

MATANGI – AN EMU FOR WELLINGTON

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SUMMARY

The paper will describe the main achievements of the Matangi rolling stock design process in satisfying several challenging aspects of Wellington's infrastructure. The development of a functional and accessible passenger saloon internal layout through the extensive use of mock-ups in NZ and Korea and through an extensive consultation process involving a wide range of user and special interest groups will be described.

The following key issues were resolved during the Design review process.

1. Kinematic Envelope and optimised rolling stock outline. The vehicle size and configuration was optimised by quantifying the infrastructure constraints of a mixed traffic railway with variable platform heights and 1880's era small, curved tunnels.
2. Large low floor area. The low floor area in the Matangi trailer car is set at 730mm ARL and extends for the full floor area between the bogies which has provided considerably enhanced access.
3. Saloon layout for improved accessibility for all passengers. The internal layout was optimised to provide a mixture of longitudinal and lateral seating, adequate aisle space, priority seating, wheelchair spaces and other user and special interest group requirements.
4. Improved platform to train access. The design process for wheel chair and emergency detrainment ramps will be discussed. These developments were made in parallel with a network-wide programme to improve many platforms however significant differences in platform heights and the need to suit passenger and freight trains remain.
5. Suitable fire performance. The process applied in ensuring the vehicles design is equivalent to BS6853 class 1b with open saloons within a two car set will be described.



Figure 1 : Unit 1 on test at Hyundai-Rotem

1. INTRODUCTION, OBJECTIVES AND PROCESSES

1.1 Introduction

The Matangi EMU's are 2-car train-sets designed and manufactured by Hyundai-Rotem (HR) in South Korea and are being purchased by Greater Wellington Rail Ltd (GWRL), a Council Controlled Organisation (CCO) of Greater Wellington Regional Council, for operation on the Wellington 1600Vdc Electrified Area.

This includes the Johnsonville, Upper Hutt, Melling and Paraparaumu / Waikanae Lines. The GWRL Matangi project team comprises Greater Wellington Regional Council, Halcrow and KiwiRail staff. The Matangi trains will be accredited, operated and maintained under KiwiRail's Operating license.

1.2 Rail industry structure

The NZ railway industry has a vertically integrated KiwiRail as the major network operator with track access available to other users, typically heritage and tourist groups. Some customers own freight wagons and GWRL own several classes of passenger stock.

The NZ Railways Act entails a co-regulatory approach between industry and the Government. Technical and operating standards that form a rail participant's safety system are the responsibility of the rail industry. New Zealand Transport Agency (NZTA) is the Government's rail safety monitoring agency. National Railway System Standards (NRSS) cover minimum standards and inter-operability requirements and are administered by KiwiRail Network (previously ONTRACK).

KiwiRail has its own design, manufacturing and maintenance standards that are continually developed yet trace their origins back to New Zealand Government Railways. These standards blend established local and international requirements as appropriate for the NZ operating environment. KiwiRail must seek guidance from a blend of appropriate sources to support its small, isolated, logistically and technically complex operation. Variations to KiwiRail's Operating License for new vehicle classes are supported by peer review, expert advice, benchmarking and continuous improvement as relevant. For Matangi, Halcrow provided the overall project management and Interfleet supported KiwiRail through the initial design reviews.

1.3 Configuring the train around people

A fundamental starting point for Matangi was the requirement for a train architecture that maximises size and shape within the restrictive

structural gauge and achieves a large amount of low floor. Within this architecture the train layout would maximize seated capacity (low user tolerance to standing), optimize passenger flow into and out of the train and integrate new accessibility requirements to ensure the overall design is inclusive of all likely users. Traditional luggage compartments would now be eliminated and full width crew cabs are required.

A significant amount of 'humanising' was involved in refining the proposed design through mock-up and design reviews to reflect the many crew and passenger interfaces and large variation in size of people. Easy boarding and good human interfaces signify a best practice modern passenger train design.

The train design was required to be compatible with passenger sizes from 5% female through to 95% male and crew sizes from 5% female through to 97.5% male.

1.4 System integration across design interfaces

Scheduling disciplines were used to ensure the correct integration of systems throughout the design review process. A PERT chart was established to guide system integration reviews across the entire train design and a broadly focused 'checking matrix' was used to link associated interfaces. Design submissions provided prematurely were reviewed conditionally subject to other agreed interfaces to maintain the correct phasing of design decisions. The developing train design was reviewed via concurrent design and mock-up processes.

1.5 Consultation

Statutory consultation included operational line managers, operational staff, the Rail and Maritime Transport Union executive (RMTU) and KiwiRail Network. Reviews were early, frequent, highly interactive and conducted in a robust 'no surprises' and very constructive environment with all decision making parties having ownership for later execution stages.

Advice on disability matters was commissioned from Barrier Free Trust (covering all disabilities) and occupational ergonomic advice was engaged as needed. Consultation included direct input from wheelchair users, blind, sight impaired and hearing impaired representation. Cycling groups and Parents networks were also included.

High level consultation around the developing train design included the Ministry of Transport, NZTA, Greater Wellington Regional Council, Transport advocacy groups, District Health Board, Local Mayors and Members of Parliament.

1.6 Design process

Three performance based design review stages consisted of system definition (SDR), preliminary design (PDR) and critical design (CDR) with submissions progressively supported by system assurance work. The initial CAD mock-up presentation (stage 1) occurred immediately after SDR and the majority of the full size mock-up issues were resolved just before PDR close. The longest running CDR and consultation subjects were the wheelchair ramp and train end arrangement, both involved significant human interface issues. Changes from the design and consultation processes were fed back into contract requirements.

1.7 Mock-up reviews

There were four mock-up review stages:

- stage 1 was a digital 3D/solid model CAD presentation;
- stage 2 was a 'flat-panel' knock-down kitset covering cab interior;
- stage 3 was a full-sized timber interior/exterior half carbody replica including 'furniture' and fittings; and
- stage 4 was a replica body shell prototype with FAI components as available.

Mock-up reviews were early to facilitate fast decision making and lead design development. HR retained Transport Design International (TDI) as industrial designers to help develop, present and validate proposals. Carbody design (size, shape, and features) were firmly linked to Mock-up progress and Kinematic Envelope assessments.

Extensive consultation with users included special interest groups, operators, maintainers and reference to KiwiRail design cases. Key mock-up objectives were early engagement and buy-in, involve users in balancing conflicting aspects, experiment and optimise, manage expectations, allow operational demonstrations and safety reviews and validate reviews and studies. Gaining enough exposure to identify problems and agreeing the division of safety mitigations between vehicle design and operational practices were key outcomes.



Figure 2 : Interior of Unit 1 (Trailer Car) at Hyundai-Rotem



Figure 3 : CAD Modeling presentation at an early design review



Figure 4 : Short listing options for the cab desk



Figure 5 : Inside the timber mock-up at Hutt workshops

2. KINEMATIC ENVELOPE AND OPTIMISED ROLLING STOCK OUTLINE

2.1 Suitability for all routes

Johnsonville line includes seven 1880's era tunnels that are small, fitted with overhead electrification, most are curved and several have double curves. These restrictive tunnels have historically dictated only smaller sized vehicles can operate on this line preventing a common EMU fleet. Increasing clearance in these tunnels will allow the new Matangi fleet to operate across the entire Wellington network.

Matangi vehicle sizes were nominally set close to the Ganz-Mavag (Ganz) so they can operate as 'sister classes'. Identical length optimises platform and loop workings and depot interfacing, however Matangi overall profile was uniquely optimised.

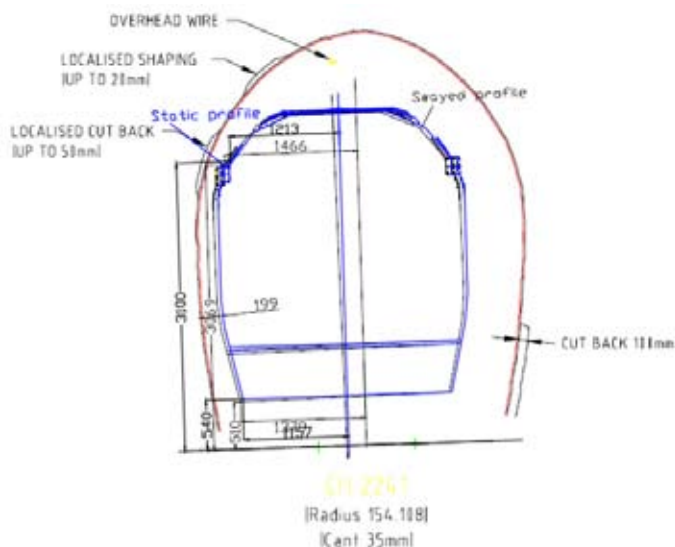


Figure 6 : Profile of Matangi within re-worked Johnsonville tunnel

2.2 Co-ordinating tunnel and vehicle designs

Increases in tunnel clearances were identified from lowering tunnel floors, modifying lower tunnel wall profiles (as needed), re-canting track and re-aligning track. During system definition and before tunnel modification work started, vehicle shape and expected clearances were compared. During vehicle preliminary design 'as-built' tunnel work was compared with the developing train design. Final carbody size and shape was not acknowledged until Vampire Kinematic Envelope (KE) work was validated using final vehicle parameters including suspension already assessed to be safe for wheel articulation over Wellington track geometry. By critical design it was decided modifying lower tunnel wall profiles was not needed.

2.3 Cross-sectional size and shape

Vehicle height and width were optimised against infrastructure interfaces. Vertical packaging of vehicles balanced achieving an acceptable saloon ceiling height with electrical clearance under overhead wire including vehicle bounce, installation of standard pantograph and low profile roof mounted HVAC systems with the necessary floor position above bogies for standard wheels and likely suspension movements. Maximum lateral vehicle shape was optimized through the KE process with particular focus on HVAC and cantrail and waste rail center throws, pantograph and doorway step extension. Physical clearance checks in modified Johnsonville tunnels were conducted with a Ganz class modified to simulate Matangi.

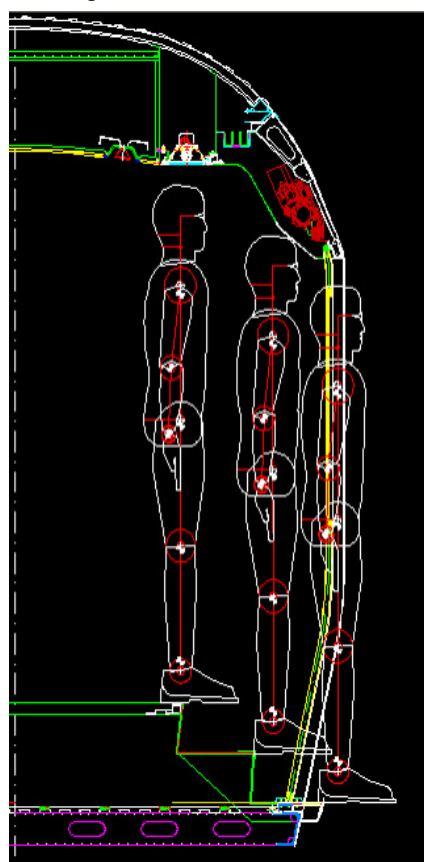


Figure 7 : Optimising the vehicle profile for 97.5% male

2.4 Platform to train gap

Platform clearance improvements, both size and consistency of, is being achieved with a network wide works programme. Clearances must accommodate curved platforms while balancing metro and freight needs with locomotive and wagon bodies that rapidly increase in width around common platform heights. Many stations are being rebuilt, several with all new platforms and many with improved platform edges. Significant differences in platform heights will remain until the modification of all stations can be justified against patronage and funding.

3. LARGE LOW FLOOR AREA

3.1 Demographics driving modern accessible vehicles

The life span of Matangi will see a significantly changed customer demographic. UK studies estimate that in 40 years time the number of people aged 80 will have doubled, and that the number over the age of 60 will have increased by 50%. Additionally up to 20% of the current population has one, or other, form of mobility impairment at any given moment [1]. Increases in the use of public transport by the mobility impaired can be expected from population growth, increasing age profile, a growing focus back towards public transport and the compounding affect of accessibility improvements across transport networks.

3.2 Accessibility is combination of ramp and saloon

The Matangi accessibility solution must combine crossing the platform to vehicle gap and movement and accommodation aspects within the saloon (seating at a priority seat or being secured at wheelchair locations). The solution should be as seamless, unaided and relatively inconspicuous as possible with overall success dependent on each of the final ramp and saloon features being individually successful. It is expected Matangi will create a step change improvement to accessibility for NZ trains. The starting point for good accessibility is establishing the train architecture that provides adequate low floor.

3.3 Low floor requirements

European requirements typified by RVAR (UK) and “The European Technical Specification for Interoperability, People with Reduced Mobility” (TSI-PRM) require priority seating to be at least 10% of total seats. These seats have requirements of increased pitch, space and proximity of hand-holds or grabs for assistance. Two wheelchairs would be required within this low floor given Matangi train-set length.

Matangi low floor and doorway step height was fixed early in the design process as 730mm ARL, slightly above the ‘standard’ platform design allowing for suspension movement and wear. Final transverse location of doorway step edge was individually optimising alongside original and modified platform locations and the higher step on Ganz.

3.4 Longitudinal packaging of train

The requirement to achieve at least 10% priority seating (with increased seat pitch) and two wheelchairs at a low floor height of 730mm dictates the longitudinal packaging of the train. The amount of low floor needed essentially

extends between both bogies (and hence doorways) of one vehicle. To achieve this while still mounting the heavy propulsion and most auxiliary equipment underslung from the carbody, all large equipment except the batteries had to be packaged under the motor car. This configuration ensured conservative or established heavy rail EMU design features avoiding risks of an arrangement untried in NZ.

3.5 Impacts to saloon of low floor

The width of the saloon floor must narrow as it is lowered to reflect the structure gauge requirements for tunnel and platform clearances. This narrow width requires low floor saloon seating to be longitudinal on at least one side of the saloon to preserve an adequate aisle width. The resulting aisle width is larger than that for the high floor benefiting wheelchair movement and providing more space to maneuver cycles avoiding conflict with seated passengers.

Two steps are needed between the motor car doorway step edge and high floor, and, within the trailer car between high and low floor sections due to the larger internal height difference caused by boarding at a lower level. Current EMU classes have only one step starting at a higher doorway step position.



Figure 8 : Finalising the interior layout of motor and trailer cars



Figure 9 : Unit 1 showing step between low and high floor areas on the trailer car

4. SALOON LAYOUT FOR IMPROVED ACCESSIBILITY FOR ALL PASSENGERS

4.1 Seated capacity and space

An objective was to closely match the 148 seated capacity of the existing Ganz sets while improving comfort. Matangi saloon floor area is virtually identical to the Ganz despite the elimination of a dedicated luggage compartment. Matangi cabs must be set back from the ends for crashworthiness and are larger for improved crew environment and to achieve fire ratings. A 5-fold increase in electrical cabinet space must also be accommodated (spread between cab and saloon)

4.2 Seating layout

Seating layout is arranged with predominately lateral or “airline style” seating for greater room and sense of personal space. A re-configurable cantilevered seat concept is used to allow either longitudinal or lateral orientations for alternative future configurations (different bases are needed to change). Seats are cantilevered from the wall and can be adjusted to any seat pitch. Cantilevered seats are a feature that accentuates spaciousness (including under-seat storage), cleanliness and style. The seat pitch adopted is similar to that of the Ganz however knee room is increased by use of slim-line contoured seat backs.

Longitudinal seating by the doors helps funnel passengers away from the boarding area avoiding choke points and helping to fill the trains to practical capacity. This passenger flow is further encouraged by arrays of hand grabs mounted on seats, vertical poles, overhead hangers and luggage shelf edgings to create standing areas or ‘stabilizing’ points. Longitudinal seating also offers locations for groups or families while providing added space for items such as prams. Aisle width allows for two people to pass relatively easily so they are comfortable standing well away from the doors yet remain confident of an easy exit.

Within the same saloon space of the Ganz, capacity was down one seat due to a combination of increased spacing of lateral priority seats and reducing the row of low floor longitudinal seats for comfort. The overall seating capacity for the Matangi is 147 seats, with 76 in the high floor motor car and 71 in the low floor trailer car. The maximum (design) load capacity for the Matangi 2-car set is 377 passengers, assuming all seats full plus 6 persons per square metre of floor space.

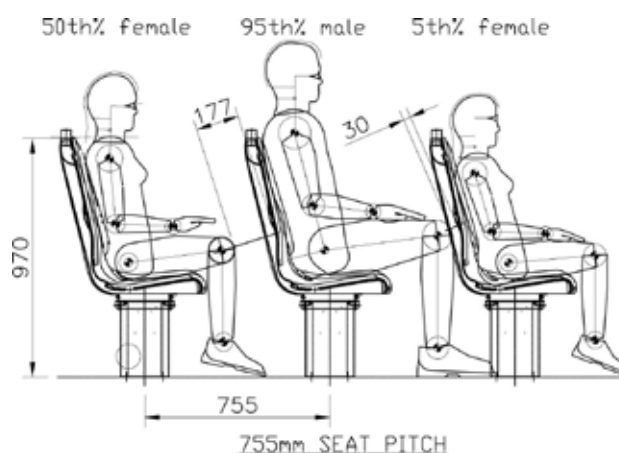


Figure 10 : Drawing showing knee clearance for standard (non priority) seating

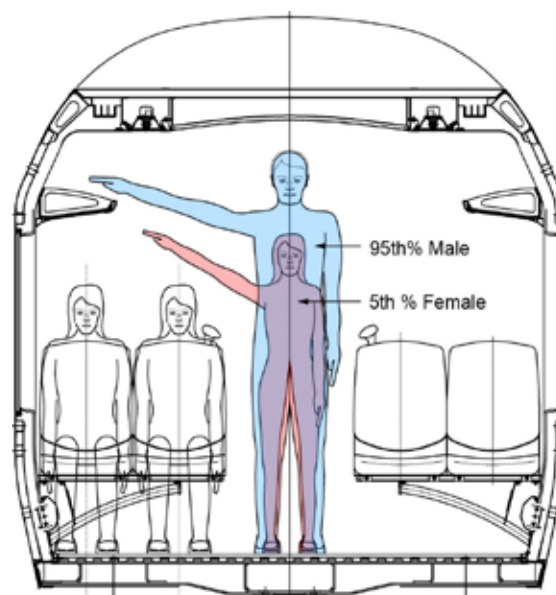


Figure 11 : Drawing of grab points on high floor areas, showing cantilever seating arrangement

4.3 Open gangway and crew movements

An open gangway design is provided between the motor car and the trailer car to allow passenger movement while creating a larger, friendlier atmosphere accentuating the benefits of rail travel. The open gangway will significantly reduce crew injuries associated with access through vehicle end doors and gangways on the existing fleets. The concertina design provides an acoustic and fire barrier. Crew access into the trains will normally be via the passenger doors using the manual emergency door release via an access key however train end doors can also be used.



Figure 12 : Unit 1 showing the wide, open internal gangway

4.4 Multi-functional area

The trailer car low floor saloon forms a multi-functional area to accommodate wheelchairs, priority seats and cycles. Relatively large open-plan doorway areas with low-intrusion draft screens and a wide central aisle maximises ease of use, functionality and ability to avoid conflict between user requirements. Two wheelchair spaces are integrated with adjacent priority seats to aid companions while cycles are segregated to the other end of the area to avoid mobility impaired having to compete with able bodied

people and carry-on objects. Priority seats are colour coded and will have bold signage. The longitudinal seat arrangement in the low floor ensures a wide aisle that allows wheelchairs to move to another (non-ramp) doorway. Overhead luggage shelves are not provided in the multifunction area to encourage the movement of able bodied passengers to other areas of the train. The Matangi trainsets will be orientated with South facing low-floor cars to locate the wheelchair doorway as per the Ganz for predictable platform boarding. Cycles will be carried in the saloon for the first time in Wellington. Cycle options were extensively researched however a simple 'modular' solution using longitudinal 'flip-up' seats and stacking cycles against each other was agreed through consultation. Folding cycles are encouraged for peak services with cantilevered seats offering increasing storage options. Considerable scope exists to carry rigid cycles off-peak and capacity can be increased by replicating this modular solution in future without loss of seats. Consultation determined the current capacity as 3 large cycles when stacked against each other with cyclists taking responsibility for securing and 'un-bundling'. Solutions for restraining wheelchairs and bicycles have been provided.

Wheelchair and cycle accommodation required a large number of 'flip-up' seats however these seats are designed to match fixed seating comfort levels. These seats spring up when un-used to benefit cycle and wheelchair users.

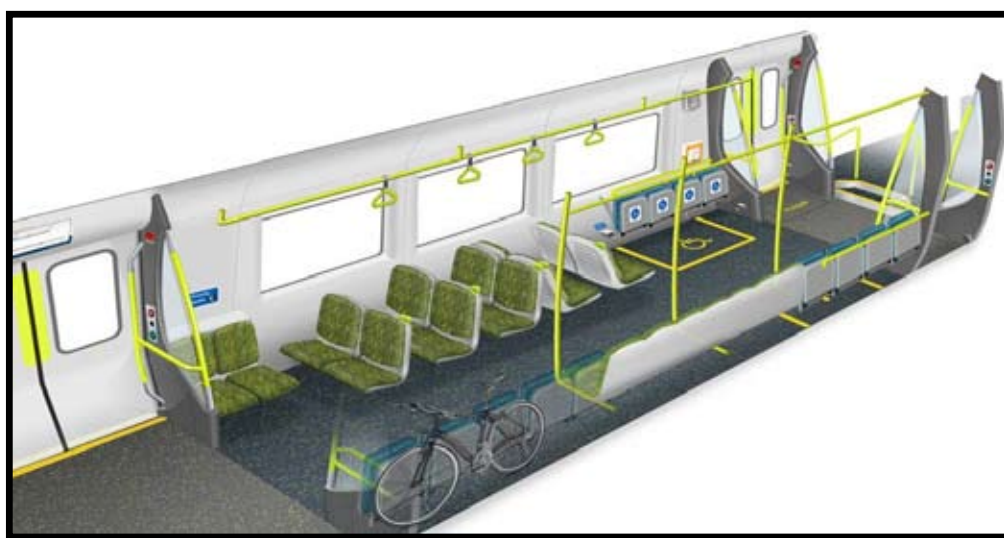


Figure 13 : Concept for trailer car multifunctional area

5. IMPROVED PLATFORM ACCESS

5.1 Wheelchair ramp types

Quickly operated 'metro-style' wheelchair ramps built-into doorways are new to NZ. Extensive

world-wide research was undertaken and each generic ramp type was reviewed at the NZ Mock-up. These ramps consisted of several portable types, a vertically mounted 'fold-down' type, a floor mounted 'flip-over' type and an under floor 'slide-out' or 'cassette' type. Research was

specifically commissioned to compare powered and automated ramps with manual types.



Figure 14 : Mobility scooter trialling wheelchair ramp options on the wooden mock-up

5.2 Floor mounted ramp

A large compound folding 3-panel 'flip-over' type was selected with the future ability to retro-fit a smaller 2-panel powered version if unmodified platforms are addressed. The 'flip-over' type was deemed to have minimal impact on the saloon environment and in the initial large manual form, the necessary length for the current variety of platform heights. The ramp is a novel design, challenging aspects are packaging such a large folding 3-panel type, operational deployment and stowage without crew injury and structural strength and rigidity. Major development issues were ease of use and structural rigidity without deeper components and final doorway trip hazards. The wheelchair ramp will require a level of training and skill.

Ramp length of 1.25m was optimised to allow the ramp inclination to meet AS 3856 guidelines at most platforms. The length is dictated by unmodified platforms however this length readily covers the worst curved platform gaps. The multi-jointed ramp can deploy to a higher platform reducing infrastructure spend and potentially countering air bag failures. Station obstructions affecting deployment of the long ramp were assessed for train stopping points. This ramp is long enough to allow train to train transfers on standard double track spacing though this is a complementary benefit, not a requirement.

Doubling the ramp length from a 0.6m (2-panel) to a 1.25m (3-panel) proposal reduced the slope allowing the following accessibility improvements:

- platforms that a unassisted wheelchair can use (better than 1:8) rose from 13% to 55%;
- those that a wheelchair needing some assistance could use (better than 1:4) rose from 32% to 45%; and

- no platforms have a ramp angle 'too steep' (previously 55% were).

A small percentage of platforms are currently not available to wheelchairs at all.



Figure 15 : Smaller powered wheelchair on the timber mock-up

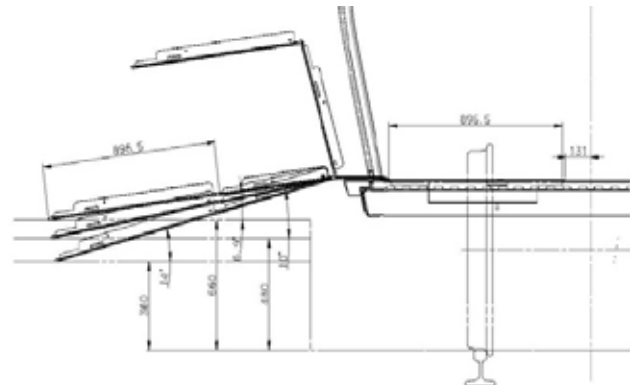


Figure 16 : Deployment sequence of 3 panel wheelchair ramp

5.3 Alternative ramps

Portable ramps were deemed slower and more difficult. Fold-down types of the required length impacted the saloon visually, would reduce seat capacity, introduced obstructions to the wheelchair path in this relatively narrow low floor area and are unlikely to be offered in powered versions in future for fast cycle times. Slide-out types can be powered, had the least impact on the saloon but had higher vehicle integration costs and as they would not work with level or higher platforms, had higher infrastructure interfacing costs. It was also expected packaging a folding slide-out ramp for the length we initially need would increase the low floor height (and hence boarding step).

5.4 Train end access and de-trainment ramp

Train end doors are required to allow crew to move between the 2-car sets and enable detrainment via a detrainment ramp in the event of an emergency in a single track tunnel. These doors are taller and wider than on the Ganz while being slightly offset laterally to increase driver station space and improve sightlines.

A high capacity de-trainment ramp was required in anticipation of the need to improve evacuation times as each train-set contains a combined open saloon compartment. A development of an existing Korean train ramp was created that was adapted for Matangi's central doorway. The central door required the ramp to be stowed in a moveable cabinet and utilize gravity deployment, both aspects dictated by the need to compactly package the ramp to enable stowage away from the train end door for unobstructed everyday crew movements, yet easy deployment to the open doorway for use. The ramp is rotated around a pivot post for stowage and deployment once the end door has been opened. Deployment from first hand contact with the end door to ramp contacting rail level is around 8 seconds. Emergency cab access can be obtained from the saloon via an emergency door handle with breakable cover.

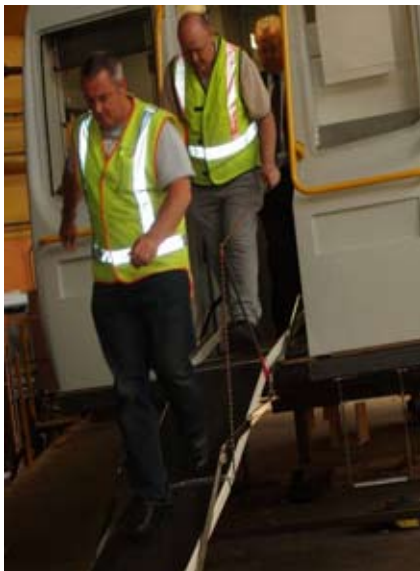


Figure 17 : Testing the de-trainment ramp on the wooden mock-up

6. SUITABLE FIRE PERFORMANCE

6.1 International framework

BS6853 was used as the design management framework to assess fire engineering measures and associated systems. BS6853 is a comprehensive and holistic standard that takes the form of guidance and recommendations, however allowance is also made for the use of

additional evidence to demonstrate an acceptable level of safety when numerical or design guidance is not achieved directly. The operating environment for Matangi has been determined as BS6853 Category 1b, being at the lower (closer to 2 than 1a) end of this Category as characterised by the short to moderate duration of tunnel journey times.

6.2 Additional measures

Matangi contains three main variances to design/numerical requirements which have required a bespoke consideration under this standard. Open saloon gangways (creating single extended saloon compartment), use of seating assessed to French NF standards and the need to consider in detail saloon and cab electrical cabinets. Expert advice was used to review the developing product via design and testing approaches.

The single extended saloon compartment required appropriate hazard analysis and particular attention to control of possible ignition sources and use of materials with high fire performance. In principle the absence of a place of relative safety on-board was deemed acceptable provided the potential for fire development on the vehicle is controlled [2]. By requiring extra evidence, BS6853 therefore created a robust framework under which the single extended compartment design was assessed.

6.3 Detailed assessment

Detailed review for fire issues covered ignition sources, risk of fire development, hazards if a fire develops, ability of vehicle to continue to a place of safety, crew ability to manage hazards and ultimately speedy evacuation. Fundamental aspects of the vehicle fire performance are designated floor, cab bulkhead and gangway concertina fire barriers.

Considerable assessment was made of the equivalence of seat standards. The seats require testing to demonstrate complete equivalence, this testing requirement increased to validate fire hardened coverings needed for the final choice of seat foam which provided more comfort to the seat cushions.

Cab electrical cabinets needed special consideration as they were open to the cab ceiling cavity resulting in a large containment (and therefore oxygen) volume. Here considerable secondary containment existed, material types and distribution were acceptable and the cab-saloon partitions including ceiling void were deemed good containment. Saloon electrical cabinets were deemed acceptable because of material type and distribution together with local containment, though the cabinets themselves are not fire containments.

Detailed assessment of the following was undertaken: the HVAC system (insulation, electrical systems, refrigerant, and containment of control panel and smoke detection), floor fire barrier and testing of and cab-saloon bulkhead fire barrier and testing of. The following had straight forward assessments: Doors, Interior panelling, Battery including containment, propulsion packages including containment, Gangway, doors, windows, and evacuation. Non-conforming items managed were driver seats, suspension rubbers, coupler rubbers, door nosing rubbers and windscreen anti-spall layers.

Human interfaces include a Public Address system (with hearing loops in both cars), passenger to crew communication points and passenger information systems. All doors have emergency over-rides and emergency lighting and evacuation ramps are fitted. CCTV is fitted. Portable extinguishers are fitted in each cab and saloon. Smoke detectors are fitted in the saloons, cabs and HVAC units which will automatically shut down the HVAC system and alert crew. Brake system allows the driver to suppress an emergency brake application requested by passengers to avoid a train on fire stopping in a tunnel.

Ignition sources are reduced by no smoking and no rubbish bin policies, clear floors from cantilevered seats, easily cleaned interior, relatively open seat and draft screen designs and visibility through overhead luggage shelves.

7. REFERENCES

- [1] Interfleet report "Matangi Wheelchair Ramp Study" ILTR-T23648-001 by Mike Evans
- [2] GJD Fire Ltd correspondence by Gary Duggan.