DESIGN OF ACCESSIBLE PUBLIC TRANSPORT

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SUMMARY

EDI Rail, one of Australia's major rollingstock manufacturers, has recently delivered and is in the process of designing new rollingstock which caters for persons with disabilities.
This paper deals with practical design considerations in designing passenger trains which are compliant with the Disability Standards for Accessible Public Transport (2002).
Several design projects both for new passengers cars and upgrades of existing in service rollingstock are examined to demonstrate a number of different solutions in meeting the requirements of the standard.
The paper outlines the main accessibility features and the design processes used to develop the end product and discusses how the operator and the various consumer advisory committees have been involved in the design process.
Some of the limitations in providing accessibility within the constraints of running and effective and safe public transport service are discussed.

1. INTRODUCTION

In April 1999, QR awarded EDI Rail – Bombardier a contract for 4 x 3 car inter Urban Multiple Units known as the IMU120 Airtrain (Figure 1). These cars entered service in October 2001 to supplement QR's fleet of existing IMUs servicing the Gold Coast line which had recently been expanded to run to the Brisbane airport. The original interior design of the IMU120 was almost identical to the existing IMU100 series however with the knowledge that the draft Disability Standards for Accessible Public Transport were soon to be become law, the contract was varied to provide enhanced accessibility.

Figure 1 - IMU120 Airtrain

The IMU120 design was then used as the basis for designs to upgrade QR's existing fleet of 30 SMU220, 10 IMU100 and 12 SMU200 three car units. The cars were withdrawn from service and upgraded with rapid turn around of one three car set per week. In total 52 three car sets were upgraded from March 2001 to November 2002.

In May 2002 the Public Transport Authority of Western Australia (PTA of WA) awarded EDI Rail – Bombardier a contract for 31 x 3 car EMUs as part of the Perth Urban Rail Development (PURD) project. These cars will herein be referred to as the PURD EMUs (Figure 2). The cars are currently under construction and are expected to enter service in September 2004 where they will supplement Perth's existing fleet of 2 car EMUs and will primarily run on the north – south route from Clarkson in the north, travelling through the city and on to Mandurah in the south as the line is progressively expanded by 2006. This contract requires that the cars comply with the Disability Standards for Accessible Public Transport 2002. Both PURD and existing EMUs are operated by the driver only.

Figure 2 - PURD EMU

This paper focuses primarily on these designs as case studies to highlight the key issues and to illustrate a number of different rollingstock design solutions for compliance with the disability standards for public transport.

2. NOTATION

EMU – Electric Multiple Unit
SMU – Suburban Multiple Unit
IMU – Interurban Multiple Unit
DM – Driving Motor
PURD – Perth Urban Rail Development.
PTA - Public Transport Authority of Western Australia
DSFAPT – Disability Standards for Accessible Public Transport
PEI – Passenger Emergency Intercom
PID - Passenger Information Display
PA – Public Address
VAS – Voice Annunciation System

3. Design Aims

The aim when commencing the design of the accessibility features was to comply with the requirements set out in the DSFAPT as far as practical.
Although there are statutory reasons for compliance with the standards the broader social objective is summarised as :
To use best endeavours to respect and promote the dignity and independence of all passengers within the constraints of running an effective and safe public transport services.

An important design aim is to eliminate as far as possible the need to provide direct assistance for passengers, not only for the independence of the individual but also to limit the burden (and associated cost) on the operator in providing direct assistance. If direct assistance were required on a railway service then this would usually be provided by the guard or by station staff. Eliminating the need for direct assistance is therefore becoming critical as railways move towards driver only and even driver less trains.

4. Range of Disability

Although the type and severity of disablement covered by the Disability Discrimination Act is wide ranging, the target groups for which the designs cater can be broken down into three major categories in terms of the type of facilities provided :

a) Mobility impaired passengers including ;
   - People dependant on mobility aids such as wheelchairs, electric scooters, crutches, walking frames, etc.
   - People with disfigurement or reduced use of the arms or hands, which often affects gripping capacity.
   - People with reduced range of movement, speed, stamina and agility such as the elderly, medical conditions and pregnant women.

b) Visually impaired passengers ranging from those with vision or colour perception deficiencies to those totally blind.

c) Hearing impaired passengers ranging from those with partial loss of hearing, often dependant on electronic hearing aids to those totally deaf.

5. REVIEW OF ACCESSIBLE FEATURES

5.1 Allocated Wheelchair Spaces and Priority Seating

The DSFAPT requires that at least two allocated spaces and two priority seats are provided per rail car however several different approaches have been taken to the positioning of these on the car as shown by the layout drawings shown in Appendix A.

The QR SMUs, all of which were upgraded after entering service, consolidate the allocated spaces on a three car set basis and provide three spaces in the centre saloon of each DM car. One advantage of this arrangement is that it leaves the vestibule area clear for standees and the rapid through put of passengers in peak hour.

Figure 3 - QR SMU220 Allocated Wheelchair Spaces

Transverse seats were removed to make room and an interface frame bolted to the original seat mounting points. The frame mounts fold down seats, longitudinal guide rails and houses additional, low height PEIs (Figure 3). A one week upgrade turn around was achieved by having kits of parts pre-assembled and using only bolt on and plug in connections.

The QR IMU allocated spaces were consolidated on a 3 car set basis and provide six allocated spaces in the saloon of the DM B Car because this car housed the wheelchair accessible toilet and it was not feasible for passengers to be expected to move from one end of the unit to the other. This was due to the aisle width between the transverse seats being of insufficient width to provide an effective accessible pathway. A minor inconvenience of this arrangement is that people using wheelchairs need to position themselves on the platform to suit where this car will likely stop and it is not always possible for operations to control which end of the set is leading.

The PURD EMU design positions the wheelchair spaces in the vestibule immediately adjacent to the doorway and weather shields have not been fitted in front of the allocated spaces. This is most convenient for wheelchair users who have only a short, direct path to traverse. The PURD cars feature four allocated spaces per car (twice as many as required by DSFAPT) and some have been extended in length and designated "multi-purpose bays". The intention is that pushbike riders stand in these spaces supporting their bikes. This is a good example of how other consumer groups benefit from accessible design principals.

Figure 4 - PURD EMU Allocated Wheelchair Spaces

In all cases Priority Seats have been positioned in the vestibules as close as possible to the doorways. Two place fixed longitudinal seats were chosen as some disabilities can warrant greater than the standard seat width for sitting. Fold down seats are not ideal for designation as priority seats because some dexterity is required to hold down the seat while sitting.
As recommended by the standard, signs are provided designating the seats for priority use by passengers with disabilities.

5.2 The use of Luminance Contrast

People with impaired vision can feel vulnerable about tripping or colliding with obstacles in their path and have difficulty orienting themselves, especially in unfamiliar environments. The provision of luminance contrast between items in the interior assists greatly.

Humans detect images by processing light reflected from surfaces and distinguish one object from another not only by difference in the wave length of the reflected light (colour contrast) but also by difference in the intensity of reflected light, termed luminance contrast.
The most effective way to clearly define a boundary, even for people with normal sight, is to design it such that a high luminance contrast is achieved. For people with colour perception disabilities, luminance contrast is critical for differentiating items.

Luminance is measured using a calorimeter which directs a light pulse at the surface and measures the brightness of light reflected.

The units for Luminance are candelas / m^2 or cs / m^2.

Luminance contrast, C is obtained by measuring the luminance, L of both surfaces and using the following equation:

$$C = (L2 - L1) / 0.5 (L1 + L2)$$

The DSFAPT require that contrast of at least 30% be achieved to define different surfaces.

As part of the design process for the QR SMU / IMU upgrades a study was untaken with the assistance of the CSIRO Building Construction and Engineering Division to quantify the luminance contrast of key interior items. Some examples are given in Table 1.

Item	**L1**	**Back-ground**	**L2**	**Luminance Contrast, C (%)**
Handrail (Y14 Yellow)	45.8	Wall (White)	78.1	52.1%
Handrail (Hammer Blue)	6.7	Wall (White)	78.1	168.4%
Seat Fabric (Maroon)	5.3	Carpet (Flotex Light Grey)	8.0	40.6%
Toilet Seat (Yellow)	40.8	Toilet Base (White)	61.5	40.4%
Toilet Seat (Yellow)	40.8	Toilet Floor (Dark Blue)	8.8	129%
Allocated Space border (Yellow Carpet)	28.4	Carpet (Flotex Light Grey)	8.0	172%
PEI Face (Off White)	73.9	Wall (White)	78.1	5.5%
Decal (Blue)	11.7	Wall and Text (White)	78.1	147.8%

Table 1 – Sample of Luminance Contrast Results

The majority of surfaces contrasted by more than 30% but there were a few items found that did not to offer acceptable contrast. For example, the existing wall PEI faces offered only 6% contrast with the wall. A dark blue decal faceplate was fitted achieving 148 % luminance contrast (Figures 7 and 8).
Another interesting result was that for fairly bright interior, such as the SMU220, which has white walls and ceilings and light grey carpet, bright yellow handrails that have become popular elsewhere achieved a luminance contrast of only 52% against a white wall. While this result is quite acceptable going by the 30% rule, much better contrast can be achieved with dark colour handrails, hence the dark blue and dark green handrails on QR SMU and IMU rollingstock.

5.3 Car Access and Pathways

5.3.1 Identifying the Access Point

The car access points are clearly distinguished for the visually impaired by bright yellow doors, contrasting with the car side and identified with the international symbol for accessibility.

The transition between the car and the platform is distinguished by a bright yellow strip, which contrasts against the dark gap (Figure 5).

Audible signals guide the visually impaired to the open doorways. An alarm and voice warning message sounds 3 seconds before the doors begin to close (also see 5.4.2 below).

5.3.2 Bridging the Platform Gap

The DSFAPT dictate that wheelchair ramps are provided if the platform to car gap exceeds 40mm horizontally and the step exceeds 5mm vertically. Gaps this small are difficult to achieve on most railway systems but this has been achieved on the PURD EMU through the use of rubber buffers fitted to the doorway tread plates (Figure5) which can contact the platforms without damage. This design has been proven on the 2 car Westrail EMUs. Platforms of consistent height and positioned on sections of tangent track are also critical to keeping the gap within limits. Packing of secondary suspension after each wheel machining is needed to maintain the vertical step within 15mm.

Figure 5 - Westrail EMU doorway with tread buffer strip

Other railways with platforms on curves and of variable height have no alternative but to directly assist passengers board via wheelchair ramps. On board ramps are provided on QR SMUs and IMUs that fold up and are stored in the driver's cabs.

5.3.3 Access Pathways

The main objective of proving good access pathways is to keep the path from the doorway to the allocated spaces free from obstructions and to keep it as short as possible. Older style vestibule handrails protruding from the ceiling have been removed from QR rollingstock and replaced with less obstructive designs and suspended flexible handgrips.

Limitations on allowable vehicle width often make access pathways restricted as shown in Figure 6 but provided at least 800mm is available then this is sufficient for an A80 wheelchair. Figure 6 shows that passengers seated in the fixed longitudinal seats need to move to let people in wheelchairs past and signs to this effect have been placed near these seats.

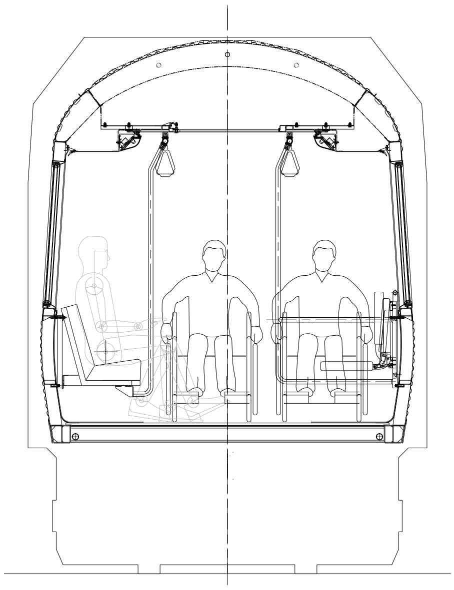

Figure 6 QR SMU / IMU Access Pathway

Contrasting handrails located near doorways and strategically positioned to give guidance for passengers along access paths have been provided. Polished stainless steel handrails popular on older rollingstock have been found not be ideal for visually impaired people because the light is not reflected evenly. All stainless steel handrails removed and powder coated in contrasting dark blue or dark green colours with a non-slip "ripple" finish as part of the QR upgrades.

5.4 On Board Communication for People With Disabilities.

5.4.1 Raised Tactile Controls

Both the QR and PTA rollingstock require passengers to push door buttons to open doors after they have been released (or unlocked) by the driver. This is done to conserve air conditioning power. As part of the QR upgrades an enhanced button design was installed (Figure 7) featuring a raised surface designed specifically for people with reduced use of the hands. The button also includes a visually contrasting bezel and tactile indicator for the visually impaired. Other controls such as PEI buttons, toilet door buttons, etc were also similarly enhanced.

Figure 7 - QR Door Buttons and tactile signage with Braille text

The PURD EMUs feature a raised, soft touch button that has a concave surface and requires very little force to activate. The button surface illuminates brightly when activated. For consistency, the same button as developed for the existing Westrail EMUs has been selected.

5.4.2 Audible and Visual Door Signals

Door Controller enhancements were made on the QR vehicles to drive door button lights and audible alarms to indicate the position and operating state of the side doors for passengers with hearing or vision impairments. There is no standard defining how this facility should operate and the operator set this. The signal states chosen by QR for typical door sequence is shown in Appendix B.

5.4.3 Tactile Braille Signage

The QR IMUs were fitted out with signage which included raised pictograms and text with the message replicated in Braille. Colours were chosen to give much greater than 30% luminance contrast. There were existing products on the market but these were expensive and there were some concerns over their durability in a rollingstock environment. EDI Rail developed a new system for the manufacture of tactile signs in conjunction with a local supplier that also tuned out to be more cost effective.
The use of pictograms assists passengers with low levels of English literacy and a spin off benefit assists overseas visitors and tourists.

5.4.4 Integrated Voice Announcement and Passenger Information Displays (PID)

Both the QR SMU / IMU and PURD designs include automatic recorded voice announcements of the next station also displayed in text on PIDs located at the ends of the saloon for the hearing impaired.
The stopping pattern is pre-programmed and the driver selects the route at the start of the run. The messages are triggered a set distance out from the next station which is determined by counting the distance from the last stop. Global position

system calibration is provided to compensate for wheel diameter setting errors or to allow the system to reboot mid run and re-establish its position on the route.
The driver can also initiate special announcements selected from a pre-programmed list.
A combination of upper and lower case text has been found to be easier to decipher than text comprising all upper case letters. Software upgrades were made on the QR vehicles to eliminate all capital text.

5.4.5 Hearing Aid Loops

Hearing Aid loops have been fitted to QR IMU and some SMU Rollingstock. All PA messages are also transmitted over an inductive audio loop run around the ceiling.
The PURD EMUs include a hearing aid loop running behind the wall linings at window sill level and it is anticipated that this will give good performance by transmitting as close as possible to ear height.

5.5 Accessible Toilet Facilities

The QR IMUs include toilet modules with the following accessibility features that were upgraded in 2001:

- Power operated, 800mm wide door with accessible door controls.
- Contrasting door surround to distinguish the door from the wall.
- Tactile signage and large illuminated occupied sign.
- Fold down handrails that can be lowered to assist paraplegics to lift themselves on to the toilet.
- Toilet Seat contrasting with both the floor and bowl.
- Automatic, hands free washbasin tap and dryer operation.
- Wall level PEI allowing the occupant call for help from the seat.
- Floor level PEI to allow the occupant to call for help in the event that they fell from the seat on to the floor and could not get back up.

Figure 8 - QR IMU Wheelchair Accessible Toilet

6. Design Review Process

Wherever possible the end customer should be involved during the concept design stage to help ensure the design will be functional and meet peoples needs.

During the PURD EMU design phase, milestone reviews were held with the disabled consumer advisory group in two stages. This volunteer group consisted of people with a broad spectrum of disabilities.
Stage 1 comprised a presentation of 3D CAD Interior Walkthrough (Figure 9). Following collation of all feedback by PTA, changes design improvements were made.

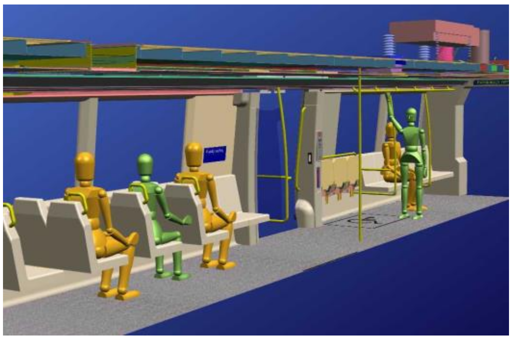

Figure 9 - PURD EMU 3D "walkthrough" presentation screen

Stage 2 comprised a review of a full scale wooden mock up by the same group (Figure 10). The mock up allowed users of several different types of mobility aids to confirm suitable access pathways and manoeuvring space. The door signals were also demonstrated. Following stage 2 a few more refinements were identified before starting the production of detailed manufacturing drawings for the car.

Figure 10 - PURD EMU Interior Mock Up Review

These two processes helped to identify a number issues up front and help to avoid cost and delays associated with changes requests made after the design has been produced.

7. Flexible Design

Flexible interior designs have now been developed by EDI Rail to allow the operator to change the car layout at minimal cost. Such a design has been included in the PURD EMUs as this was contract requirement. The design features seat and handrail mounting rails in the walls and in the ceiling running the entire length of the saloon. Reasons for such a change could be future increases in the patronage by disabled people as infrastructure is improved and made more accessible over time. This design also allows the operator to run different car layouts to match the service requirements of individual lines. For example, a line with a stop at an accessible station near a hospital may warrant the running of trains with more allocated spaces.
Westrail have made a number of changes to layout of their 2 car EMUs since they were introduced in 1993.

8. Other Benefactors of Accessible Design Principals

While not usually the primary motivation, other groups of the general public benefit greatly from accessible public transport designs.
Some examples include:

- Parents with young children in prams.
- People carrying luggage or shopping loads.
- Push bike users who can ride on to the car and stand with their bikes in the allocated wheelchair spaces.
- People with less than average mobility due to fitness or weight issues.

9. Design Limitations and Restrictions

Despite all good intentions there are practical limits to the extent that transport design can cater for all forms and severity of disablement.

Better facilities could be provided if the car bodies could be made wider but this is of course limited by the vehicle outline gauge permitted by infrastructure. Wider cars would give better passing and manoeuvring space (also see Figure 6).

Provision of allocated spaces generally leads to a minor reduction in the number of seated places. This is minimised through the provision of fold down seating that can be used if there are no wheelchairs in the allocated spaces as shown in Table 2.

	Seating Capacity per 3 car set.		
	Original Design	Accessible Design – Allocated spaces in use.	Accessible Design – Allocated spaces unused
IMU120	224	202	217
SMU220	236	212	226
PURD EMU	-	214	242

Table 2 – Seating Capacity Comparison

Positioning of allocated spaces in the vestibule area generally results in the least loss of seating where longitudinal seats are usually installed in any case.

The 25kVA overhead system is not the ideal environment for hearing aid loops as they do pick up background interference. Areas on the car free from propulsion equipment such as main transformers, motor converter modules, etc result in the least interference so these areas were designated as hearing aid zones as designated by the international symbol for deafness. This is usually sufficient in terms of the number of hearing aid dependant passengers who would use the service at any one time.

PID displays are limited to pre-programmed text and the speed of message delivery is slow compared to voice announcements. There is scope in future designs to allow on board staff to key in special announcements but this is not really practical in driver only railways unless the train is stopped. In future designs, it may be possible for a remote control centre to transmit any special messages over the VAS and PIDs.

10. CONCLUSIONS

Providing accessible rolling stock interior design is relatively simple and cost effective when incorporated up front in new designs and offers significant improvements in the ability of people with disabilities to use public transport services with improved independence.

Existing rollingstock can be upgraded to provide enhanced accessibility with minimum down time using the “kit” design approach.
Accessible design principles offer advantages to other members of the public in addition to those with recognised disabilities.

11. ACKNOWLEDGEMENTS

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The contribution of QR’s MRE department in the development of the IMU and SMU designs is acknowledged.

The contribution of the PTA of Western Australia in the development of the PURD EMU design is acknowledged.

12. FOLLOW UP ENQUIRES

Further information on any of the above can be obtained by contacting :
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Appendix A - Layout Drawings

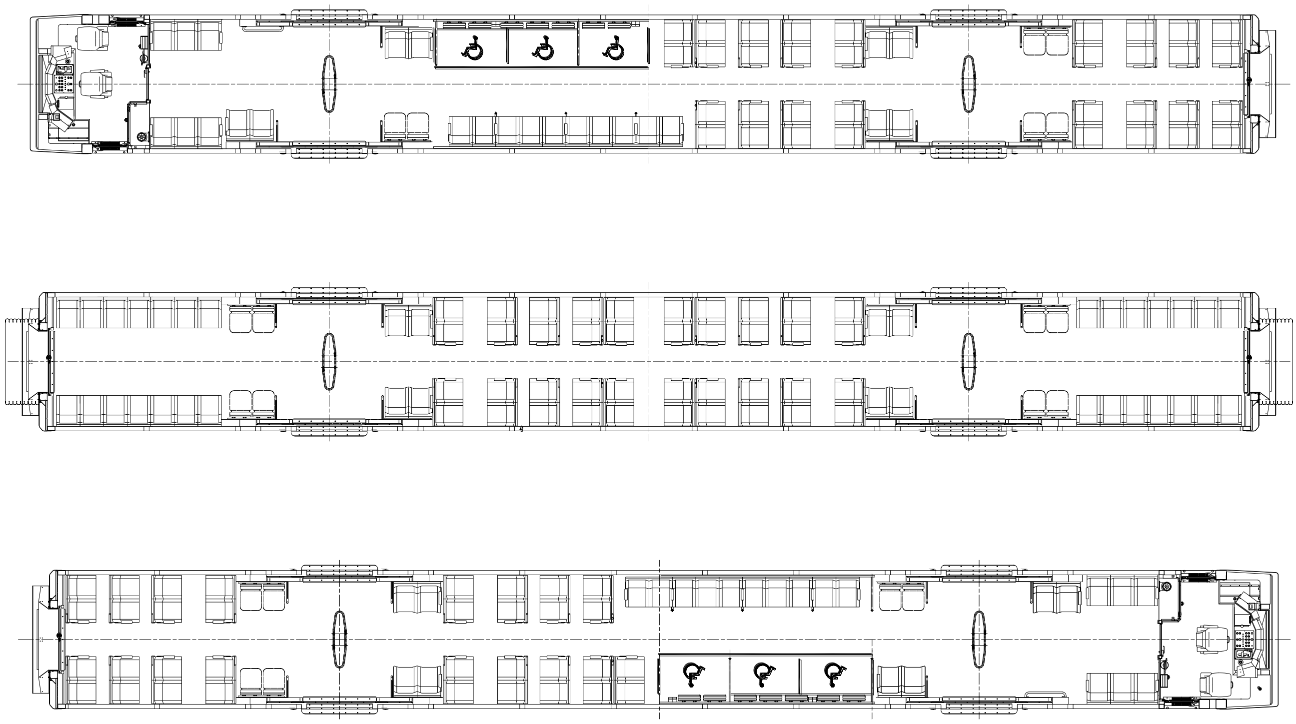

Figure A1 – QR SMU Layout

Appendix A - Layout Drawings

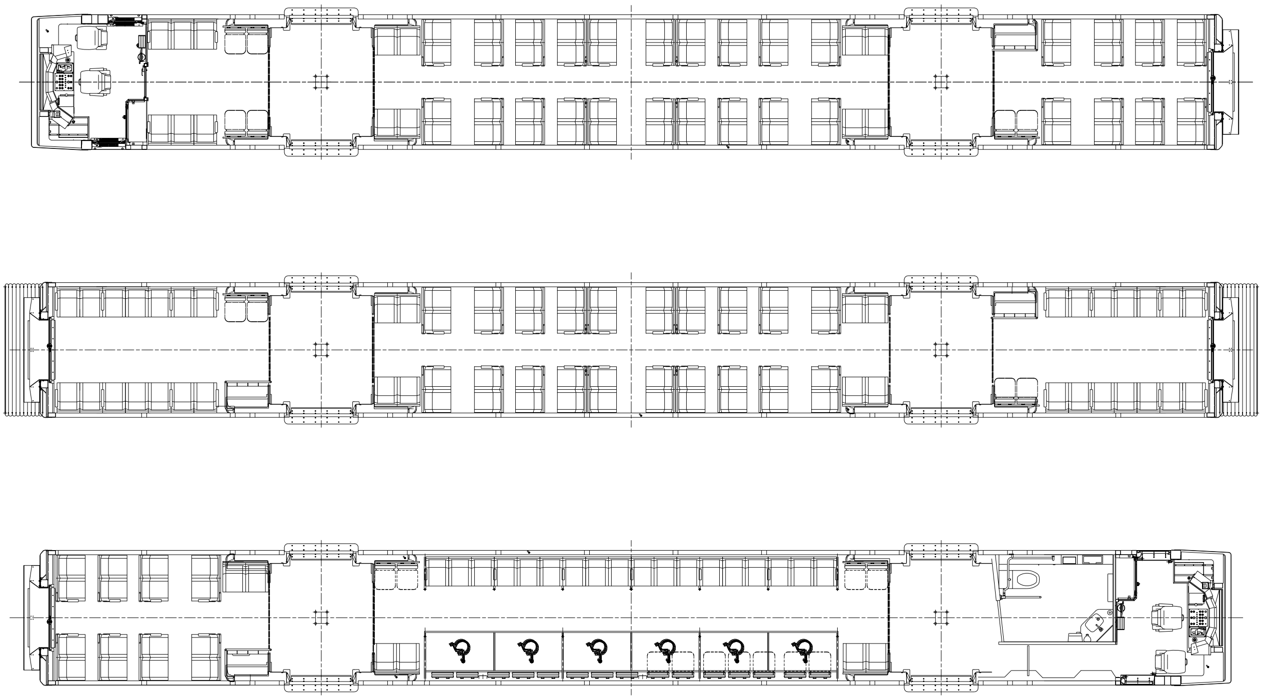

Figure A2 – QR IMU Layout

Appendix A - Layout Drawings

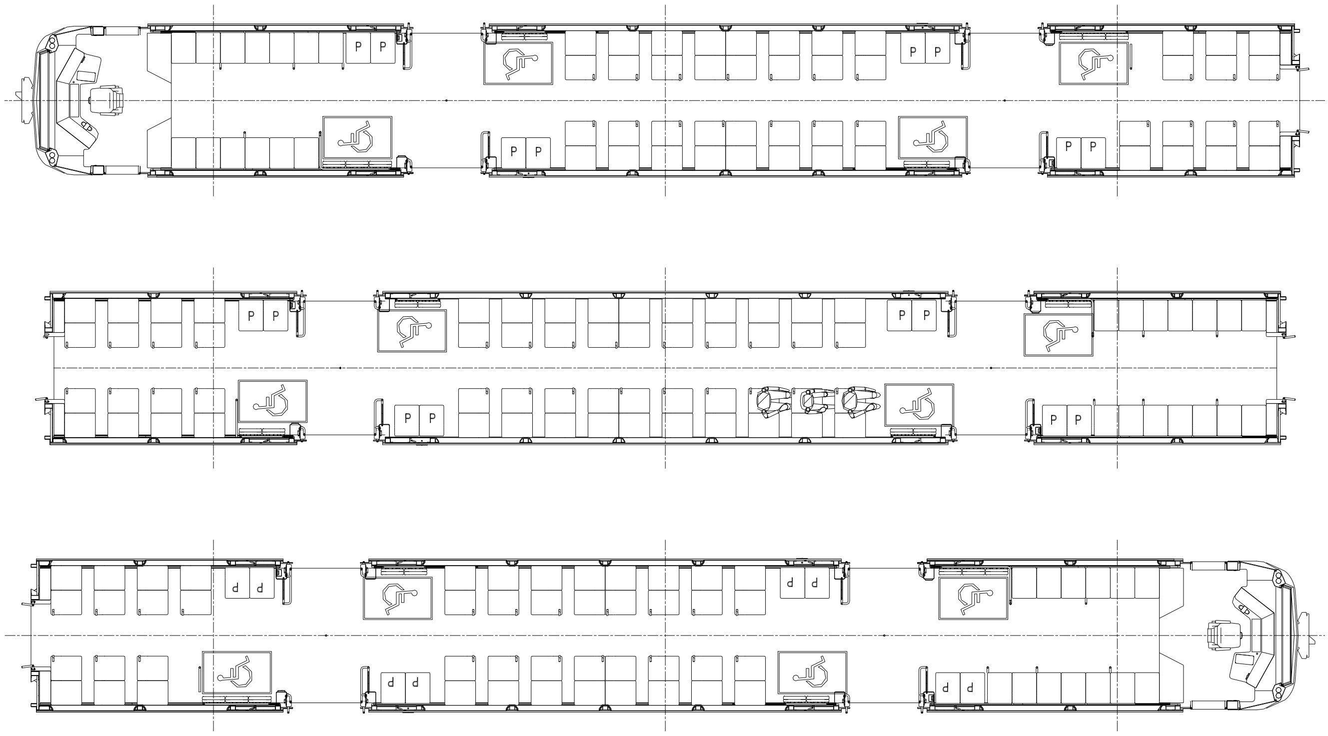

Figure A3 – PURD EMU Layout

Appendix B – Summary of Audible and Visual Door Signal Operation

Passenger Action:- Inside pre-call button pressed
Driver Action:- Doors open button pressed
Driver Action:- Doors close button pressed