PRT Stations – Physical Planning Dimensions

1 Objective

To develop and summarise the physical characteristics of PRT stations which meet the requirements of the three European systems (Vectus, Ultra, 2getthere). Where appropriate, exceptional requirements, are also identified.

Stations are critical elements in PRT systems and ensuring that station capacity matches demand with limited passenger waiting time is an essential part of the system design process and each station should be designed for its specific location and passenger throughput characteristics.

This paper is concerned with providing basic dimensional parameters to guide early system planning and budgeting studies.

2 Introduction

An essential feature of PRT stations is that these are located “off line”, vehicles destined for the station, leave the through track and utilise track dedicated to the station function.

This study deals with track and structures used for;

- deceleration from the through track line speed,
- vehicle queuing,
- vehicle berth(s) aligned to provide access to the passenger boarding area
- the passenger waiting/ boarding area,
- vehicle manoeuvring space to rejoin station track,
- acceleration to re-join the through track at line speed.

PRT vehicles or “pods” are typically 3.5m long and 1.5m wide with capacity for seating 4 adults with luggage, or groups up to 6 persons with some seat sharing. Pod internal dimensions also allow access for baby buggies, bicycles and wheelchairs.

PRT pods are typically 1100-1500kg in weight, with load distributed equally over front and rear axles.

Vectus are developing cars which will take 6 seated and 3 standing passengers, with a fully laden weight of 2,500 kgs.

PRT operations are planned such that foot passengers will most often arrive at a station to find an empty pod waiting and available for immediate boarding. Circumstances will arise in which some passengers will wait in the boarding area for a pod to arrive for their use. This may be an empty pod sent to the station in response to a demand call or a loaded vehicle arriving to discharge passengers.

PRT pods are intended to carry passengers (up to the pod limit) in self selected groups. There is no requirement to wait until all seats are occupied before the pod departs for its destination station. In high demand stations, ride sharing, where passengers with a common destination are grouped to fill all seats/pod capacity, is being explored, to increase the station throughput during high demand periods.

The boarding area is separated from pod manoeuvring area by the use of screen doors, for which the opening is co-ordinated with pod doors and pod availability. The layout of this boarding area is a function of the station location in its setting and is not developed in this paper.

3 Station Track Configuration

The components of station track are illustrated in Figure 1 and include;

a) turnout from through track,

b) deceleration track leading up to

c) queue point and low speed vehicle manoeuvring area,

(the berth region is described in Section 4)

d) acceleration track, and

e) merge track to re-join the through track.

Station capacity studies have indicated the advantages of a store for empty vehicles immediately upstream of the berth area. This allows rapid supply of empty vehicles into a station where there is a high demand not matched by incoming PRT passengers. For example a commuter railway station where peak hour directional flows are unbalanced. Station track element diagram (Figure 1) indicates one way in which such storage could be provided, through an alternate use of section (b), with arriving occupied vehicles routed along element (f) directly to the berth. The system designer will need to consider turn out speeds and requirements for off line deceleration if this layout is adopted, as element (c) may need to be lengthened to function as a deceleration track.

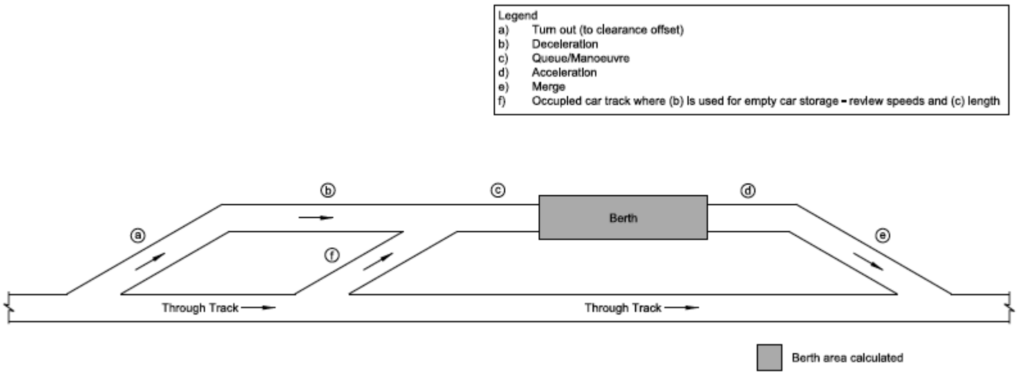

Figure 1: Components of Station Track

PRT systems operate at line speeds up to 40kph. For the purposes of summarising station track characteristics, diverge or turnout speeds of 50, 40, 20 and 10kph have been used. These speeds may arise from lower through track speed or pod slowing on the through track before reaching the turn out (diverge) point. Systems are under development with potential line speeds up to 70 kph, but it is likely that line speed will be reduced to at least 50 kph ahead of the turn out in order to apply tighter radii for the station tracks.

Similar assumptions are made for the merge speeds.

Passenger comfort is an important design consideration and so jerk, rate of change of acceleration, in both line of travel and lateral directions, is limited to $2.5m/s^3$. This factor influences acceleration and deceleration profiles, turn out and curve radii.

For the purposes of track design pod acceleration and deceleration is limited to 0.35g or $3.43m/s^2$ based on ASTM APM standards for seated passengers.

An upper bound deceleration rate of $5m/s^2$ is used to demonstrate the implications of applying a higher rate. This rate is achievable with the pods and might apply if passengers used seat belts for example.

Pod speeds in the vehicle manoeuvring area are typically 3 m/s. This has been taken as the end speed for the deceleration track, and the starting speed for the acceleration track.

It is assumed that speed through the turn out, until the offset at which the vehicle kinematic envelope is clear of the through track, will be the same as the through track speed at that point. The distance to clear the kinematic envelope of vehicles on the through track provides for achieving an offset of 1.5m before slowing from line speed commences.

Under some control systems it is possible for pods to arrive at the station before there is an empty berth for immediate use. In these circumstances, a single “queue” point may be provided on the approach to the low speed area where a pod can await the departure of a pod and access to an empty berth. A nominal allowance of 4 m has been included in the total length requirement.

Results of this analysis are tabulated below;

Line speed kph	**5050**	**40**	**20**	**10**	**3**
Line speed m/s	13.89	11.1	5.6	2.8	0.83
Length to clear through track (m)	15.29	12.26	6.27	3.39	1.76
Length to decelerate					
at 1.25m/s^2	76.88	49.10	12.07	2.81	0.00
at 2.50 m/s^2	38.44	24.55	6.03	1.40	0.00
at 3.4 m/s^2	28.02	17.90	4.40	1.02	0.00
at 5.0 m/s^2	19.22	12.28	3.02	0.70	0.00
Queue point (m)	4.00	4.00	4.00	4.00	4.00
Total slowing lane length (m)					
for 1.25 m/s^2	96.17	65.37	22.34	10.20	5.76
for 2.50 m/s^2	57.73	40.82	16.30	8.80	5.76
for 3.4 m/s^2	47.31	34.16	14.67	8.42	5.76
for 5.00 m/s^2	38.51	28.54	13.28	8.09	5.76
Total for Acceleration lane (m)					
for 1.25 m/s^2	92.17	61.37	18.34	6.20	1.76
for 2.50 m/s^2	53.73	36.82	12.30	4.80	1.76
for 3.4 m/s^2	43.31	30.16	10.67	4.42	1.76
for 5.00 m/s^2	34.51	24.54	9.28	4.09	1.76

4 Station Configurations

PRT stations can have multiple passenger alighting and boarding positions.

For the minimum single position, the pod would stop on the station track opposite the screen door, through which passengers alight and board. The length of the track in this instance is that required for final deceleration, loading (pod length) and acceleration to 3m/s. The final stopping distance is 0.27m for the lowest deceleration/acceleration rate from the range above. This gives a total length made up as follows;

stopping 0.27, berth 3.9, accelerate 0.27 = 4.44 m

In line multiple berths are possible, but departure must be in sequence as there is no scope for a rear pod to pass a vehicle closer to the merge point. The dimensions for in line berths are as above, together with an allowance each additional stopped pod with spacing between berths, of say 4m.

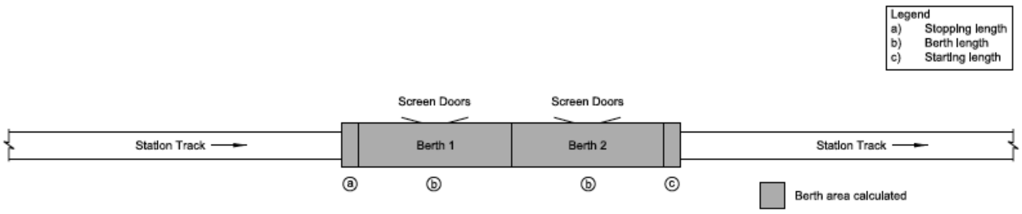

Figure 2: Linear Berth Components

Requirements for single and multiple berth arrangement as follows;

Berths	1	2	3	4
Length m	4.44	8.44	12.44	16.44
Width m	1.6	1.6	1.6	1.6
Deck area m^2	7.1	13.5	19.9	26.3

The larger linear station may be used where high throughput leads to application of empty car platooning, and platoon despatch.

An efficient pod despatch sequence for multiple berths is secured by the use of inclined saw tooth berths, from which pods reverse in order to start their new journey from the station stop. Departure from berths can be in any order. The dimensions of the berth approach and stopping area is determined from the berth angle, and safe operations to ensure pods can manoeuvre past any other parked pod. Control interlocks , to avoid conflict, limit the number of pods in motion at any time.

The maximum number of berths at any station is determined from practical issues of passenger control and direction information, and is probably limited to four berths. If demand exceeds this then consideration should be given to providing another station in the same area.

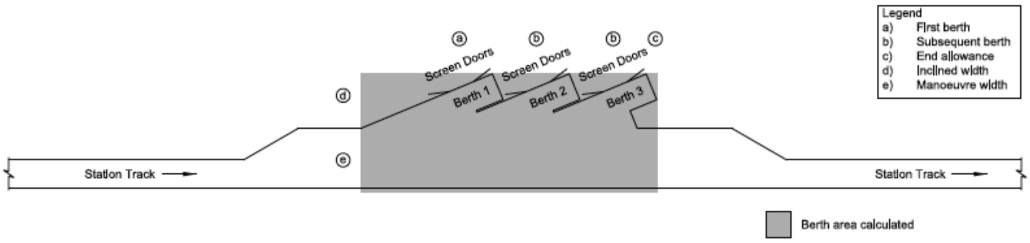

Figure 3: Inclined Berth Arrangement

The angle of the berth is a variable in design over a limited range according to site constraints. For the purposes of this analysis the range 20^0, 25^0, and 30^0 measured from line of track, has been considered.

The overall length of a berth with end buffer and navigation points to confirm pod location, is 5.850 m, with a width between parked pods of 1.63 m. This dimensioned rectangle can be oriented according to the chosen angle of berthing.

It is assumed that the queue point length is also used for the start of the turning manoeuvre into the first berth, and no additional allowance is made for this.

Some overlap is achieved such that the running length for berths after the first is reduced as in the table below.

The width of the final berth implies a further running length which needs to be accounted in overall layouts. A two berth arrangement would have the following dimensions.

Angle	First (M)	Second (m)	End (m)	Total (m)
20^0	5.50	4.47	0.56	10.53
25^0	5.30	4.64	0.69	10.63
30^0	5.07	4.85	0.82	10.74

The running length for multiple berth stations would therefore be as follows:

Length m	1 Berth	2 Berth	3 Berth	4 Berth
20^0	6.06	10.53	15.00	19.47
25^0	5.96	10.63	15.27	19.91
30^0	5.89	10.74	15.59	20.44

These running lengths are additional to the slowing track dimensioned in Section 3 above.

As noted in the diagram above, the clear track width between the end of the berth and the opposite edge of the through station route is required for forward and reverse manoeuvres. The width for manoeuvring is taken to be 2.55m from the kerb end of the angled berth. This kerb end offset also varies with angle as below.

Angle	Kerb end offset (m)	Manoeuvre width (m)	Total width (m)
20^0	2.08	2.55	4.63
25^0	2.47	2.55	5.02
30^0	2.93	2.55	5.48

With these results it is possible to give approximate areas of simple rectangular deck required to support the angled berth and manoeuvring track for various angles and berth numbers.

Area	1 Berth (m^2)	2 Berths (m^2)	3 Berths (m^2)	4 Berths (m^2)
20^0	28.06	48.75	69.45	90.15
25^0	29.92	53.36	76.66	99.95
30^0	32.28	58.86	85.43	112.01

Note; some of this rectangular plan area, approximately $7m^2$, will be available to support screen doors and passengers waiting to board or leaving pods. This is taken into account in Section 5 below.

5 Station Passenger Elements Organisation

The passenger elements comprise all features on the passenger side of the screen doors. These include passenger arrival and waiting areas, features for ensuring that boarding and alighting passenger conflict is avoided, and pre-boarding destination selection and payment systems.

Each pod could carry up to 4 persons, and a further 4 persons could be waiting to board an arriving loaded pod, giving a group of 8 persons accumulated around the screen doors. It is recommended that Fruin Level of Service concepts for crowding be applied for determining the area of passenger assembly, as below (Taken form Port of New York Authority and Network Rail standards);

LoS A > $1.2m^2$ per person

LoS B = 0.9 – 1.2 m^2 per person

LoS C = 0.6 – 0.9 m^2 per person

This would give a platform area to accommodate 8 persons, of 9.6 m^2 at LoS A to 4.8 m^2 at the lower end of the C standard. Given that speedy unloading and boarding is to be encouraged, and some passengers will bring luggage or buggies, it is recommended that the upper end of this range be applied where practical.

As noted above, a triangular area of approximately 7 m^2 has already been accounted with the berth deck area, so a modest increase of 2 –3 m^2 at each berth is required to meet the standard.

For systems which have a car capacity of 9 persons the comparable station platform area would be 21.6m^2 at LoS A.

The location and configuration of these areas will depend on how the station platform area is to be integrated with other features of the station , in particular stairs and lifts.

Stations are generally located in relation to the through track and therefore elevated above roads and footpaths. For stand alone stations there will be a requirement to facilitate passenger movement between ground and station levels. This may be achieved by stairs, lifts and escalators or combinations of these to allow access for all types of passengers and their luggage, equipment, and travel aids.

Where a station is part of a building clearly passengers would use the building vertical circulation facilities. Where a station is free standing the issue of passenger vertical movement requires considerable care. If the height of the station is at a road clearance height of 5.2m then stair access will not be attractive, and will not serve disabled or passengers with luggage.

As passengers will travel in small parties, up to say 6 persons of which one may be in a wheelchair or pushing a buggy, a small lift would provide a simple service to meet all needs. Based on the LoS concept above the floor area for an 8 person lift (6 with wheelchair) at standard C would be 4.8 m^2 or 2.2 m square. A pair of lifts would provide resilience and continued operation during maintenance and would improve the level of service provided at multi berth stations.

6 Summary

The considerations above have developed lengths and areas of structures required to support PRT operations through off line stations. The findings are as follows;

Deceleration track from diverge point on through track to station berthing area. Length includes low speed manoeuvre or queue track

Line speed kph	50	**40**	**20**	**10**	**3**
Line speed m/s	13.9	11.1	5.6	2.8	0.83
Length of track	m	m	m	m	m
1.25 m/s^2	96.17	65.37	22.34	10.20	5.76
2.50 m/s^2	57.73	40.82	16.30	8.80	5.76
3.4 m/s^2	47.31	34.16	14.67	8.42	5.76
5.00 m/s^2	38.51	28.54	13.28	8.09	5.76

Acceleration track takes same dimension as above from station berth manoeuvre area to merge point on through track. The difference is that final manoeuvre or queue point has not been included.

Line speed kph	50	**40**	**20**	**10**	**3**
Line speed m/s	13.9	11.1	5.6	2.8	0.83
Length of track	m	m	m	m	m
1.25 m/s^2	92.17	61.37	18.34	6.20	1.76
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5.00 m/s^2	34.51	24.54	9.28	4.09	1.76

In Line Stations

Length and area requirements are summarised as follows;

Berths	1	2	3	4
Length m	4.44	8.44	12.44	16.44
Width m	1.6	1.6	1.6	1.6
Deck area m^2	7.1	13.5	19.9	26.3
Passenger area m^2 (4 person cars)	9.6	19.2	28.8	38.4
Passenger area m^2 (9 person cars)	21.6	43.2	64.8	86.4

Angled stations

Length and area requirements are summarised as follows;

	1 Berth	2 Berths	3 Berths	4 Berths
Length parallel to track m				
Angle 20^0	6.06	10.53	15.00	19.47
25^0	5.96	10.63	15.27	19.91
30^0	5.89	10.74	15.59	20.44
Berth area m^2				
20^0	28.06	48.75	69.45	90.15
25^0	29.92	53.36	76.66	99.95
30^0	32.28	58.86	85.43	112.01
Passenger area m^2				
Total m^2 (4 person cars)	9.6	19.2	28.8	38.4
(additional to berth) m^2	3	5	8	10