisfaction however.

Navigating the Station - This study considered the need for clear signs and markings to ensure airport passengers understand where to position themselves and where to board the metro.

Boarding quickly and easily - A smoother boarding process would be implemented from these designs as passengers with luggage would have clear access to the waiting area. This removes the chance of a bottle neck effect down the narrow aisles caused by passengers with luggage attempting to manoeuver between the seats and taking up space by placing luggage on seats and the floor; all of which can prevent access for other passengers.

High level of technology expected - The presence of an on-board check-in and bag drop facility would be a completely new concept and the presence of this would incorporate a high level of technology. The MD1 Service Desk provides a greater range of facilities than in Design 1; including LCD screens for the passengers.

Clear gangways - As in the Tyne and Wear Metro, the lack of storage causes seats and aisles to be taken up by baggage. This reduces the capacity of the metro, creates a safety hazard and reduces the efficient flow of passengers inside the metro. The storage area safely stores away any airport related baggage on-board the metro and clears up the gangways.

7.3 Measure of System Performance Comparison with Existing Solutions

To provide valid assessment of the proposed design and operations of the on-board check-in system, comparisons have been made against existing systems and performance. This section of the evaluation provides a clear comparison with the differing performances available with a selection of alternative check-in and bag drop facilities to highlight the benefits and limitations of the design proposed from this study. To evaluate this study, Design 2.1 has been used to compare with the existing systems as this was deemed the best design through comparison with the other proposed designs and customer opinion. This assessment can be seen in Table 10.

Overall, this evaluation shows that the on-board check-in and bag drop facility is able to provide similar features to the already successful Hong Kong in town check in. Design 2.1 may be forced to impose stricter rules surrounding luggage size and weight, however, it provides a versatile opportunity which can be adapted to existing rail services and thus reduces the need for change to the infrastructure and therefore cost. Furthermore, the design provides a wider range of locations where passengers can check-in luggage therefore making it accessible and convenient for a greater percentage of the population. A further look at the measures of system performances is discussed next.

Baggage Capacity - Design 2.1 would limit the maximum luggage that could be transferred per day unlike the other systems in place. The design should however provide a sufficient capacity of luggage for Newcastle International Airport with it being one terminal.

Measures of System Performance	Design 2.1	Hong Kong In-Town Check-In [10] [30]	Daniel Brice's Newcastle Bag Drop [12]	Virgin Bag Magic [31]
Baggage Capacity of Service	Up to 1485 'large' baggage per day	Unlimited	Every single passenger on every plane could be accommodated for	Unlimited
Maximum Luggage Size	Large Suitcase (0.11m^3)	Unlimited (bags that exceed 0.209m^3 induce added cost)	Unlimited (costing not discussed for this study)	0.189m^3
Maximum Luggage Weight	30Kg	Unlimited (bags that exceed 30kg induce added cost)	Unlimited (costing not discussed for this study)	30Kg
Number of Bag Drop Locations	30 (bags can be checked in by boarding an airport metro at any of the 30 stations prior to the airport)	2 (Hong Kong Station or Kowloon Station)	1 (Haymarket Station in Newcastle Centre)	Unlimited (bags collected from desired location)
Luggage Collection Location	Collected from luggage collection point at airport destination	Collected from luggage collection point at airport destination	Area of study not discussed yet	Luggage dropped off at requested address
Time Taken for Luggage to Arrive at Destination	Dependant on the flight time and airport destination handling times	Dependant on the flight time and airport destination handling times	Area of study not discussed yet	Over 24 hours
Time Passenger is Baggageless	Passenger become baggageless soon after boarding the metro	Passenger becomes baggageless following arriving at Hong Kong/Kowloon Station	Passenger becomes baggageless following arriving at Haymarket Station (Newcastle City Centre)	Passenger baggageless for whole journey
Additional Preparation Compared to Standard Airport Check-In	Purchase of airport metro check-in ticket	Purchase of Airport Express train ticket	Area of study not discussed yet	Service must be paid for online and luggage must be packed a day in advance
Infrastructure Adaptation and Construction Required	No change to infrastructure required	New rail track constructed specifically for check-in area. Construction of station required with this	Extension of Haymarket Station would be required	No change to infrastructure required (existing road courier service used to transport bags)
Hours of Operation	6am – 12pm (18 hours)	5.30am – 90 minutes before last flight departure	Freight train operates 24 hours per day	Collection and delivery operates Mon-Fri, 9am – 5pm
Destination Availability	Any destination	Any destination	Any destination	Within the UK

Table 9: A display of the comparison of measured system performances with existing systems

Maximum Luggage Size - This design would provide a smaller than average maximum luggage size. Alterations could easily be made to this by incorporating the same concept from the Hong Kong in town check in where passengers simply pay extra to check-in larger luggage. This assures the system retains the same turn over for each journey made. The seating within the storage area could be used to store larger items of luggage.

Maximum Luggage Weight - For Design 2.1, a strict 30kg luggage allowance should be enforced. Luggage loaded onto the roll container is then required to be pushed into the airport; baggage which exceeds the 30Kg weight would make it impossible and unsafe for the member of staff to navigate the container from the metro and into the airport.

Number of Bag Drop Locations - The proposed on-board check-in and bag drop facility offer a bag drop location nearby for most of the population in the Tyne and Wear area. The Hong Kong and Newcastle City Centre bag drop limit the location to which passengers are able to check-in luggage and create an added inconvenience.

Luggage Collection Locations - Like the Hong Kong check-in, Design 2.1 allows for luggage to be collected in the usual way at the baggage collection point at the airport destination.

Time Taken for Luggage to Arrive at Destination - By allowing the handling of the luggage to be handed over to the airport staff and airport processes followed, the Check In and Bag Drop Service ensures that the usual time taken for luggage to arrive at the passenger’s destination is retained and means that the luggage flies with the passenger. Virgin Bag Magic provides interesting benefits however is greatly limited by the inability to receive the luggage upon arriving at the destination.

Time Passenger is Baggageless - Passengers using the Hong Kong and Newcastle bag drop facility must potentially use extensive public transport to arrive at the in town check-in desk. Design 2.1 provides a service where passengers are able to travel to the nearest metro station to check-in baggage.

Additional Preparation Compared to Standard Airport Check-In - Virgin Bag Magic requires luggage to be prepacked and collected well in advance of the flight making it unsuitable for last minute flights. Just like the Hong Kong check in, passengers can use the facility close to the departure of the flight.

Infrastructure Adaptation and Construction Required - A primary benefit with the proposed design is the requirement not to change the current infrastructure of the Tyne and Wear metro. The Newcastle bag drop proposal would require major changes to Haymarket Station and the operation of the metro and thus making the funding for this unrealistic. In the case of the Hong Kong check-in, this required new stations and rail tracks where such funding for this would not be available for the Tyne and Wear area.

Hours of Operation - The metro currently already operates within a similar schedule to flight departures from Newcastle International Airport. Therefore the metro would be available when most flights are departing. To improve this further however, the metro would need to operate to a timescale similar to the Hong Kong in town check-in. Virgin Bag Magic is limited as it does not operate outside of working times.

Destination Availability - With the design and operation proposed, it is easy to accommodate all passengers no matter what the destination of luggage is. Handling of the luggage by the Tyne and Wear Metro ceases at the Airport Station and therefore the destination of the luggage does not need to be considered. This applies to other existing systems however Virgin Bag Magic handles the luggage for the whole process and therefore are limited to delivery inside the UK only.

8. Technical Validation

To validate the design, assurance is needed to provide certainty that the metro can still operate with the added weight of the facilities and storage of luggage. As quoted by Nexus, the passenger capacity of a Tyne and Wear Metro car is assumed to be six passengers per square metre standing. The storage area would be considered as the area containing the highest increase in additional mass. It has a standing area of 2.53m^2 and accommodates six seats. This considered, the maximum capacity of the storage area is 15 standing passengers plus 6 seated passengers. The totals are to the metro for being able to operate with 21 passengers in the storage area. Considering 21 persons weighing 80Kg, the maximum weight capacity could accumulate to over 1.6 tonnes. In the case of Design 3, the design with the greatest additional mass, the storage area would be required to hold 33 items of luggage weighing a maximum of 30Kg each. This would accumulate to a mass of 990Kg. This would leave a further 600Kg of weight which the metro axles could support. With just the further addition of a roll container, safety barrier, luggage racks and 'fold out arms', it is not possible for these pieces of equipment to exceed 600Kg and therefore it can be said that the axle loading is acceptable.

Features based on the 'Initial Design Limitations' have been applied to all designs to allow for a valid design solution to be adapted into the Tyne and Wear Metro and assure the designs follow all the requirements currently in place on the metro vehicles. These features can be seen in the design solutions for Design 1, 2.1, 2.2 and 3.

9. Conclusions and Future Work

This study presents solutions to the designs and operations required to have an on-board check-in and bag drop facility on a light rail service. Conclusions can be drawn about the possibility of such a facility being enabled.

There are two potential areas for a check-in desk in a rail vehicle. These are at the ends and the centre of the rail vehicle. This study concluded that the centre of the Tyne and Wear Metro carriage provided the optimum area due to its pre-existing layout which provided enough floor space, by use of longitudinal seating and wider aisles, which suited towards passengers with luggage. This open space provided enough room to install equipment without the need to reconfigure the internal layout. The pivoting tractor bogie located beneath the centre of most light rail vehicles, provides a layout consistent with other light rail vehicles. A low seating density and absence of doors in this area creates a heavily pre-fabricated area.

Cost funding is an influential factor in determining the positioning of the desk. Whilst positioning the desk at the ends of the rail vehicle accommodate more luggage and wider range of facilities, it would also require extensive internal redesign and relocating of the current equipment. The engineering involved would cost more.

Organisation is vital if this proposal is to become a reality. Realistic terms must be met in which the check-in service on each metro car is provided to specific set of passengers destined to a predetermined destination. If each train operated for specific flights, estimated numbers of passengers can be predicted for each metro journey, and equipment programmed to check-in for a set number of flights. This would control the passenger flow and improve the organisation of the luggage. Clear communication between the airport and the rail service is essential to provide an efficient service without affecting the punctuality of the train. Retaining customer satisfaction amongst all rail users is vital. If regular riders are deterred, overall passenger may not increase.

Simplified details of how the facility operates can be shown to passengers by the development of smart phone applications, website information and signs on both the platform and interior of the rail vehicle. This study shows that a straightforward design can be developed which would provide little confusion amongst passengers.

The limitations uncovered during studying the Tyne and Wear Metro, could also apply to other rail vehicles. To keep cost down, it is important that the current vehicle configuration is retained. Thus, compact designs have been proposed which do not use much of the vehicle. The check-in and bag drop facility should not be a permanent installation to an existing rail vehicle as this would generate unnecessary costs and occupying space on rail vehicles not travelling to the airport. In the case of the Tyne and Wear Metro, where not all trains go to the airport, the ability to remove and install equipment efficiently depending on the destination of the train has been achieved by producing designs which are able to be transferred to other vehicles. This allows rail vehicles to operate in the usual way when not serving the airport.

Comprehensive health and safety factors are implemented into most light rail vehicles around the world. A design which tampers with these factors makes it harder to gain acceptance of the check-in facility. The health and safety features on the rail vehicle should be maintained for any design developed. In the case of the Tyne and Wear Metro, emergency door handles, fire extinguishers and disabled access were all unaffected by the introduction of the check-in and bag drop facility.

Efficient boarding and organisation of passengers was achieved through the use of a waiting area which was possible due to the location of the check-in area. Priority seating is provided in this area which offers an incentive for airport passengers to use rail transport. To help funding this facility and to enlist the airport's support, advertising space could be offered within the waiting area, sponsored by the airport.

With each design produced for this study, safety and security have been seriously considered, both in the event of an emergency and during a routine journey. All designs are positioned and then locked down to the surrounding hand rails, thus assuring the stability of the desks. It was concluded that the installation of X-rays machines would not be possible, however, through the use of CCTV, public awareness and passenger inspections, a sufficient level of security could be achieved. Transferring luggage from the metro and straight onto the aeroplane was considered but this was thought unrealistic due to security issues where the airport cannot allow an external source to check luggage outside the airport building. Luggage would therefore be transported to a baggage drop point inside the airport terminal which allows all the usual security checks to be administered by the airport.

Design 1 provides a highly versatile design that can be adapted effectively to the current metro vehicle. The compact design of both the check-in desk and storage area allows a similar operation of the rail vehicle when the equipment is stored away. The storage area is a simple design using small components that can be easily set up and collapsed and take up no capacity on the metro when not in use. A luggage rack has been designed proving for available space for them to be installed whilst this facility can be applied to all metro vehicles and improve customer satisfaction amongst all passengers. The check-in desk is easily manoeuvrable which is vital as the desk is relocated after arrival at the airport station. To assist in a compact design and the security of the equipment, an extensive internal storage area has been designed into the desk where all the equipment from the on-board check-in and bag drop facility can be stored inside and safely locked away.

Design 2.1 provided the best outcome following the evaluation of the designs. The performance of the desk was optimised in providing comprehensive facilities for passengers whilst ensuring a large storage area. The use of a roll container removes the need to unload luggage from the metro vehicle, saving time and allowing for an efficient process. Security of the luggage is improved as baggage would remain in the container until inside the airport. When arriving at the airport, it is a quick process to convert the rail vehicle to reopen the area to all passengers. A negligible area of floor space is required permanently for the check-in desk when the facility is installed, but there is a cost for separate transportation of the roll containers to be returned to the first station of the rail line. For larger light rail services this may cause an issue, however, alternative designs within this study can be considered.

Design 2.2 removes the issue of requiring separate transportation of the roll containers. This is done through the implementation of a side ramp installed on the container which allows for the check-in desk to be stored inside. Thus, all equipment can be transported on the rail vehicle when travelling away from the airport, minimising the amount of room it uses. Damage of equipment is prevented as equipment can be stored inside the container and thus out of reach. Handling of the equipment would be harder for this design, however, the process remains simple.

Design 3 showed that in the case of the Tyne and Wear metro, an impressive amount of storage could be accommodated within a small area. This setup shows that there is potential for high capacity luggage check-in facilities to be available on rail services even where there is limited room. Evaluation of this design showed increased costs, uncertainty about both the safety of the operation required and usability of the equipment. This design would require more staff members to operate it and take more amount of time to unload luggage and store away equipment which may result in the need for alterations to the current operation of the rail service.

The highest cost predicted for operating an on-board check-in desk on-board a rail vehicle is the staff required. Research from this study suggests that two members of staff should be on-board the vehicle where a check-in facility is used. Therefore implementing this for every metro vehicle containing the check-in desk may be expensive.

The research into the customer perspective towards the designs proposed was positive and suggested that several key areas of customer satisfaction would be addressed which in turn would help generate interest in the use of the facility. This shows that there would be a desire for the on-board check-in and bag drop facility to be implemented on a rail service.

Comparisons of existing systems with the designs and operations proposed in this study suggest a similar service can be provided but without the need for change to the operation of the rail vehicles and without major reconstruction of track line and stations. Limitations are highlighted in the maximum capacity of luggage however, this can be resolved through use of the check-in desk in Design 2.1 where a low working surface is designed in which large luggage could be passed over. Additional costs could then be charged for baggage that exceeds the size of a 'large' suitcase.

In conclusion, there is clear evidence that there is an opportunity for rail vehicles to have an on-board check-in and bag drop service. The designs produced have successfully met the design criteria and offered realistic and achievable interior designs and operations which can be further investigated.

There are many considerations in achieving a successful check-in service on a rail vehicle. This study has highlighted the key challenges presented and offers intuitive designs which allow for functionality of the check-in facility. The study suggests the possibility for a check-in and bag drop service to be implemented without the need for large infrastructure changes in the cases of redevelopment of stations and signalling systems in place.

In the case of each design, the functionalities which airport check-in desks provide can be installed onto a rail vehicle whilst sufficient storage for luggage can be provided without the need to use a large amount of the vehicle capacity. It has been proven that vehicle modifications can be kept to a minimum and thus this concept can be applied to a variety of global rail services without the need for extensive funding and major redevelopment of existing rail vehicles.

A cost benefit analysis must be constructed for this study. This would provide a value as to the estimated funding required to implement the designs and operations proposed. This can obtain the advantages and limitations raised and convert them into an analysis of whether the overall outcome would provide a beneficial service. Understanding the costings of the designs can assist in providing further comparisons with existing systems before then being able to estimate a cost at which the on-board bag drop and check-in service would be able to be provided for the customers. This would help in better understanding the additional number of staff that would be ideal for the proposed designs and operations. Analysis can be conducted which observes the most cost beneficial and effective service in terms of the ratio of metro vehicles travelling to the airport equipped with the check-in facility. Further development of these designs should be avoided until this analysis is conducted.

The operations and designs from this study should be generated into a computer simulation. This would allow for estimations to be calculated for the number of passengers likely to use the facility based on the efficiency and costing of the service. Different operations can be proposed as to how to accommodate the equipment and then assessed to determine the most effective operation. Values can be produced as to the estimated time each design would take to be installed and stored away which would provide a better understanding as to whether the designs are able to work within the current time scales and operation of the Tyne and Wear Metro. Conducting this simulation would provide a greater validity of the designs and operations proposed.

A customer survey should be conducted within the Tyne and Wear area to acquire feedback on the implementation of the on-board check-in and bag drop facility. A clear display of the operations proposed and the designs produced can be shown to Tyne and Wear passengers to acquire feedback as to the preference of designs and whether such a facility would be utilised by themselves and if it would positively or negatively affect the opinion of the rail service.

Further analysis of the designs proposed must be done by assessment of a material study of the components. By selecting the best materials to use, a better understanding of the addition weight added to the metro, the manoeuvrability of the equipment and the overall costing can be obtained. Analysis by finite element methods can be used to conduct in depth structural analysis of the proposed designs to provide a better understand as to the robustness of the components which can assist in a more conclusive evaluation.

Managing the external operations should be looked at in greater depth. This study contains brief discussions as to how the equipment would be required to operate outside of the metro, however, this should be investigated further to understand the facilities and storage Nexus and Newcastle International Airport could provide and how the equipment would be managed and transferred across different rail vehicles.

To investigate the maximum potential the Tyne and Wear Metro has, a similar study should be conducted in which the check-in desk is observed at the end of the metro. This would require a greater amount of reconstruction of the vehicle and costing, however, the potential for an increased capacity of luggage and wider range of equipment may raise interesting considerations as to how an on-board check-in and bag drop facility could operate on a rail service and should therefore be investigated to be compared with the proposals from this study.

Acknowledgement

The contribution of David Mee, Principal Engineer of Nexus Rail, for providing expert opinions throughout the study and answering desired questions contributing to the research and designs proposed.

References

1. Department for Transport, "Transport Statistics Great Britain 2015," 2015. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/489894/tsgb-2015.pdf. [Accessed July 2016].

2. Civil Aviation Authority, "Main Outputs of Reporting Airports 1991-2015," Heathrow, 2015. [Online]. Available: https://www.caa.co.uk/uploadedFiles/CAA/Content/Standard_Content/Data_and_analysis/Datasets/Airport_stats/Airport_data_2015/Table_02_1_Main_Outputs_Of_UK_Airports_2015.pdf. [Accessed 2016].

3. D. B. Rüger, "Baggageless," Vienna University of Technology- netwiss, 2016. [Online]. Available: http://publik.tuwien.ac.at/files/PubDat_232400.pdf. [Accessed 2016].

4. GOV.UK, "Public experiences of and attitudes towards air travel," 2011. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/8907/attitudes-towards-air-travel-feb-2010.pdf. [Accessed 2016].

5. Department for Transport, "Road Traffic Estimates: Great Britain 2015," 19 May 2016. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/524261/annual-road-traffic-estimates-2015.pdf. [Accessed June 2016].

6. W. Henley, "Is it greener to travel by rail or car?," The Guardian, UK, 2013.

7. H. Lewis, "Building the Tyne and Wear Metro," The Chartered Institution of Highways & Transportation, Newcastle Upon Tyne, 2012.

8. Nexus, "Metro Strategy 2030- Background Information," Newcastle Upon Tyne, 2013.

9. D. C. Reece and M. Marinov, "How to Facilitate the Movement of Passengers by Introducing Baggage Collection Systems for Travel from North Shields to Newcastle International Airport," *Transport Problems,* vol. 1, no. 1, 2015.

10. InPost, "About InPost," 2016. [Online]. Available: https://inpost.co.uk/. [Accessed May 2016].

11. E. Jaffe, "Every City Needs Hong Kong's Brilliant Baggage-Check System," City Lab, 22 August 2014. [Online]. Available: http://www.citylab.com/cityfixer/2014/08/every-city-needs-hong-kongs-brilliant-baggage-check-system/378826/. [Accessed June 2016].

12. D. C. Reece and M. Marinov, "Modelling the Implementation of a Baggage Transport System in Newcastle Upon Tyne for Passengers Using Mixed-Mode Travel," *Transport Problem,* vol. 1, no. 1, 2015.

13. D. Brice and M. Marinov, "A Newly Designed Baggage Transfer System Implemented Using Event-Based Simulations," *Urban Rail Transit,* vol. 1, no. 4, pp. 194-214, 2015.

14. Monorails Australia , "Melbourne Airport Monorail," November 2014. [Online]. Available: http://www.monorailsaustralia.com.au/airport.html. [Accessed May 2016].

15. Nexus, "Metro timetable- South Hylton," January 2014. [Online]. Available: http://www.nexus.org.uk/sites/default/files/metro/stations/MT1312.A4.SHL_.pdf. [Accessed August 2016].

16. Office for National Statistics, "Census result shows increase in population of the North East," News Release, 2012.

17. D. Harari, "Regional and Local Economic Growth Stastics," House of Commons Library, 2016.

18. "Passenger Statistics," Newcastle International Airport, 2016. [Online]. Available: http://www.newcastleairport.com/passengerstatistics. [Accessed Februrary 2016].

19. Univeristy of Cambridge, "Technology roadmapping: facilitating collaborative strategy development," IfM Management Technology Policy, Cambridge, 2010.

20. RVAR, "RVAR and PRM TSI Compliance," March 2015. [Online]. Available: https://webcache.googleusercontent.com/search?q=cache:5kaCsILEA40J:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/426131/class-365-erg-compliance-assessment.xls+&cd=1&hl=en&ct=clnk&gl=uk. [Accessed August 2016].

21. M. Savrasovsa, A. Medvedev and E. Sincov, "RIGA AIRPORT BAGGAGE HANDLING SYSTEM SIMULATION," Transport and Telecommunication Institute, Riga, Latvia , 2007.

22. Tyne and Wear Public Transport Users Group, "Metro Strategy 2030– Response from Tyne and Wear Public," 2015. [Online]. Available: file://campus/home/home01/b2023344/Downloads/Metro%20Consultation%20v6.pdf. [Accessed 2016].

23. Desko, "Desko Xenon 1900 Brochure," 2016. [Online]. Available: https://www.desko.de/cms-wAssets/docs/brochures/Brochure_DESKO_Xenon_1900.pdf. [Accessed June 2016].

24. Avery Weigh-Tronix, "H305 Low Profile Bench Scale," 2015. [Online]. Available: http://www.averyweigh-tronix.nl/wp-content/uploads/2015/04/H305Weegplateau.pdf. [Accessed June 2016].

25. Sita.Aero, "Heavy Duty Printers for Major Airports," 2016. [Online]. Available: https://sita.aero/globalassets/microsites/atis-2016/sponsor-brochures/custom-atis2016.pdf. [Accessed July 2016].

26. Embross, "MD1 Mobile Service Desk," Embross, 2016. [Online]. Available: http://www.embross.com/md1-mobile-desk/. [Accessed July 2016].

27. Workplace Products, "Titan Expanding Barriers," Workplace Products, 2016. [Online]. Available: http://www.workplace-products.co.uk/titan-expanding-barriers-3-metre.html. [Accessed July 2016].

28. APTA Standards Development Program, “Security Operations for Publics Transit,” American Public Transportation Association, Washington, 2013.

29. Departmnet for Transport, “Light Rail Security Recommended Best Practice,” London, 2014.

30. RSSB, “Faster, Safer, Better: Boarding and Alighting Trains,” Rail Research UK Association, 2016.

31. N. Baker, “Transport Minister Inspects Tyne & Wear Metro Progress,” Rail.co.uk, 2012. [Online]. Available: http://www.rail.co.uk/rail-news/2012/transport-minister-inspects-tyne-wear-metro-progress/. [Accessed June 2016].

32. KLM, “Checking in at the airport,” KLM, 2016. [Online]. Available: https://www.klm.com/travel/gb_en/prepare_for_travel/checkin_options/airport_checkin/index.htm. [Accessed March 2016].

33. LHR Airports Limited, “Facts and Figures,” Heathrow, 2016. [Online]. Available: http://www.heathrow.com/company/company-news-and-information/company-information/facts-and-figures#. [Accessed 2016].

34. Cathay Pacific, “Departure and Check In Services,” Hong Kong International Airport, 2016. [Online]. Available: http://www.cathaypacific.com/cx/en_DK/travel-information/airport/hong-kong-international-airport/departure-and-check-in-services.html. [Accessed July 2016].

35. Virgin Trains, “Virgin Bag Magic,” Virgin, 2016. [Online]. Available: https://www.virgintrainseastcoast.com/special-offers/on-board-the-train/luggage-collection/. [Accessed June 2016].

36. Metro, “Metro Maps,” Nexus, 2016. [Online]. Available: http://www.nexus.org.uk/metro/metro-maps. [Accessed 2016].