Self-driving vehicles For Tunbridge Wells

BACKGROUND PAPERS

For

The Proposal

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Tunbridge Wells Borough Council

Version P1 **12th October 2015**

The attached Background Papers are designed to provide additional information and comment for the proposal: Self-driving vehicles for Tunbridge Wells. The author welcomes further constructive input to come forward with suggestions on how to implement a self-driving autonomous system to help reduce congestion in Tunbridge Wells.

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Paper A. Congestion

Everyone in Tunbridge Wells is seriously impacted by congestion. This may be in trying to find a convenient place to park, waiting in their car or bus in slow moving or stationary traffic or damage to their parked cars, through air and noise pollution.

Tunbridge Wells, similar to many other towns, suffers from a high level of congestion on our main routes as well as on side streets evident in roads clogged with parked cars and the many ‘rat-runs’ particularly during peak times. This congestion creates many issues impacting substantially on economic, environmental, safety and residents and commuters general wellbeing aspects of daily life in the town.

Take a look along any of Tunbridge wells key routes, the A26 and the A264 (Pembury Rd and Langton Rd) or any of the ‘rat-runs’ such as Cornford Lane, Mereworth Road and others, during the rush hour or on a Saturday shopping trip. Find a parking slot for a mum returning from the ‘school run’ in the morning. The roads are clogged, drivers and others are stressed and safety is compromised.

Tunbridge Wells suffers particularly due to the lack of capacity on the main cross routes through the town and few ways of avoiding these main routes. Tunbridge Wells sits on a cross roads with main traffic flowing through the middle, as well as a destination and start point for many trips by road. It has a long linear centre from the shopping commercial area in the north to the historic area of the Pantiles in the south. It is also ‘disconnected’ with it’s out of town shopping area that has grown up at North Farms. However the construction of additional (traditional) road space would be costly and potentially very damaging to the ‘corridors’ through which the existing roads pass.

Congestion also creates difficulty for many in accessing surrounding areas including the hospital situated at Pembury and other potential developments away from the central part of the town. Residents of surrounding towns often prefer to drive to say Bluewater than suffer the congestion of reaching the centre of Tunbridge Wells.

Tunbridge Wells is a popular place to live and work. It is also a popular town from which to commute primarily to London – mainly by train but also by car and bus. In addition there is a significant amount of through traffic travelling on the North-South A26 or on the West-East A264 (Pembury Road) - and roads linking to these main routes/arteries through the town. According to recent traffic surveys a high proportion of journeys either commence or complete in Tunbridge Wells.

The town’s only by-pass is the A21 (currently being improved) which allows vehicles to travel from the North to the South East of the town towards Hastings. This is also used to allow vehicles travelling to or from the North to enter or leave the eastern side of Tunbridge Wells using the A264 (The Pembury Road).

There is a good railway service, mainly used by commuters to London from two stations in the town. Others use the train to more local stops to the North and the south east of the town or ad hoc journeys typically connecting through London and to a lesser extent through Tonbridge.

Tunbridge Wells hosts an out-of-town shopping and entertainment area (North Farms) and a hospital, both at the perimeter of the town to the North East.

A key feature of the town is that a high proportion of residents live within 2 miles of the town centre. However most people still prefer to travel by car for many of their journeys for a range of personal reasons. The town's schools are highly attractive for many however they also cause congestion by the pupils who travel in parents' cars or by bus further clogging the streets at key times during the day.

Tunbridge Wells roads are ill equipped to carry either the volume of traffic movements or the on-street parking of residents' and others' vehicles. Delays are frequent. Much use is made by many of 'rat-runs'. Residents and commuters often have to park at some distance from their intended destination. It is believed the reputation of the town's congestion reduces the number of visitors to the town. Many avoid travelling to the out-of-town shopping and entertainment area for the same reason.

The sheer number of cars, both stationary[1] and moving also reduces the attractiveness of alternative means of transport or travel including walking, cycling or by bus. Some efforts are and have been made to improve these modes with enhanced pedestrian and cycle paths / areas and enhance bus travel with more frequent and attractive buses and bus lanes.

Moving vehicles cause substantial environment and health damage in the town. They restrict movement, are noisy and detract from the other features of the town. Parked cars clog streets, often on and damaging pavements. They restrict other users and are a safety problem for adults and children. They are unsightly with long lines parked along residential and historic streets.

The general impact on the town is summarised in Table A1 Summary of the main impact of congestion in Tunbridge Wells – see following page. Undoubtedly congestion is a significant concern to most people who live, work or visit Tunbridge Wells. It does reduce the town's attraction to people and businesses and causes problems in the daily lives of many.

Many of those who work in the town travel from areas outside the town. Without better access the ability to attract people and businesses to the town is clearly hampered thus also reducing the value of key sites in the town and ultimately the services that are available in the town.

The town is highly restricted in design and sits in the middle of Green Belt and areas of outstanding natural beauty. Hence the desire to avoid damaging the heritage and attractiveness of the town limits the ability to make major changes to the town's infrastructure to accommodate new or broader roads in or round the town. Many also feel that these would not lead to a reduction in congestion and have adverse impacts within the town.

[1] Cars are parked for around 95% of their time. Often figures of 4% are also quoted. – see: http://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html

Table A1 Summary of the main impact of congestion in Tunbridge Wells

Impact on Traffic and Infrastructure	**Impact on People**	**Impact on Businesses & Services**
• Slow moving • Traffic jams at junctions • Pollution, particularly from slow moving vehicles • Difficulty and time in finding parking • Extensive use of road space with parked cars • Damage to verges and pavements • Damage to infrastructure	• Delay and time taken • Rat runs • Increased risk to safety for the traveller • Increased risk to safety in residential, school and other areas • Frustration and anger • Shunned journeys e.g. not going to North Farms • Reduced visits to TW • Increased costs	• Lack of custom • Recruitment problems • Under use of facilities • Reduced value of property • Missed appointments • Sites uneconomic to develop • Delays • Increased costs • Slow deliveries • Reduced economic activity of the town

There are many ideas and suggestions on how to reduce congestion and hence improve the town. These are summarised in Table A2 Summary of ideas to improve congestion in Tunbridge Wells – see following page.

The key is increasing the range of choices of mode of travel/transport open to everyone for each trip they are about to make. Each trip is different. What is considered the most preferred way of travel will change depending on the circumstance of that trip and the individual or group that is about to make the trip. The overwhelming number of cars on the road has tended to reduce the range of choices open. Many people no longer see walking or cycling or public transport as good options – even if they or their parents did for similar trips in the past.

However it is in the interest of every person who wishes to make a journey by car that others choose – at least some of the time – to use another means to travel. By persuading just a few not to travel by car will free up the road space for those who wish or need to travel by car for those situations where it is their preferred means of travel.

If other means of travel (compared to by car) can be improved it may be possible to persuade just enough people to sometimes not to travel by car thereby reducing car journeys and the consequences of the existing levels of congestion. We do not need everyone to travel by bike, public transport or to cycle – just a lot more people than now. This is preferably done by improving other means of transport rather than penalising car transport or degrading it such it is no longer attractive.

Let's enhance travel - not make it worse than at present. Self-Driving vehicles on segregated Pathways* can be a low cost, low environmental impact way of helping to achieve this.

Table A2 Summary of ideas to improve congestion in Tunbridge Wells

The Town's Arteries

- Improved bus services
  - Additional bus lanes
  - Park & Ride schemes
- Enhanced traffic flow
  - Improved road junctions
  - Enhanced A26
  - Southern by-pass (e.g. A21 to A26)
- Dualling of Pembury Road
  - For cars
  - New buses lanes
- Better Cycle lanes and Pedestrian paths
- Enhanced rail services
  - Existing line
  - The Eridge line
- Car share and car hire clubs
- Self-Driving vehicles

The Town's Centre

- Pedestrian areas
  - Fiveways and Calverley Road
  - Mount Pleasant and the High Street
  - Access to cyclists
- Transport in the town
  - Pantiles to Victoria Centre
  - The centre to North Farms
  - To and from the hospital
  - Links to out of town shopping
- Bus and rail transport
  - Access to the centre
  - Convenient bus staging area
- Improved parking
  - In & out of town
- Improved safety
  - Reduced vehicles
  - 20's Plenty campaign

Paper B. Self-Driving cars

Autonomous (self-driving) vehicles

There are four main aspects of Automated Vehicles each of which are developing at a different rate. Each of these tend to be interchangeable and can be modified as needs change and new developments become available. Each aspect has key considerations in their design and adoption. These are summarised below:

1. The routes, the Towns Arteries and Infrastructure
   - Their routes - new or existing routes; adding or displacing current traffic; their relative cost compared to existing infrastructure and their impact on the town's heritage.
2. The vehicles
   - Their size and design; whether they are for personal or mass transit.
3. The computing technology
   - The complexity of the system; central and vehicle components; the interaction with other vehicles.
4. Operational aspects
   - The ease of use, speed, safety, independence, operation etc.

Hence in designing a system for Tunbridge Wells different features of the various examples of existing and new automated vehicles can be considered and adopted for the town.

For simplification current systems which are either operational or under trial are described in Paper C. A summary is provided in Table B1 Automotive (self-driving) Vehicles – Current Operational or Trial Systems which sets out the key design objectives, the status and key features of six current developments as representative of systems of relevance to Tunbridge Wells. Of particular relevance to helping reduce congestion in Tunbridge Wells through the creation of a public transport system of Self-Driving Vehicles are the first four systems described in the table.

Their current status are also shown in the table B1 on the following page.

Self-Driving cars – also called automated (driverless) vehicles - have the promise to bring significant benefits to society through the efficient movement of people and possibly goods – potentially leading to a marked reduction in congestion, improvements in safety as well as benefits to the environment. As many of the Self-Driving vehicles being developed are light and can drive on narrow custom built pathways*[2] it is likely new specialist pathways* can be created for Self-Driving vehicles without significant damage to the town's infrastructure along routes away from the existing roads.

In addition to increasing the range of choice to existing road users they also could offer a new lease of mobility to those who do not drive whether on account of age, disability or choice.

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[2] **Pathways*** for pods are described in Paper C. These are lightweight and designed for fast and easy construction. Their profile is considerably lighter that previous 'overhead' transport vehicle systems, designed to be as unobtrusive as possible.

Automated vehicles already exist and have demonstrated a high level of operational efficiency as well as high user satisfaction. These are typically on segregated routes carrying passengers and goods between key points – such as the Heathrow Ultra system. Substantial work is also currently being undertaken to develop more versatile automated (self-driving) vehicles that can integrate with pedestrians and / or other vehicles. Trials are being undertaken in various towns and cities in the UK and elsewhere where they are seen as potentially the future for personalised transport.

The initial users of Self-Driving systems are likely to be the commuters, tourists, other visitors and those who visit specific locations such as the hospital, North farms and up and down from The Pantiles to the top of the town. Everyone in Tunbridge Wells and surrounding areas will benefit through reduced traffic making access to the centre of Tunbridge Wells easier, less traffic noise and less pollution – whether traveling on the system, driving, cycling or walking. Business and services will be more accessible increasing custom to them and hence make them more economically viable.

In the longer term – as Self-Driving vehicles become more versatile they will be increasingly be used by residents to replace many of their car journeys.

This paper explores ways in which Self-Driving vehicles can start to be introduced into Tunbridge Wells and developed as the versatility of this type of technology increases.

Is the above possible? Travel back in time and ask residents in 1900 how they saw the future for horses and cars. Closer to now – ask yourself what you envisioned ten years ago about iPads and other tablets or a little earlier – about mobile phones. Did you foresee television or films on demand?

Self-Driving cars are already here – in the UK. Self-Driving pods have travelled over 2 million miles at Heathrow Airport - Terminal 5. More advanced systems are being trialled in many cities across the world. They are going to become an increasing feature of Tunbridge Wells' streets. We have the opportunity to design the infrastructure to take best advantage of them. Doing so will help the town enjoy the full benefits of them. It will also attract many visitors – tourists, businesses, academics and others which will bring further prosperity.

Our problem is simply one of imagination and design. We must imagine what is feasible and design the infrastructure for self-driving cars so that they are attractive in our town and are able to provide many benefits through new uses beyond those envisioned here.

Table B1. Automotive (self-driving) Vehicles – Current Operational or Trial Systems

Current systems	Design Objective	
	Status	**Key features**
1. Heathrow Ultra '4 person' pods	Allows fast and frequent pods to travel independently and directly between the start and stop points along narrow, light weight tracks, not stopping along the way.	
	Available now, tried and tested	Segregated routes
2. Greenwich trial system	Allows a Self-Driving mini-bus to commute between centres along existing roads and walkways at walking pace.	
	Under test	Defined but not segregated routes
3. Milton Keynes trials pods	Two person pods travel along pedestrian areas and segregated paths. Routes are not predetermined.	
	Under development for use in broad pedestrian areas	Local pods with flexible routes
4. Netherlands WEpod shuttle	Six seater electric Self-Driving shuttle between two towns – more destinations to follow.	
	Under test	On regular roads amongst public traffic.
5. Google pods / cars[3]	Free ranging vehicles designed to travel mainly along existing roads at speeds comparable with other vehicles.	
	Could use segregated new arteries and existing roads.	Fully autonomous vehicles
6. Cars with Self-Driving options	Systems are designed to 'take over' from the driver for specific tasks, e.g. parking, motorway driving.	
	Does not solve our congestion problems.	Normal cars with automation where suitable

[3] Google Cars do not directly address our Congestion problem – although in the long-run they make long distance travel easier to use a Self-Driving car 'hired' for specific journeys rather than rely on one's own car.

THE COMPUTING TECHNOLOGY

The 'Heathrow' technology is designed to allow the fast movement of pods along segregated Pathways* not intermingling with pedestrians or other vehicles. The software efficiently schedules the pods along these Pathways* modifying its route depending on the destination point and other pods on the system. Each pods is maintained at least 4 seconds apart.

The system is thus inappropriate for the centre of the town where the pods must be able to interact with pedestrians and other hazards. The 'Greenwich' technology will be needed for this segment where routes can be designated in advance and relatively little choice of routes is required.

The technology being used by 'Milton Keynes' pods brings a much greater level of flexibility in routes. The routes may operate anywhere in the pedestrian areas being solely determined by the vehicle depending on the circumstances at the time. The vehicle simply has a map of permitted areas of operation and plans routes as appropriate changing direction to avoid obstacles as appropriate.

The 'Google' technology allows a higher level of manoeuvrability to allow the pods to operate at speed along existing pathways.

Hence initially a combination of 'Heathrow' and 'Greenwich' technology is envisioned. This may later be enhance with the technology being developed for the 'Milton Keynes' pods or even the 'Google pods and cars'.

The cost of technology licences are dependent on negotiations at the time. Current estimate, based on earlier discussions regarding the 'Heathrow' system is £5 million.

Paper C. Vehicle Technology

There are an increasing number of Self-Driving systems at various stages of operation and development. While they all have a number of similar features it is useful to consider them in relation to how they operate. The six systems described in Paper B can be reclassified as follows:

1. Segregated routes - e.g. Heathrow Ultra pods
2. Defined but not segregated routes - e.g. Greenwich trial system
3. Local pods with flexible routes - e.g. Milton Keynes trials
4. Shuttle pods using existing roads – e.g. The Netherland WEpods
5. Fully autonomous vehicles - Google pods / cars
6. Cars with Self-Driving options - Normal cars with automation where suitable

The two vehicle designs currently favoured by the author of this report is those designed for the Heathrow Self-Driving system and the Netherlands WEpods. They are designed round the family unit and are pushchair and wheelchair friendly. They are comfortable to ride, easily cleaned and maintained. They are also relatively small and reasonably manoeuvrable.

1) Segregated routes - e.g. Heathrow Ultra pods

The Heathrow Pod is designed to carry up to 4 people with baggage, a pushchair or wheelchair and user. These pods may be modified to also include two additional ‘flip-up’ seats. Hence their design is highly attractive for the ‘family group’ or a number of schoolchildren.

These pods are electric using battery power which is topped up whenever they stop for a passenger or are waiting or are going downhill or braking. Batteries are continuously monitored by a central computer (along with many other technical aspects of the pods) and are directed to a charge point, maintenance or cleaning station as appropriate and timely.

The pods have already completed over 2 million miles in service with few problems and have a reliability surpassing all other ground transport vehicles including London Tubes, buses etc. The pods only travel when needed but are designed to operate a high percent of every day, and able to travel round the complete system at frequent intervals.

The pods are constructed using standard automotive parts with the addition of lasers and other sensors and are thus easy to maintain. The prototypes were hand built at a cost of £120,000 each, however as more are built the cost is rapidly coming to at least half and towards the cost of other mass produced small vehicles.

Heathrow Ultra Pods

Tunbridge Wells Borough Council

The vehicles

- Family sized (4 or 6 person)
- Wheelchair, pushchair friendly
- Electric, battery powered
- Zero local pollution, silent
- 25 mph, 4 second intervals
- Standard car parts

The technology

- Standard car computer
- Laser guidance
- Central control
- Fast assignment of routes
- Well tried (over 2 million miles)
- Constant computer diagnosis

Heathrow Ultra Pods

Tunbridge Wells Borough Council

Routes / Arteries

- Designated & segregated
- Cycle path width
- Light weight (slimmer than at LHR)
- Flexible, easy construction
- Hidden behind hedges / in tree line
- Low cost

Operation

- Non-stop to final destination
- Simple / easy to use
- Many safety features
- Minimal waiting times (average under 4 seconds)
- Minimal manual requirements

Prepared by Cllr David Scott and represents his views and recommendations and should not be construed as representing those of Tunbridge Wells Borough Council or any other body.

2) Defined but not segregated routes - e.g. Greenwich trial system

The Greenwich Self-Driving bus is designed to carry up to 10 people standing and to stop to pick up or drop off passengers along the way. This is appropriate for the tasks identified in Greenwich historical and Dome entertainment areas. However this reduces the efficiency and increases travel times due to the frequent stopping. In quiet times more ‘empty seats’ may be transported as passenger numbers fade out.

The vehicles are designed to travel relatively slowly along pedestrian areas or along existing roads.

3) Local pods with flexible routes using normal roads - e.g. Netherland WEpods

The Netherland WEpods are self-driving six person, Self-Driving vehicles. They will drive on standard roads, among public traffic. A Control Room will monitor the vehicles and the safety of passengers. They will have a maximum speed of 25 kilometres per hour. Initially they will run between two towns on a fixed route but are expected to expand to more routes and other regions in the country from May 2016 onward.

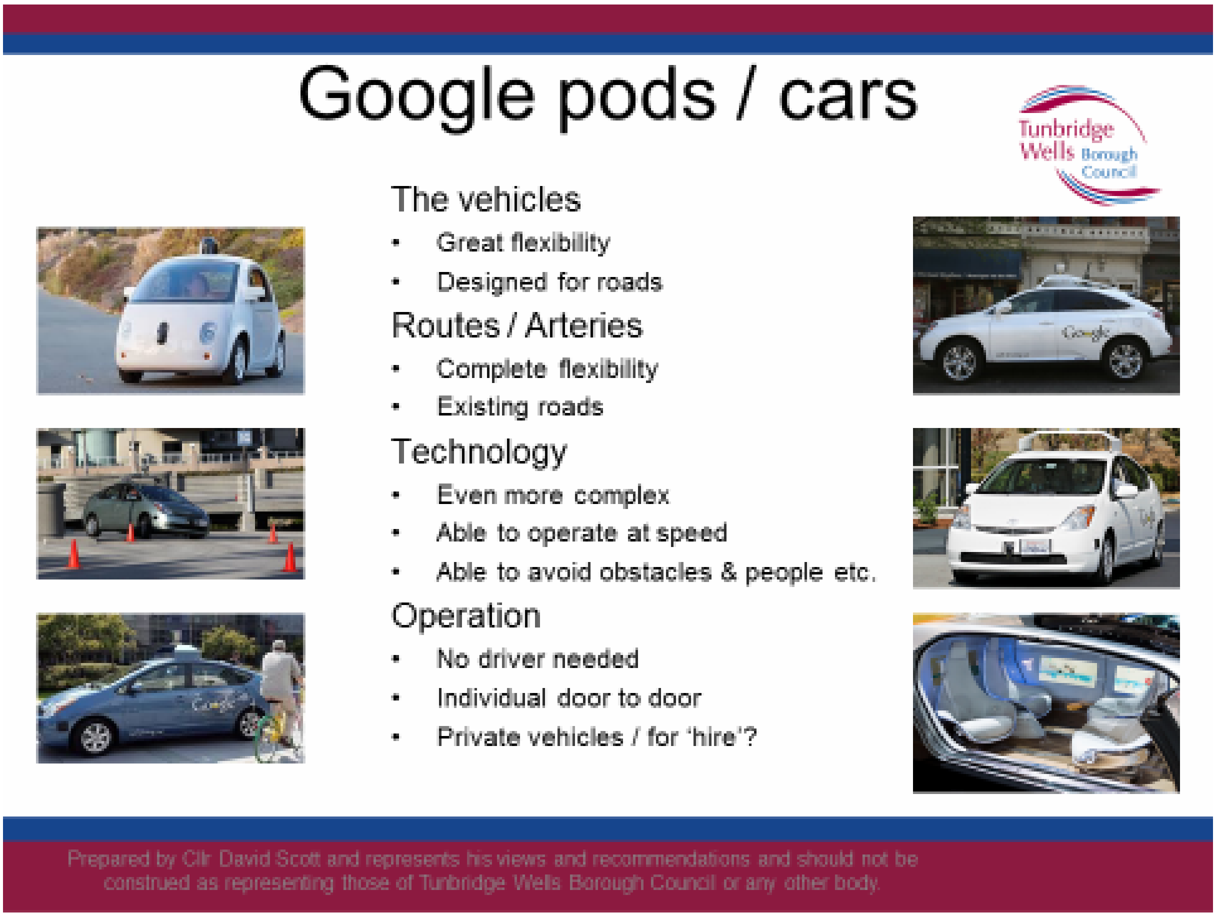
4) Local pods with flexible routes - e.g. Milton Keynes trials

The Milton Keynes pods are designed as two person, highly manoeuvrable electric vehicles. The current design is not wheelchair or pushchair friendly – although future versions will be more versatile. Manoeuvrability increases their ability to circumvent obstacles (such as people, other pods, stationary or moving items).

They can also travel faster in non-pedestrian areas.

5) Fully autonomous vehicles - Google pods / cars

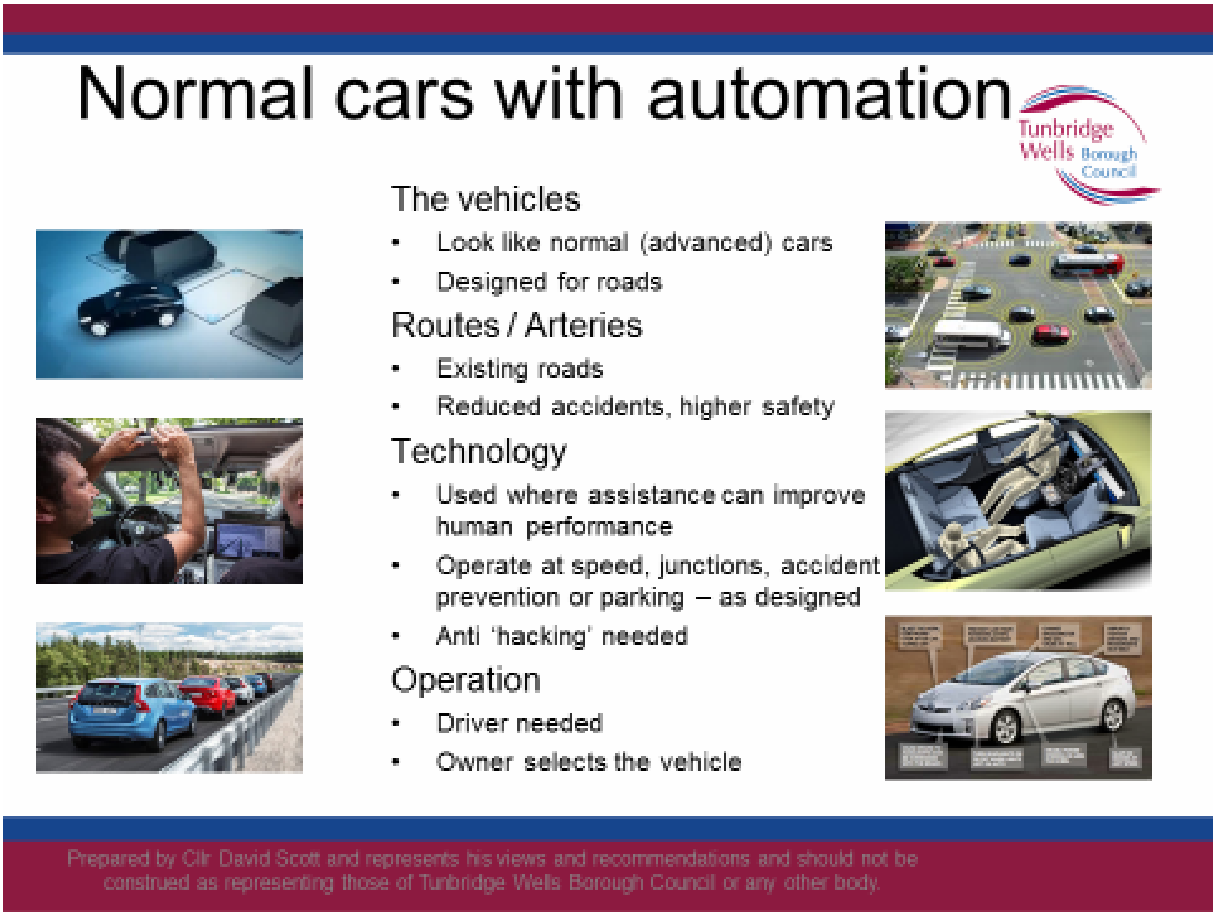
Google pods have been developed which look like a cross between the Milton Keynes Pod and the Heathrow pods. Most essentially assume a car like structure with people facing forward. Google have also placed their systems into normal cars to drive on normal roads and freeways.



6) Cars with Self-Driving options - Normal cars with automation where suitable

These pods are probably the least relevant to Tunbridge Wells at in relation to dealing with the Town's congestion. They allow vehicles to switch between manual driving to self-driving for specific tasks. This may be for such things as self-parking or motorway driving.

They are shown here for 'completeness'.



Paper D. Potential Routes

Zones A, B and C (see section 3)

The exact routes are likely to be modified in relation to those identified in this report as they will be dependent on both the detailed design and planning processes and subject to public scrutiny. We anticipate considerable debate as part of this process before these routes are finalised.

NB The plans shown here are schematic only.

Zone A, The Artery Routes (to and from the town) and Zone C, Route Extension to North Farms and the Hospital

The proposed routes within Zone A are designed in two 'Figures of 8'. The larger part of the route runs from the Crescent Road carpark to the Pembury Park-and-Ride near the Tesco Superstore.

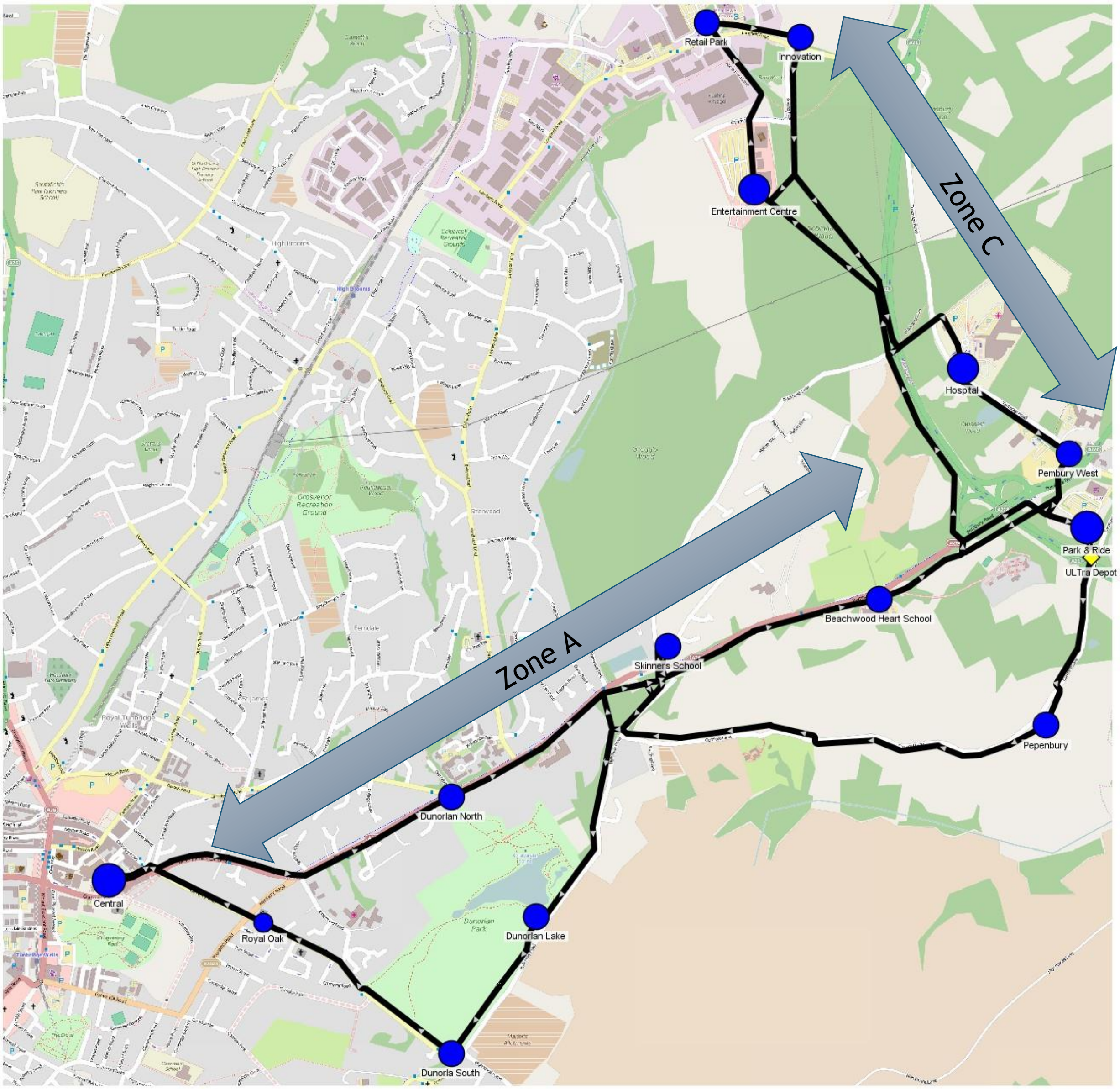
The total estimated track length for Zone A is 8.5 kms (5.5 miles) with a little over half at ground level and the remainder elevated. On current estimates this is likely to cost of the route in Zone A is around £16 million.

The areas of main concern requiring depth design work are the Pathways* from the Crescent Road carpark to Pembury. Detailed photographs and comments have therefore been included in Paper E to allow further debate.

It is not considered necessary to build a segregated route for Zone C the 'extension' routes to North Farms and the hospital. The existing roads from Pembury (Tonbridge Road) and Longfield Rd are not congested and should be able to adequately carry the additional TW-Pod traffic. However much of the area in Zone C can easily accommodate a segregated pathway* for the TW-Pods. This would potentially cut down on travel times.

The Plan below shows how such a segregated pathway may be built. The extensions in Zone C to North Farms and the Hospital have also been designed as loops in a 'Figures of 8' of approximately 4.5 kms (3 miles).

Diagram D1: Zone B: Main Arteries and C: Extension Routes (if segregated)

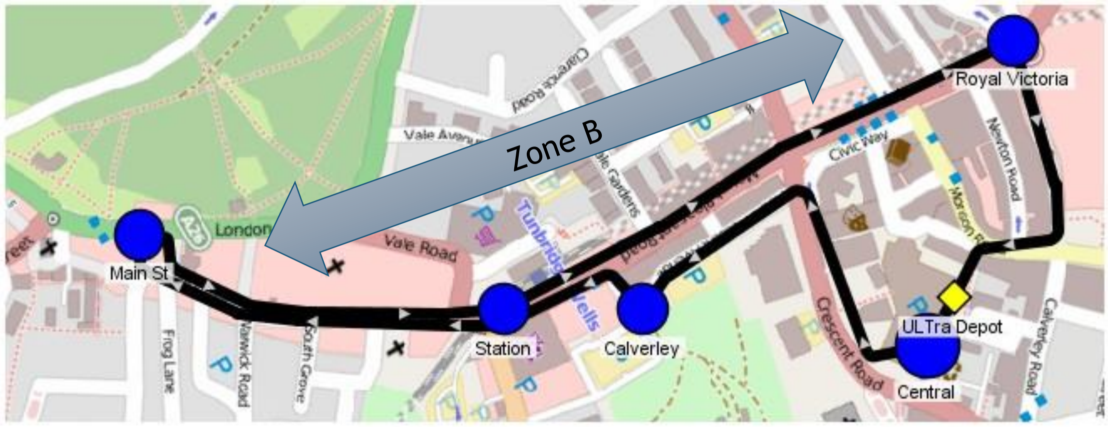


Zone B Town Centre Routes

These are probably the most flexible part of the proposed routes and are mainly dependent on streets selected to be pedestrian areas with limited access given to delivery vehicles. Many of the deliveries in these areas may be handled by modified pods operating from a common delivery point.

The blue dots mark the key pod stopping and waiting points. The pods are able to stop elsewhere along the route at designated points to drop or pick up passengers as required by them.

Diagram D2: Town Centre Routes (Zone B)



The marked routes are approximately 2.5 kms (1.6 miles) in length. Additional routing could be extended to Monson Road, part of Camden Road and Calverley Road if these roads are also designated as pedestrian only areas.

Paper E. Zone A - Discussion of the potential route

A detailed inspection and design of the Pathways* for Zone A needs to be undertaken. This section provides some initial suggestions and discussion of parts of a proposed route. Professional designers, architects and engineers need to be engaged to ensure the pathways* are constructed in a way most acceptable to residents and users of the system.

Much of the route can be built in existing wooded, grass or shrub areas. Some parts of the route would need to be raised to tree canopy height. This would allow other vehicles to travel underneath the TW-Pods.

The Pathways* described are single lane, approximately the width of a cycle path. They can run on the ground, sunk in cut and cover (probably covered with glass) or raised to tree canopy height. On the ground a hedge placed in front of them will generally remove visual site of the route and any traffic on it. As the TW-Pods are electric and silent with no local pollution they will not disturb any surrounding houses or the general tranquillity of the countryside.

At tree canopy the light weight nature will frequently blend into the general tree foliage. The upright posts are relatively thin (narrower than most full height trees). See Paper F: ULTra Infrastructure Explained, for details.

Significant thought should be given how to best blend in these light weight Pathways* into the environment. However consideration should also be given to the passengers who will great satisfaction from viewing the countryside in all its splendour while travelling silently in or out of Tunbridge Wells.

The desire is to use this system to help reduce congestion. The existing roads, the vehicles and resulting congestion currently substantially damages the environment and the heritage of Tunbridge Wells. The TW-Pods will significant reduce the level of damage done by the congestion of existing and increasing numbers of other vehicles crowding Tunbridge Wells streets.

All the photos were taken on an early Sunday morning for safety and convenience – when few cars were travelling.

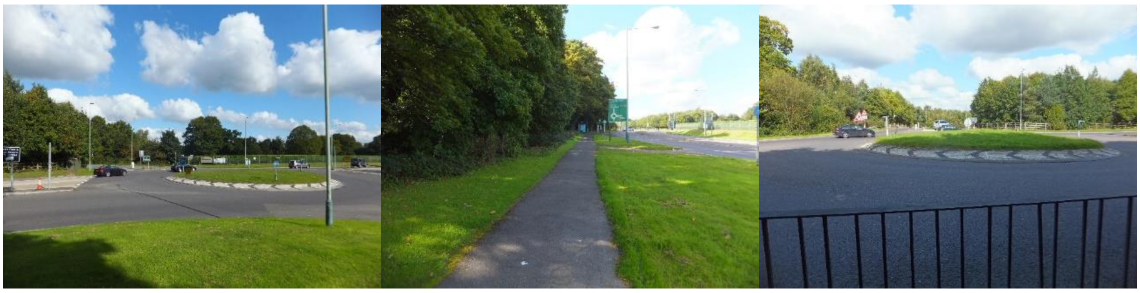
Section 1. Tesco – The proposed Park & Ride carpark

Land has already been set aside for use as a traditional bus Park & Ride facility. However without any radical change to the Pembury Road to allow buses to pass other vehicles there is no real incentive for commuters to use the system.



Section 2. Crossing over the A21

The TW-Pod can cross over the A21 or at the edge of the A264 (The Pembury Road). There is ample room.



Pembury Road to

Open ground exists on both sides of the Pembury Road.

Section 3. West to Halls Hole Road

On the left the Pathway* may pass through the school grounds giving an opportunity for a TW-Pod stop to be constructed in the school grounds for pupils and others. Further along there are a few houses. If constructed on this side the Pathway* may be position to the south of these. There is a pedestrian tunnel to the playing field which may also be used as a link to a TW-Pod stop.

Section 4. Halls Hole Road junction

The Pathway is likely to rise above Hall's Hole Road into the area surrounding the Water Tower. A branch loop could cross over Pembury Road to provide a TW-Pod stop at Skinners School.

A further loop will link to the Pathway running between Pembury and the southern corner of Dunorlan Park.

Hales Hole Junction:

The Water Tower:

Section 5. The Water Tower to Dunorlan - West bound

The route may then run through the grounds of Beachwood School providing another TW-Pod stop for school pupils. It may then run in the tree canopy along the left hand side of the Pembury Road to Dunorlan park north entrance where a TW-Pod stop may be constructed.

Section 6. Dunorlan to Calverley Park Gardens

Along this stretch there is ample tree foliage to allow the Pathway* to run above the pedestrian and cycle paths and remain reasonably unobtrusive although a notable sign for those in cars stuck in the traffic below.



Section 7.

(a) Calverley Park Gardens (OR 7b)

The high hedges on this road will provide visual protection to the houses on either side. While the pods are at the same approximate height of a double decker bus, additional intermittent shielding will stop passenger looking into these properties.


....

(b) Continue to the Royal Oak junction turning right at the Royal Oak

Similarly the high hedges can reduce the visual impact of the Pathway* until it reaches the grounds of the Salvation Army. At this point (if this route is adopted) it would join with the Pathway running to the southern edge of Dunorlan Park.


....

(c) Calverley Road to Carrs Corner

The north (right hand side) pavement and high wall and trees provides an opportunity to position either a single track or one above each other. These may be at a height to allow walkers below the pathway (potentially providing shelter from rain) or on the ground moving all pedestrians to the southern pavement.



Section 8. Carrs Corner to Crescent Road carpark

This is probably the most difficult part of the route to design, particularly due to the narrow start of Crescent Road. If other traffic is reduced then the TW-Pods may run on the ground down the middle part of Calverley Road towards the town centre for the northerly end of Zone B – pedestrian areas. Alternatively they may be designed to run by the few shops that are due to be demolished in Crescent Road.

Good ideas and design is needed for this section.



Section 9. Entry into Crescent Road carpark

Part of one floor of the existing carpark could make an ideal site for TW-Pods to interchange between Zone A and Zone B. As the pods can run on the same surface as cars, only facilities to make passengers more comfortable and guide them to the pods are necessary. Electric charging points can also be installed for any pods waiting.

Section 10. Bayhall Road – going east

The TW-Pods first travel to the Royal Oak / Salvation Army corner – as described above. The Salvation Army carpark could provide an opportunity for a TW-Pod stop to serve users or others in the local community.

Section 11. Bayshall Road to Dunorlan Park - east bound

This is another difficult section due to the narrowness of the road ‘corridor’. Another high wall on the north side potentially provides a similar solution to that of Calverley Rd. There are fewer trees and a raised single track seems the main possibility of a segregated track. Alternatively the TW-Pods may travel along the normal road with other traffic.

Section 12. Dunorlan Park (South side)

The park grounds can be entered at the top South West corner. There is already a thin layer of vegetation which can be used to position the pods preferably at ground level, behind bushes and thus largely out of sight. There is also room for a pod stop.

At this point user of the TW-Pod would start to gain beautiful sights across the park.

At the south eastern corner of Dunorlan Park a further TW-Pod stop can be created for the use of AXA employees and others.



Section 13. Dunorlan Park – Eastern side

The Pathway* can be kept to the edge and tastefully positioned in shrubs and trees. Another pod stop can be created at the existing car park. This would provide greater access to the park for many – without cars.

Careful design of the route, preferably running on the ground, with surrounding foliage would be needed to ensure the beauty of the park is maintained and enhanced for both pedestrians and those in the TW-Pods.



Section 14. Calverley Park Gardens - east bound

One section of the Pathway* may turn eastward towards Cornford Lane avoiding the houses to the south of the lane. Most of this route will be at ground level.

Another section will travel shielded from sight in the woods along Halls Hole Road to create a loop with the Pembury Road Pathway*.

Section 15. Cornford Lane to Pepenbury

Open fields on both sides of the lane are a joy to view. Unfortunately this lane is currently overwhelmed by excessive traffic at peak hours. The TW-Pods will help remove congestion on the Pembury Road thereby relieving the need and value to motorist of using this lane. It then can be turned back for walkers and cyclists. A gate half way along near Pepenbury would ensure traffic is substantially reduced.

The TW-Pods can easily be accommodated, mainly at ground level, blending into the countryside – largely invisible to others yet able to 'show off' this Tunbridge Wells country to all who travel on them.



Section 16. Pepenbury

Currently this facility is home for those who are disadvantaged by physical and/or brain injuries is isolated from all others. Access is only by minibus or a very perilous walk to Pembury along narrow, winding single track roads with no pavements. The TW-Pods and a Pod stop would give them the link to the rest of society – which they should have. Employees will also be able to commute to the centre without their cars or risking their lives on Cornford Lane.


Section 17. Pepenbury to the A21

Delightful views continue along both sides of Cornford Lane giving ample opportunity to design something, primarily on the ground largely out of sight to others, so all the residents and visitors to Tunbridge Wells can enjoy this beautiful countryside.

Travelling by walking is currently extremely hazardous along this stretch of road. Car are fast. The lane is narrow and twisting. There are few areas where one can walk off the road.



Section 18. A21 to Pembury (TESCOs)

The TW-Pod pathway would cross the over A21 somewhere between the existing Pembury Road and Cornford Lane bridges. There is ample room to create a Pathway through the countryside.

This brings the Pathway* to the Pembury (TESCO) Park & Ride carpark.

Section 19. Pembury Park & Ride

Passengers can alight at the Park & Ride or travel on to a destination along the Pembury Road or into Zone C, the hospital, Garden Centre, North Farms entertainment areas, shops and other businesses.


ULTra Infrastructure Explained

Details of infrastructure required for the Heathrow' type system is contained in the attached document. New specification may allow lighter weight materials to be used. Kerbs can be smaller as more advanced guidance systems are now available.

Slightly broader Pathways* (10cms to 15cms) may be needed if another type of Pod vehicle is selected.

07Infrastructure_ULTra.pdf

Briefing papers are available regarding operational, safety, regulatory aspects as well as possible designs for stations and trackways (guideways).

In addition 'Sketchup Models' for Guideways, Stations and the vehicle are available. These set out the design requirements of the tracks, stations and vehicles (Pods).

It should be noted that some requirements are becoming more flexible due to advancements in guidance technology and experience in construction. Additional guidance will have to be obtained in respect of the 'Greenwich' designed system and integration of these with those of the 'Heathrow' system.

ULTra Infrastructure

ULTra infrastructure encompasses guideway, stations, an operations/maintenance facility, and vehicles. Implementation responsibilities are explained.

All guideway, station, and maintenance facility construction materials will be sourced locally.

1.1 Guideway

1.1.1 Guideway Description

For many applications, all guideway is expected to be elevated and made of precast concrete. Expected elevated guideway headroom is 16', although a city might allow 14' in some locations.

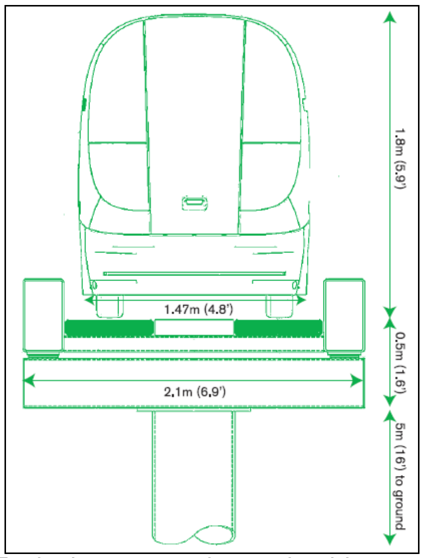


Figure 1.1: Typical one-way elevated guideway cross section

One-way guideway is roughly a two-meter-wide trough, comprising a flat floor with a central cable tray and 18" high "kerbs." The guideway is unpowered. For London Heathrow, elevated ULTra guideway structure is made of steel, with a precast concrete running surface for the rubber-tired vehicles. The standard Heathrow span length was 18m, with some spans reaching 36m long.

The guideway is of lightweight construction due to the low overall loading (British Standard for floor loading is 5kN/m2, ULTra loading is 2.2kN/m2). This low overall loading also allows the vehicles to run on existing building floors without significant strengthening or modification. Cantilevering off the sides of new buildings is also enabled. For London Heathrow, at-grade guideway has an asphalt running surface with concrete kerbs.

Various other guideway solutions are available, including "cut and cover with glass" in a culvert, shown below. With this treatment, station guideway may be brought up to grade for simplified pedestrian access. As far as the passenger experience, elevated guideway may provide a better view, providing more of a "transportainment" experience.

Figure 1.2: Cut and cover with structural glass guideway treatment

1.1.2 One-way Guideway Dimensional Requirements:

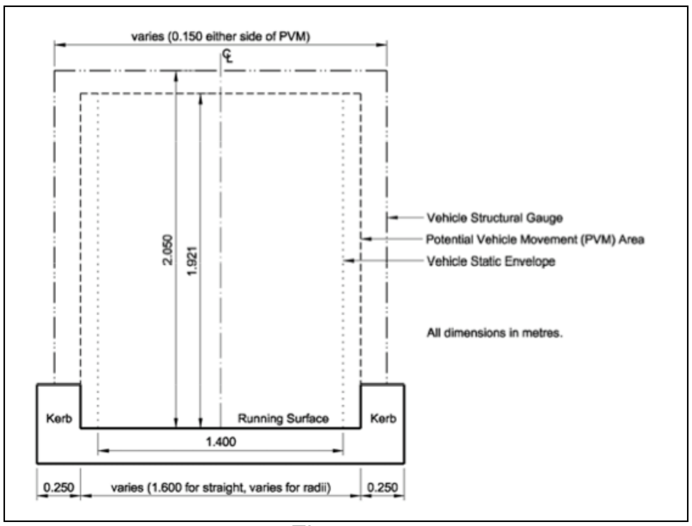


Figure 1.3

The guideway consists of a flat running surface, a minimum of 1.7-m wide, with 25-cm kerbs on either side. It can be built from any material. The kerbs must be constructed to within ± 2 mm of their intended locations.

The profile shown above, if constructed of precast concrete, should be sufficient to span 20 meters. Longer spans can be achieved by creating outer beams deeper than the standard 0.45m.

1.1.3 Structural Requirements

In station areas, the structural live load on the guideway is 3.5 kN/m (distributed as 13 kN loads at 3.7-m intervals). On guideway spans, the design load is 2.2 kN/m (typically distributed as 13 kN loads at 10-m intervals, with an allowance for 21 kN loads in the event of a vehicle-recovery scenario).

Deflections under maximum live loading shall not exceed the span length / 200.

1.1.4 Standardized Curves

The guideway must be widened on curves, according to the specifications below.

Vehicle Path Alignment Radius VPA (m)	Inner Kerb Face Radius Ri (m)	Outer Kerb Face Radius Ro (m)	Guideway Width (m)	Front Axle Centre Radius LRA (m)
25	24.177	25.888	1.711	25.069
20	19.171	20.909	1.738	20.086
12.5	11.654	13.469	1.816	12.638
10	9.142	11.007	1.865	10.172
5	4.083	6.169	2.086	5.335

Table 1.4

1.1.5 Junctions

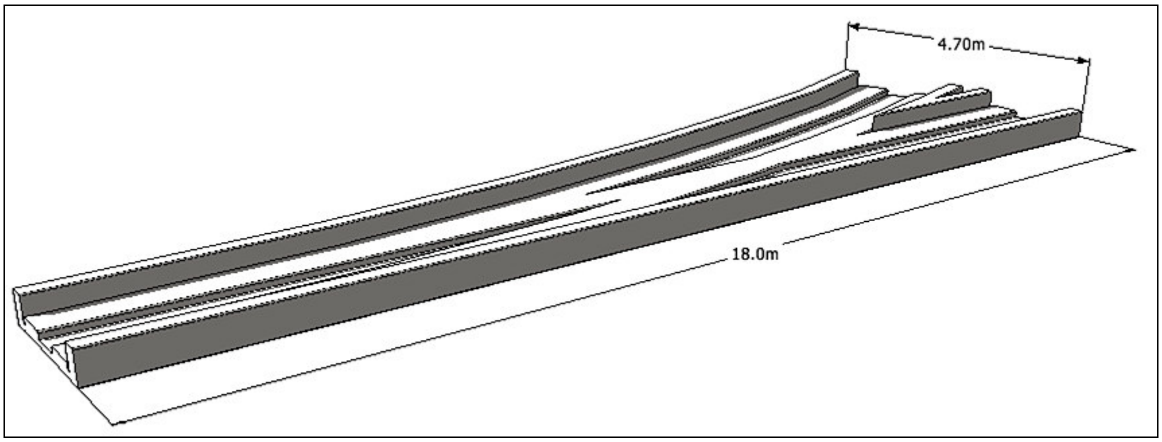


Figure 1.5

Junctions are characterized by one or both guideway paths being a non-circular arc (typically a cornu spiral). Although there will be a number of different junction configurations, each configuration should be replicated enough to order in bulk quantities.

1.1.6 Vertical Transitions

Vertical transitions occur at stations and grade changes. These are circular arcs with radii ranging from 40 to 440 meters.

1.1.7 Dual Guideway

The dual guideway is used for bi-directional traffic:

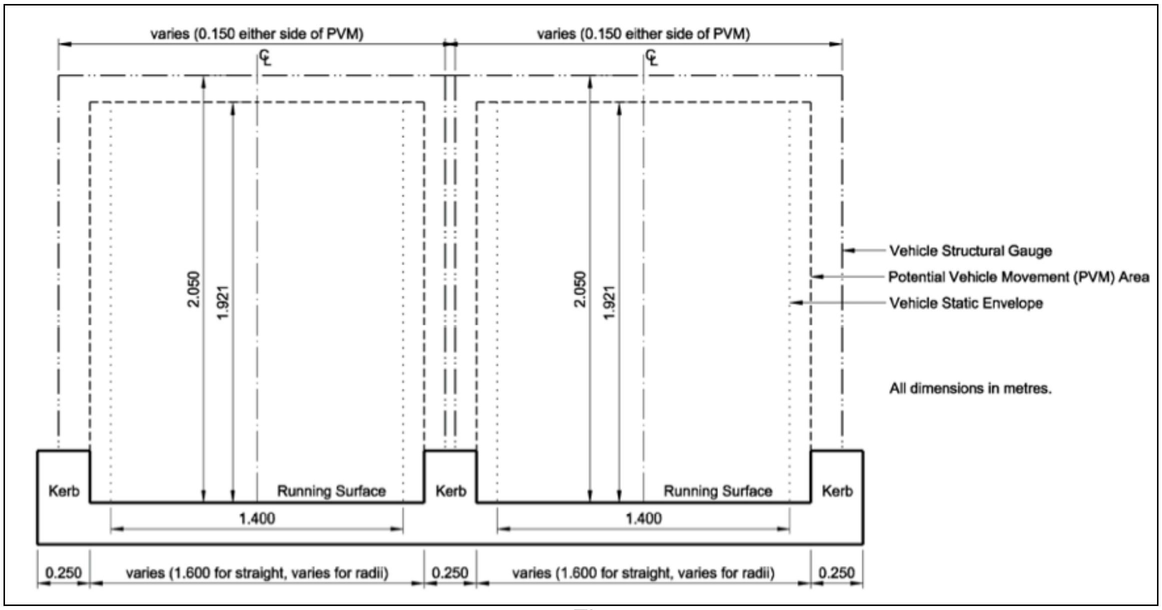


Figure 1.6

1.1.8 Safety Railing

Emergency safety railing is required for safety of maintenance personnel and for emergency evacuation. A visually minimized safety rail is desirable – a simple pipe column welded to the guideway beam, with tensioned wire cables and a top handrail. The railing must be able to withstand a horizontal force of 0.74 kN/m.

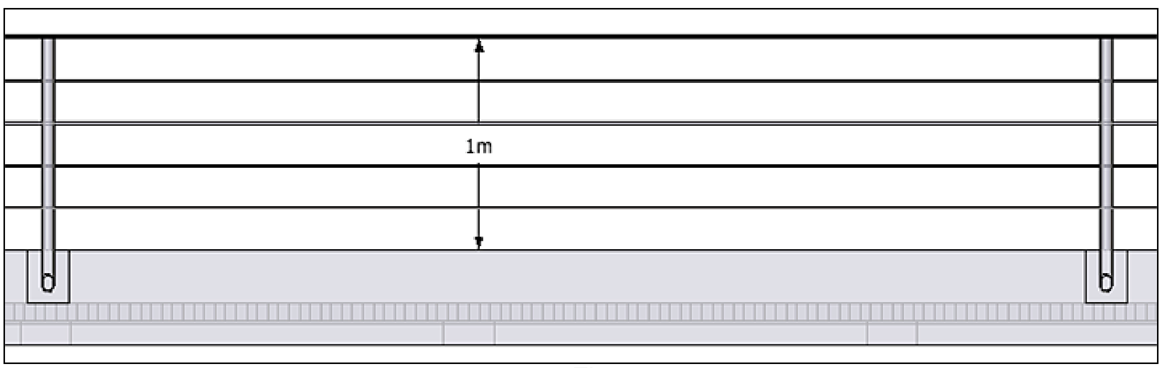


Figure 1.7

The safety railing used for ULTra London Heathrow is not visually appropriate for many sites as the visual impact is too large:

Figure 1.8: High-visual-impact safety rail (LHR) is not appropriate

Figure 1.9: Thin cable safety rail is more appropriate for most locations

1.1.9 Type 'B' – Precast Concrete w/ GRP Open Grid

This guideway type consists of monolithic precast spans, with concrete joists spanning between the two primary beams, approximately every 2 meters on-centre. These joists are then covered by a structural polycarbonate mesh panel (glass reinforced plastic or GRP). The dimensions of the grid: interior opening square dimension is 1 3/16"; the GRP is 1/4" wide; depth is 15/16." The guideway is fully permeable, so no gutters are required. Robust tiedowns are required for each polycarbonate panel.

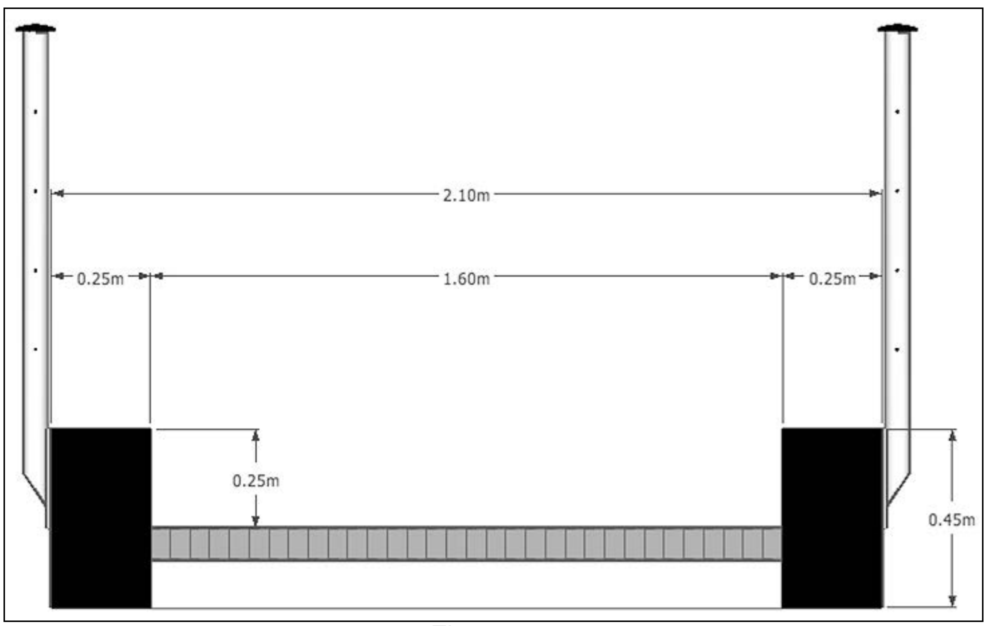


Figure 1.10

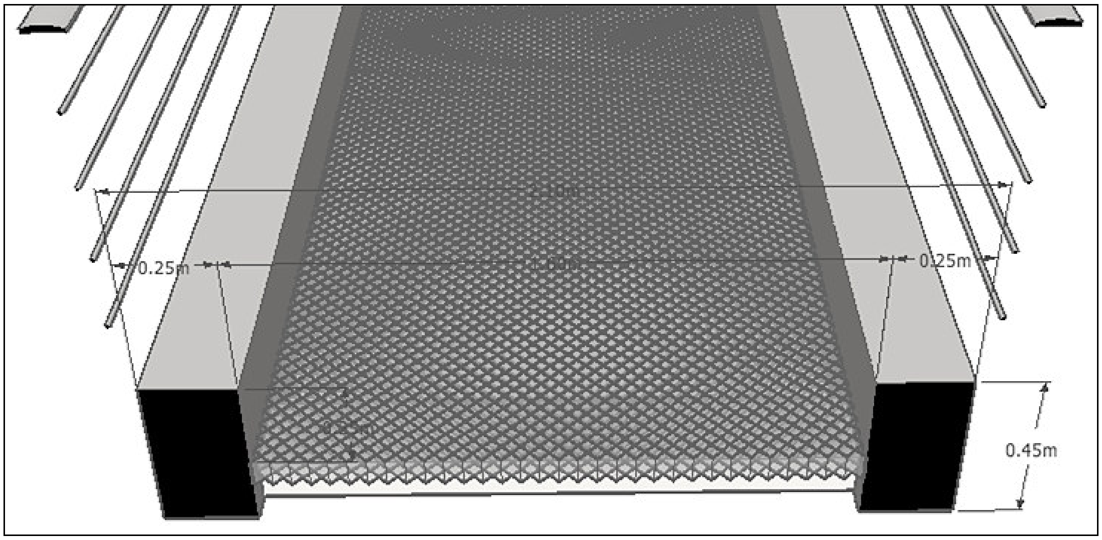


Figure 1.11

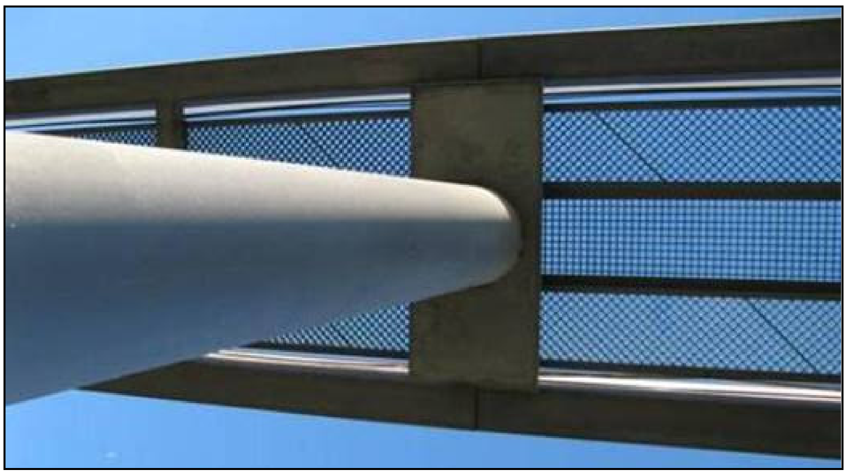


Figure 1.12: Guideway: 20% sunlight occluding GRP full grid running surface

Cable tray: Running down the middle of the guideway, tucked just below the GRP running surface, is a 2" high x 12" wide cable tray that houses communications and utility cables.

The open grid GRP guideway lets rain through without requiring gutters. This guideway also robustly handles ice events that occur: A) It is difficult for ice to form and attach to the pebbly GRP surface. B) Movement of vehicles on the guideway acts to flake off any ice that sticks.

1.1.10 Outfitting

The guideway is outfitted with:

- All-weather fixed-position CCTV cameras
- Control system communications equipment

Street lights may be affixed to either side of the guideway, negating the need for separate street light poles. Likewise, above-ground utilities such as power lines, fiber optic cables, and telephone lines may be hidden within the guideway cable tray.

1.2 Columns

1.2.1 General Column Info

Columns should be modular elements, each of which is capable of meeting the requirements of the most demanding conditions. Therefore, Column footings and caps may be varied depending on local soil conditions and guideway support requirements, however the main column body should be a standardized element, varying only in height. Except for the pilings and footings, the column elements are assumed to be reinforced precast concrete.

1.2.2 Column Dimensions

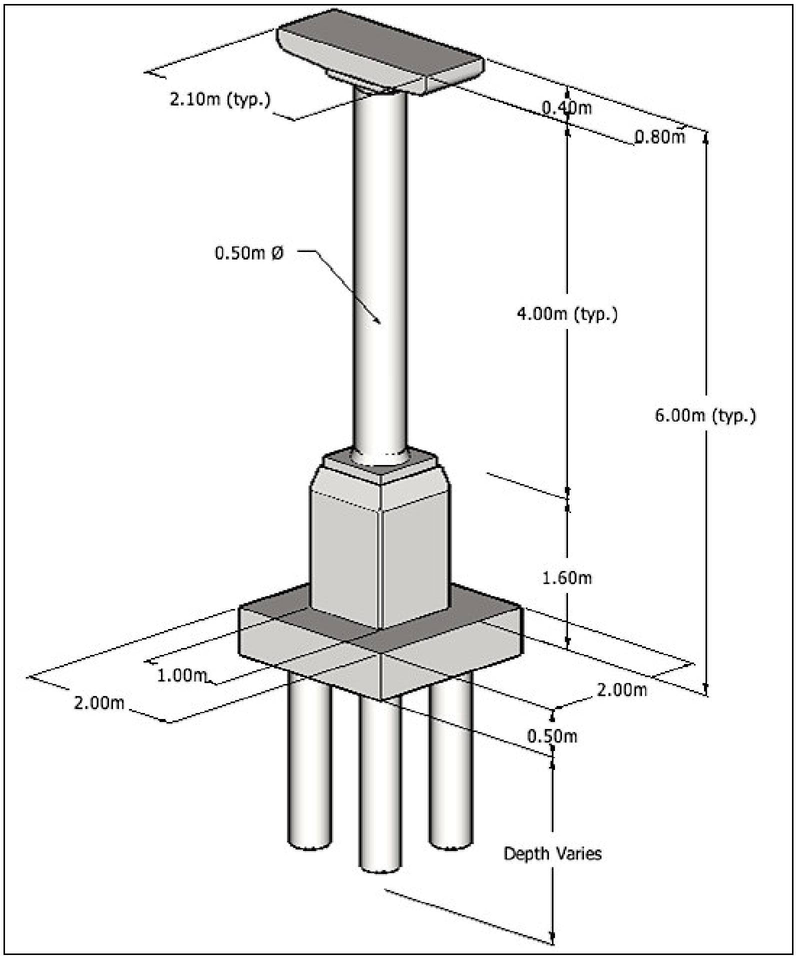


Figure 1.13

Columns are comprised of several elements:

- **Column Head**: typically 2.10m in width (for a single guideway), this must be expandable to 4.95m in width (for a dual guideway), or even 7.65m for a dual guideway with a junction. The column head should include weld plates to attach the guideway spans. On rare occasions, the column head may support a cantilevered guideway, although this would also have ramifications for the footing and piling design.
- **Column**: This should be a standardized circular-profile column, approximately 0.50m in diameter, varying in height according to the requirements of the site and guideway.
- **Plinth**: This is an impact-resistant base, 1.00m x 1.00m x 1.60m.
- **Pile Cap**: Typically 2.00m x 2.00m x 0.5m., although this will vary depending on local site conditions.

- **Piles**: approximately 0.40m-diameter piles, with varying depth depending on the soil conditions. The piling locations can be varied as necessary, to avoid intersecting in-ground infrastructure (if necessary, the pile cap can be enlarged to accommodate this).

1.2.3 Structural Requirements

Each column must be capable of supporting the weight of up to four 36-meter spans, in addition to the live loading of 2.2 kN/m per span.

1.2.4 Construction Disruption and Moving Underground Utilities

PRT infrastructure construction is faster and less disruptive than typical transportation infrastructure projects. Once column piles are in place, then a four-person crew can erect a mile of pre-fabricated guideway in one week. Construction of piles and pile caps can be scheduled to impact only a small portion of campus at any one time. Underground utilities such as water, electric, gas, or communications may run under some streets in the location where ULTra columns will be placed, hence movement of underground utilities may be required. During London Heathrow Airport ULTra system construction, no utilities were moved.

Once pile caps and piles are in place, then a four-person crew can erect a mile of pre-fabricated guideway and columns in one week.

1.3. Stations

Envisioned is a “traditional” PRT open-canopy elevated station design, providing shelter for passengers and vehicles from thunderstorms and golf-ball sized hail storms, while providing full shade protection from hot days. Station features include: stairs, an ADA-compliant elevator, and safety railing. A number of renderings of such stations have been created over the years for slightly different PRT technologies:

Figure 1.14: Images courtesy Cities21

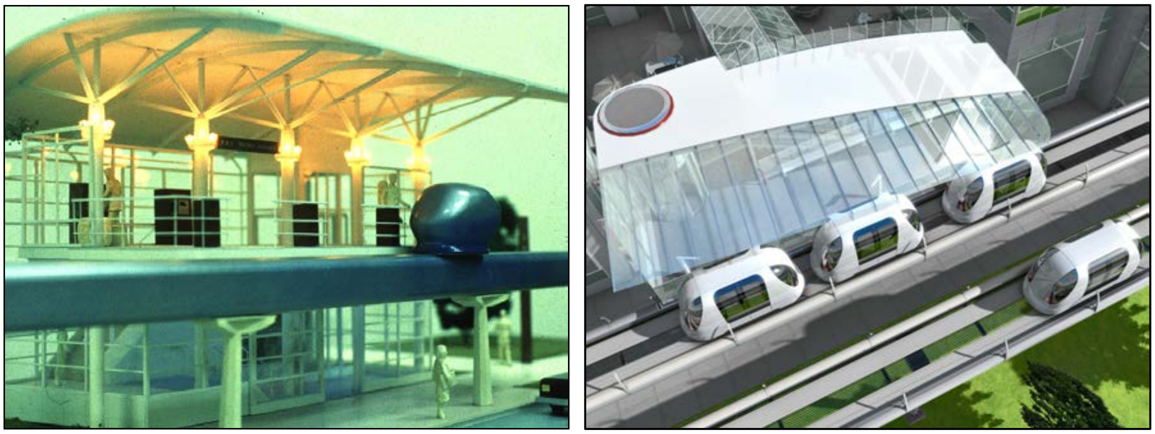


Figure 1.15: Images courtesy Jerry Schneider, ULTra PRT

The open-canopy must not only provide shade for passengers, but must also provide shade at appropriate sun angles for PRT vehicles parked at station berths. This reduces air conditioning operations costs.

Station design will be modular, so that additional vehicle berths may be added in the future at minimal incremental cost. The modular design is envisioned to include standardized components that are manufactured off-site for rapid on-site assembly/erection.

For relatively lower-demand two-berth stations, we will utilize “serial” vehicle berths, where the first vehicle must exit before the second vehicle may exit. UM provides a somewhat homogenous, agile population, providing faster vehicle load/unload behavior than found in other environments such as airports. In higher demand instances we will use sawtooth berths, as utilized for London Heathrow ULTra.

Some stations could potentially span across a street from sidewalk to sidewalk, with stairs running down to both sidewalks. This could be attractive for some pedestrian situations.

1.3.1 Station Dimensions

Shown below is a 20’ x 13.5’ elevated station platform for a 2-berth serial station, using an Oyster Card swipe and DSP (Destination Selection Panel). Elevated serial berth stations have the following elevated platform area space requirement: 135 square feet per vehicle berth. ADA elevator and stairs are in addition to this space requirement.

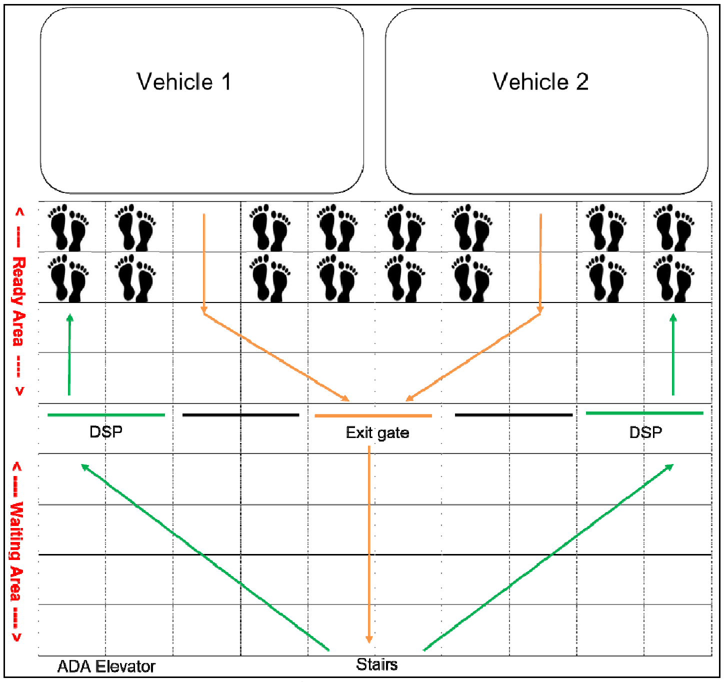


Figure 1.17: Floor plan for elevated two-berth serial station

Sawtooth station configurations are also used:

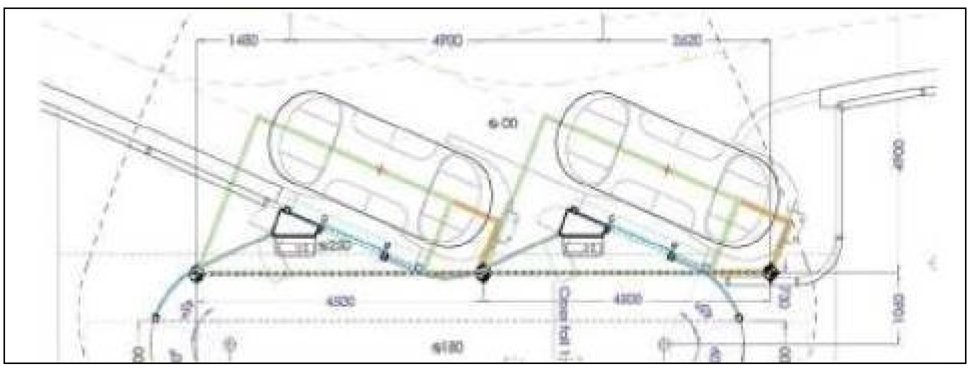


Figure 1.18: Floorplan for two-berth sawtooth station

Sawtooth stations allow vehicles to depart as soon as they are full of passengers, rather than having to wait for the vehicles in front to clear, as is the case with serial berth stations. Compared to serial stations, sawtooth station platform area requirements are doubled, 270 square feet per berth.

Examples of ULTra Destination Selection Panels (DSP) can be found in the ULTra Heathrow Terminal 5 four-berth sawtooth station:

Figure 1.19: DSP

Station square footage requirements for costing purposes are provided in the separate, confidential business model spreadsheet.

One of the top references for station design is: *Building Type Basics for Transit Facilities,* by Kenneth Griffin, 2004, John Wiley & Sons. "Provides guidelines, cautionary advice, and lessons learned from a variety of actual transit design projects--such as facilities serving heavy- and light-rail trains (including subways), airports, buses, and ships--to steer everyone on a project toward making sound decisions early in the planning cycle. Descriptive illustrations and need-to-know information offer valuable coverage on such essential topics as ridership analysis, station-area development, vertical circulation, and safety and security issues." Sub-topics covered include: ADA, materials/finishes, lighting, acoustics/vibration, wayfinding, ticketing, queuing space, station platforms, sizing, fire safety, elevators, and stairs.

1.4 Operations and Maintenance Facility (OMF)

This section provides details for a PRT Operations and Maintenance Facility (OMF) or depot. The OMF will be used to perform scheduled and routine inspections, vehicle maintenance, on-car repairs, and exterior cleaning of the PRT vehicles. The OMF will also be the base for PRT Facilities Maintenance (station and guideway cleaning and maintenance crews), and serve as the base for field service technicians and PRT recovery vehicles. The facility will also serve as component storage and change-out location.

Major items such as large-scale component rebuild, major body repairs, vehicle painting, major machine shop work and body/sheet metal work will all be performed at another location. This will be accomplished by contracting out to local shops with space, manpower and equipment to perform this work. Minor machining and electronic repair work, however, will be performed at the OMF.

OMF interior materials shall be chosen for durability and low maintenance. Finishes should be as follows: a) sealed concrete floors in shop areas and the roof storage area, b) wall areas in shops shall have a minimum 8' high concrete or concrete block wainscoting, c) office areas shall be metal stud and 5/8" gypsum-board construction. Floor and ceiling materials appropriate with use. Sound insulation shall be provided between adjacent office spaces, d) toilet/shower areas shall have ceramic tile floor and wall finishes.

1.4.1 OMF Building Features:

The OMF houses the control room, office space, vehicle maintenance bays, parts storage, electrical room, and vehicle storage.

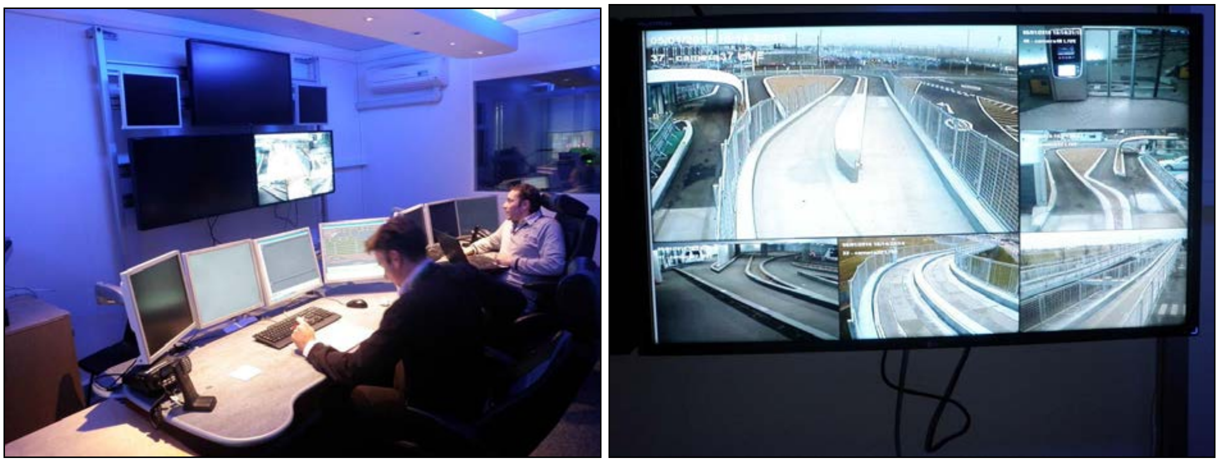


Figure 1.20: Heathrow OMF control room & control room CCTV

Figure 1.21: Heathrow OMF Maintenance Bays

Building features include:

- A hydraulic freight elevator shall be installed that can accommodate complete PRT vehicles and pallets of heavy components (such as batteries).
- A loading dock will be provided on ground level. This dock will face into the site area (not the roadway) and have an adjustable dock height to accommodate a variety of truck floor heights. The dock will either be immediately adjacent to the freight elevator or open directly into the freight elevator.
- A minimum 13 feet of interior vertical clearance is required in the hydraulic lift areas.
- A 3 ton overhead crane shall be provided in the Service and Inspection Bay area and shall also be accessible at the freight elevator door.

- An emergency battery backup UPS system and automatically-activated standby diesel generator will be provided to ensure uninterrupted power to operate the Control Center and all communications systems related to PRT operation.
- A shop DC power supply.
- Provision for shop compressed air outlets
- Car wash water recycling system
- A small electronics lab within the maintenance area
- Building access shall be secured via the use of ID card readers

Site access shall be secured via fencing

Maintenance / inspection tasks conducted in the facility include:

- Service, remove and replace PRT battery modules.
- Replacement of brake shoes
- Service, remove and replace PRT heating, ventilation and air-conditioning units.
- Exchange of defective components with new or rebuilt parts.
- Repair of miscellaneous system equipment and components.
- Periodic inspection and maintenance.
- Steering system inspection and maintenance
- Door system inspection and maintenance
- Communications system inspection, test and maintenance
- Replacement of modules and/or PC boards in PRT vehicles (sent off-site for repair)
- In-house repair of selected components
- Air-conditioning unit secondary maintenance and overhaul.
- Safety inspections.
- Thorough interior cleaning (light interior cleaning will be done by station cleaning staff)
- Automated exterior cleaning using the test-track-mounted wash rack
- Loading/off-loading equipment to/from vendors
- Wheel and component replacement on axles.
- Tire replacement.
- Motor replacement

1.4.2 System vehicle storage

Vehicle storage is distributed throughout the system. The OMF would not be designed to hold all of the vehicles. During system shutdown, vehicles are stored under canopies in stations, under canopies in adjacent-to-guideway storage just upstream of high-demand stations, as well as within the OMF.

1.4.3 OMF size: square footage

Calculation of required OMF square footage is calculated via an extrapolation of London Heathrow's Depot as well as two previous studies for other "medium-sized" PRT systems. The calculation worksheet is provided in the separate, confidential business model spreadsheet.

1.5 Vehicles

ULTra vehicles are four wheeled with rubber pneumatic tires. The vehicles are front wheel steered and have conventional damped spring suspension. The vehicles comprise an aluminum ladder rack chassis on which the majority of the vehicle propulsion and guidance equipment is mounted. Sitting on top of the chassis is an aluminum honeycomb floor. The above floor level is constructed of a steel frame and an ABS panel body that can be fitted with single side or double side electric doors. The vehicle interior and exterior bodywork design can be made to suit individual client demands. The vehicles are air-conditioned, have internal destination and information screens, CCTV internal surveillance and audio controller contact.

Figure 1.23

Vehicles use a laser sensor system to guide the vehicles on the guideway and in the stations. Vehicles use lithium-ion batteries optimized for rapid charging. The vehicles are designed to be adaptable for future battery developments and for other power sources such as hydrogen fuel cells, ultracapacitors, and new advances emanating from the fast-moving electric vehicle industry (Tesla Motors, etc). Batteries are charged via electrical contacts at station berths, or at waiting points. ULTra vehicles have a very low energy usage of 0.15Kw h/vehicle km at 25mph.

Each standard car has carrying capacity of five adults + luggage (Total 500kg); it has a turning radius of 5 meters and has a top speed of 25mph. The standard car has four contoured seats although other arrangements for example bench seating is available.

The cars can be modified to carry freight. PRT freight might relieve some central campus congestion by eliminating the need for delivery trucks, recycling trucks, food/vending machine deliveries, etc. Recycling materials could be ferried to a central campus perimeter drop site for city pick up.

Figure 1.24: Views of vehicle interior and buttons

1.5.1 Vehicle dimensions

Length	3.7m
Width	1.47m
Height	1.8m
Empty weight	820kg
Door opening	> 1.5m x 0.9m (h x w) (ADA compliant)

Flat floor area	1.44m x 1.2m
Turning radius	5m
Max climb angle	> 20%
Planned climb angle	10%
Planned descent angle	6.25%

Table 1.25

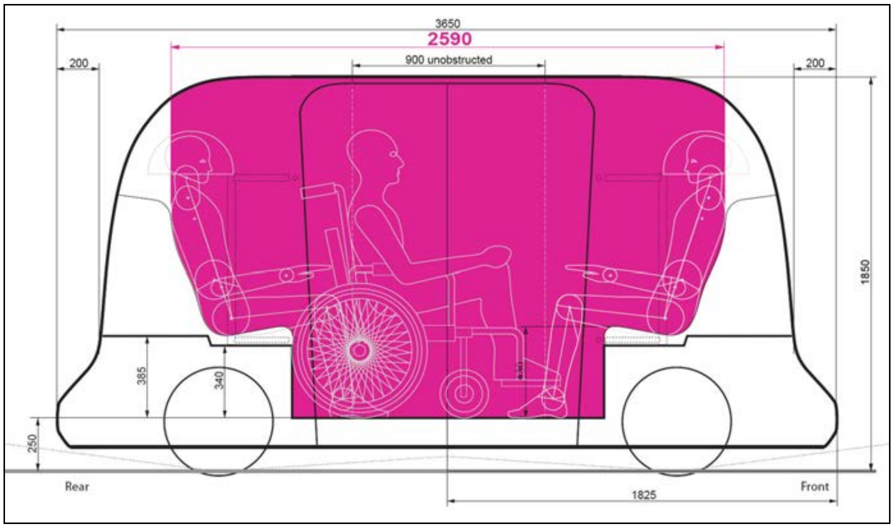


Figure 1.26: Vehicle dimensions for ADA access - in millimeters

1.5.2 Vehicle performance

Max speed	25 mph
Emergency deceleration rate	3 m/s^2
Maximum range on a battery charge	63 miles
Maximum payload	500 kg

Table 1.27

1.5.3 Vehicle configuration and features

Powertrain, and Energy Systems

- ‘7kW’ Synchronous AC Drive Motor (Typical average motive power use < 2kW)
- Solid State Drive Controller / Inverter
- Lithium Ion Batteries (rear mounted) 48V nominal
- Automatic Charging Connection System
- Fixed ratio transaxle assembly
- Front Wheel Drive

Braking Systems

- Drive motor regenerative braking
- Fail Safe Electromagnetic ‘hold off’ Motor Brake (1)
- Fail Safe Electromagnetic ‘hold off’ Rear Wheel Brakes (2)
- Safety interlocks between brakes, motor and doors

Figure 1.28 Vehicle Braking System

Chassis, Suspension and Steering Systems

- Fabricated Aluminum 'Ladder Frame' lower chassis with structural Aluminum Honeycomb floor and bulkhead Panels
- Separate Front and Rear Aluminum fabricated subframes with mountings for suspension, steering, motor/ transmission and batteries
- Bumper structure designed to progressively absorb impact energy and limit passenger deceleration
- Welded Steel tubular upper frame to support exterior and interior bodywork, side doors and front / rear hatches
- Double Wishbone suspension Front and Rear using predominantly aluminum machined wishbones, coil over damper units and standard automotive joints, bearings and bushes
- Rack and Pinion steering gear operated by Automotive Electric Power Steering unit
- 13" Wheels with automotive tubeless radial (135x70R13) tires

Figure 1.29: Vehicle Chassis and Frame

Figure 1.30: Vehicle body, doors, and glazing

Exterior Body, Doors and Glazing

- Body panels constructed in self colored ABS with high gloss Acrylic capping
- Vacuum formed exterior panels bonded to vehicle structure
- Twin leaf plug and slide doors
- Doors actuated by dc motors through reduction gearbox and locking linkage system
- Microprocessor controlled door operation
- Door leaves constructed of ABS panel, steel reinforcement and bonded laminated (tinted) glass
- Flashing door header rail warning
- Vacuum formed tinted Acrylic 'Quarter Window' glazing
- External vehicle operating lights (Front White and Amber, Rear Red and Amber)

Figure 1.31: Vehicle Interior

Interior and Passenger Controls

- Interior panels vacuum formed from grey, grained ABS
- Seats facing front and rear providing flexible accommodation for 4 adults
- Illuminating Door / Control switches
- Illuminating Communication / Alarm switches at both ends of vehicle (diagonal pair front right and rear left)
- Cabin speakers (one with each communication panel), ceiling mounted inductive loop and microphone for passenger communication
- Internal and externally releasable emergency exit (locked while vehicle in motion)
- Passenger information LCD screen
- Internal lighting sufficient for reading
- Vehicle signs / symbols and information labels
- Non-slip easy clean floor covering
- Cabin heating, ventilation and air conditioning
- Cabin smoke detector, emergency fire extinguisher and two internal CCTV monitoring cameras mounted in ceiling to monitor all of cabin
- Weight sensors to monitor vehicle loading and prevent operation if overloaded
- Wireless communication system for 2-way data, passenger comms and command exchange between vehicle and system central control

1.6 System Costing

System costing is provided in the separate, confidential business model spreadsheet. For costing, two estimates were received from major local firms.

1.8 Minimal Infrastructure Vandalism Risk

The ULTra system is grade-separated. The guideway is fenced off from access so that boisterous, thrill-seeking riders may not endanger themselves. In addition, closed circuit TV monitoring of the guideway by operations personnel should catch thrill-seekers well before they endanger themselves. Vandalism is not expected to be a large issue. Graffiti is typically spray-painted on large rectangular areas that can be read by by-passers from significant distance. The ULTra system presents few large target areas.

Vandalism is minimized in the following ways: (thanks to J. Edward Anderson)

By Surveillance. The stations will be CCTV television monitored with two-way voice communication. They are small areas that can be surveyed easily, and infrared detectors will be used to detect the presence of people so that the operator, in slack times, need not constantly view the screen.

By Identification. A means will be provided to permit a boarding passenger to reject a vandalized vehicle. An alarm signal will then be sent to the nearest control room where a human operator is alerted to roll back a video memory unit and make a permanent record of the last passenger to egress from the vandalized vehicle, and to command the vehicle to the nearest maintenance shop. Normal police methods will then be used to apprehend the vandal. Experience at the Morgantown automated people mover system has shown that knowledge of such a procedure, not possible in conventional transit, will by itself deter most vandalism.

By Psychology. In public places, vandalism has been greatly reduced by the application of human psychology (see *Psychology Today*, September 1982). Plain walls that look like writing tablets invite being written on. Textured walls and walls with diagonal lines or protrusions markedly reduce graffiti. Appropriate colors, music, architectural design, and plants reduce vandalism. Frequently cleaned public places are not as subject to vandalism as dirty ones.