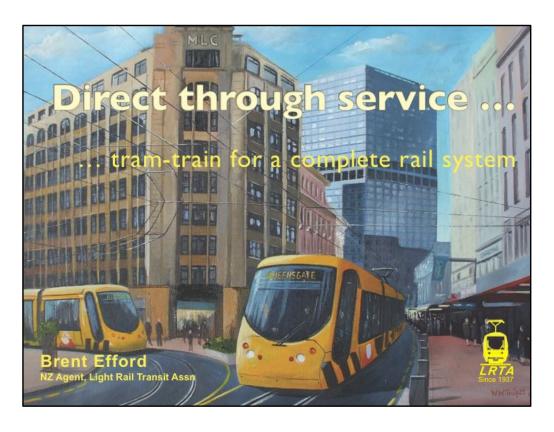
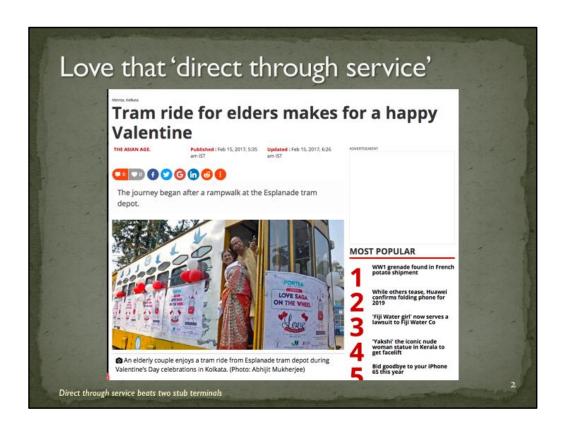
The content, ideas and opinions expressed in this presentation and notes are those of the Author alone. They should not be considered as necessarily representing the views of either the Railway Technical Society of Australasia (RTSA) or of its parent bodies, Engineers Australia and Engineering New Zealand.



[Intro comments] Note that:

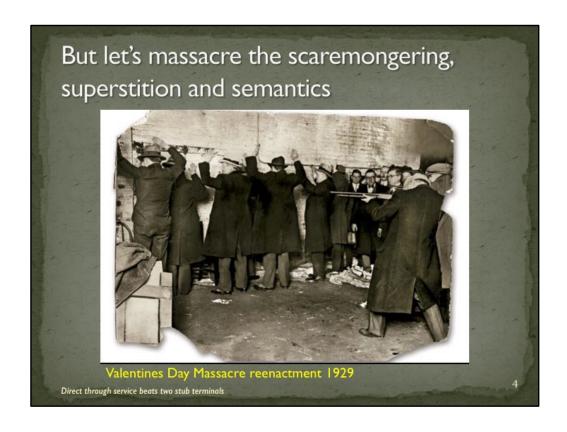
- Wellington PT use is not high by best world standards
- 75% of the half-million residents in the region live in the rail catchment north of the CBD
- Wellington is one of the few regions with a rail transit spine stopping at the edge of its CBD
- Improvements like better bus services and new trains add only a few percent to PT
- World experience is quite unequivocal: a continuous rail spine is absolutely essential to make real shifts from cars and continuous motorways to PT.



Given the date, I searched Google for a Valentines Day theme for this presentation. A bit hard to do, perhaps ...



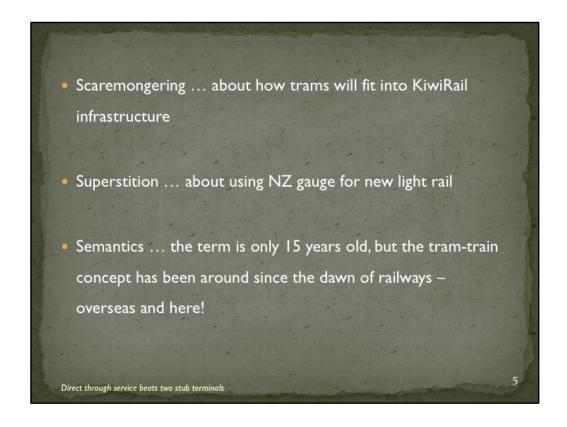
... although the Christchurch Tramway restaurant sees a fair bit of romance ...



... but Simon Wood urged me to concentrate on tram-train.

The slightly skeptical tone of Simon's email to me showed how tram-train has been surrounded by scaremongering, superstition and semantics in recent years.

Even though it was a feature of the world's very first rail transit line. Even though it was planned for Wellington 140 years ago, and even though our current Metlink operations strongly resemble tram-train on the mainline.

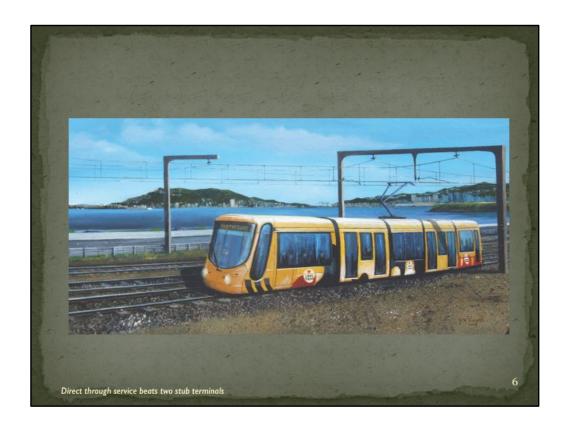


Scaremongering – about allowing light rail onto heavy rail tracks is rife, even though it is just a matter for the more distant future.

Actually, the difference between the operation of the Matangis and the likely operation of tram-trains is minor, and when tram-train does happen automation will have changed the paradigm completely. Our only duty at the moment is to allow that to evolve.

Superstition – a belief system unsupported by objective evidence – is behind the meme that standard gauge, not our 1067 mm gauge, is so advantageous for light rail that it is virtually essential even at the cost of future options.

Semantics – just because the term was invented as recently as 2004 (why so recently for such a simple and obvious term I do not know) should not obscure the fact that the integration of railway and tramway has been around since the dawn of the railway age.



The Wallace Trickett painting of a tram-train in Lambton Quay, which I commissioned and own, is quite well known and has been used often in the Dominion Post.

Not so well known is its twin showing the same tram-train speeding along the harbourside bound for Queensgate. All that is more than artists licence – it is exactly what was planned in the 1999 Regional Land Transport Strategy, and was proposed for completion this year.

And, although it may be too late, it is worth reviving the concept for Auckland, too, as a solution to some specific rail transit problems.



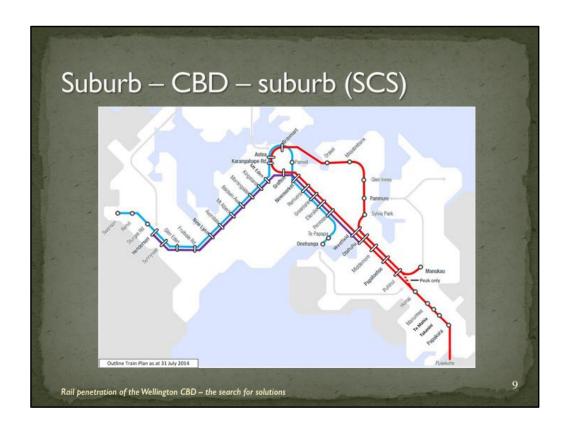
Wellington is particularly well suited to a continuous rail spine.

Integrating a street tramway with the railway north of Wellington Railway Station has been proposed and studied quite often since 1878.



It is a truism universally recognized in the public transport world that a stub terminal at the edge of the CBD is the very worst configuration for transit service. It kills both capacity and patronage, reduces overall service speed and greatly handicaps public transport in competition with the private car.

Yet that is what we have in Wellington, one of the very few cities in the world to be so handicapped. Transit systems in cities like Los Angeles and Auckland still with CBD stub terminals are working at a cost of billions to eliminate them wherever geographically possible.



Achieving SCS service with only brief dwells at city centre stops is designed into the Auckland City Rail Link – and the capacity and patronage leap that will flow from it was its prime justification.

Note how no services will terminate within the CBD when the underground link is in operation.

It may cost billions but it is the only sensible way to go.

Support Zero Carbon 2050 Conserve and improve the value of investments already made (e.g. the 92% complete rail network.) Preserve and enhance options for future generations One integrated rail PT spine for the whole region Influence the modal split: from road to electric rail Reduce impediments to PT use Maximise access and convenience Establish SCS (suburb > CBD > suburb) service – at last! Stage the implementation over years – and keep it 'light' Anticipate and facilitate automatic operation after 2045.

Although Metlink and its governing politicians would like us to think we have a near-perfect rail transit system here, in fact there is a lot wrong with it – more than just catenary that sags in hot weather. In total we need some serious investment – investment which must service these objectives. If it can't do this it isn't worth doing. "Not a winner" as Dr Watson has said.

Number 1 is first for a reason: if the world doesn't get on top of climate change quickly, the Wellington CBD, Kilbirnie, the Hutt Valley and the Kapiti Coast may be under two metres or more of seawater in less than 100 years, and all the other objectives will be unachievable.

So light rail leading to tram-train is an investment in optimism.

Any infrastructure investment anywhere must build towards a zero carbon future, and we can confidently say that electric rail will do just that. But only if it covers the whole region.

away!				
Vehicle type	Matangi	Tram - 100% LF	Tram-train 1	Tram-train 2
Date	Current	2025	2035	2050+
Range (ultimate)	WRS – Waikanae, Upper Hutt	WIA – J'ville	WIA – Plimmerton, Lower Hutt	WIA - Palm Nth, Masterton
Service speed	100 km/h	70 km/h	100 km/h	130 km/h
Width	2.7 m	2.7 m	2.7 m	2.7 m
Length	<mark>42 m</mark>	42+ m	42+ m	?
Electrification	1500 VDC	<mark>1500</mark> VDC/battery	1500 VDC/ battery	1500 VDC or 25 kV AC/H2
Control	Manual	Manual	ATO	ATO
Notes		Trams continue to serve J'ville south & waterfront after 2045		

Introducing light rail and then tram-train will be a staged process, and it is safe to assume that automatic train operation of both freight trains and in-street trams will be commonplace when the Matangis retire. That will further lower the barriers to integrated rail operation – it is the apparent frailty of rail operation by human beings that makes tram-train so frightening to some.

The ethical duty of the current generation of decision-makers and engineers, who will likely be retired by the time tram-train actually happens, is simple: don't restrict the options available to the next generation by, for example, building a gauge-incompatible light rail system downtown.

The areas of commonality between Matangis and theoretical future tram-train is highlighted in this table. I could have added more – number of units per train, for example.

But I could also note that tram-trains, being trams at heart, are lighter than EMUs, use less energy, accelerate and brake faster and, with low-floor level boarding through many doors, will have shorter dwell times per stop.

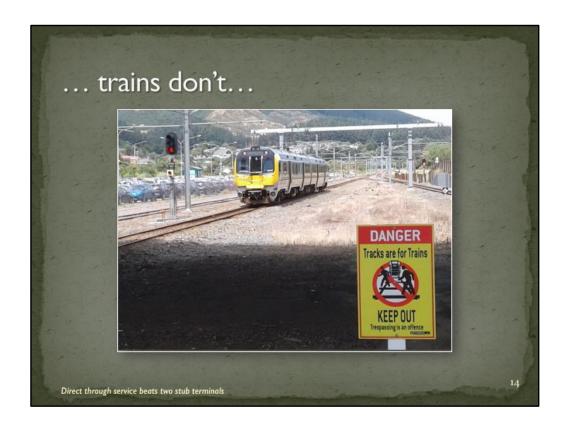


A visitor from Karlsruhe, Kassel, Mulhouse, Sheffield or a dozen other cities could well conclude that we have tram-train already if looking only at the mainline, so similar is the Matangi operation to those tram-trains.

The giveaway is that Matangi units have only two separate car bodies, whereas trams of the same length would have five, articulated. Articulation makes the tram, and tram-train, more expensive but far more versatile.



This versatility means trams can share any urban environment where a right of way with a less than 10% slope can be arranged. They routinely go where either buses or heavy rail would be unacceptable.



Trains definitely don't. Tracks are for trains, and that is the end of the matter.

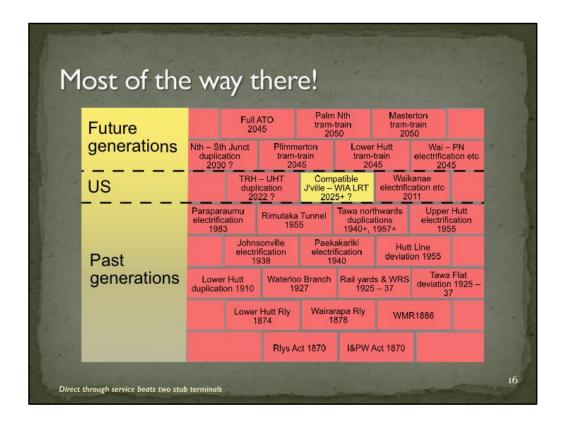
That gives heavy rail the advantage of potential speed and huge capacity, but the need for exclusivity means that extension through urban areas –'rail penetration of the CBD' – requires hugely expensive subways, such as is now being built in Auckland.

That is fine for a big city growing towards two million plus, but problematic for middling regions like Wellington, unlikely to ever exceed 750,000.



So what about a tram, already on rails, that can share the rails used by trains?

That simple concept has been around and used for so long that it is truly bizzare that it took so long for the term itself to be invented.



We have got to this situation as the result of several generations of capital investment, each generation building on the legacy of the previous. We are most of the way there.

Rail infrastructure already covers 92% of the regional transport corridor that needs it.

Doesn't that suggest that we should be augmenting and extending what has already been built, with an integrated rail network? Shouldn't we leave the greatest freedom of choice to the future generations who will have to consider how to replace the Matangis?

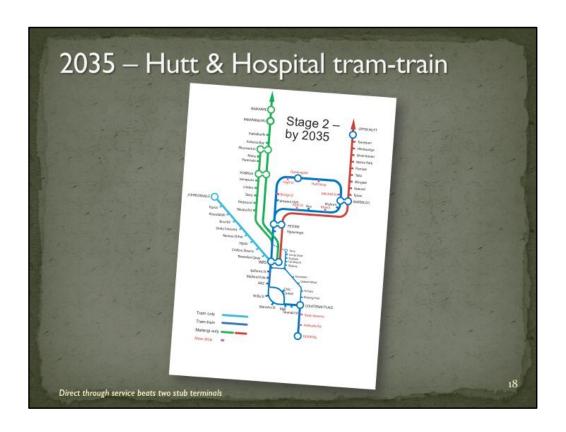
All we need to do right now is ensure that new infrastructure for light rail is built to be compatible with the infrastructure that has been expanding here for 145 years.



The initial stage, just to get started, would involve both a Golden Mile main route and a waterfront tramway for CBD circulation and the long-considered conversion of the Johnsonville Line – releasing Matangis for more capacity on the other lines.

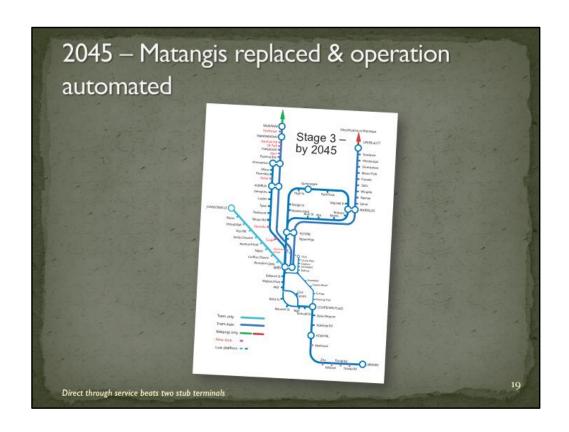
This would involve reconstructing platforms 1 and 2 to align with the end of Lambton Quay.

The only interface with heavy rail at that stage would be non-revenue tram access to the Thorndon EMU depot.



The next stage would involve the installation of automatic train protection, the construction of the light rail line through central Lower Hutt and the introduction of the first tram-trains as illustrated in the paintings.

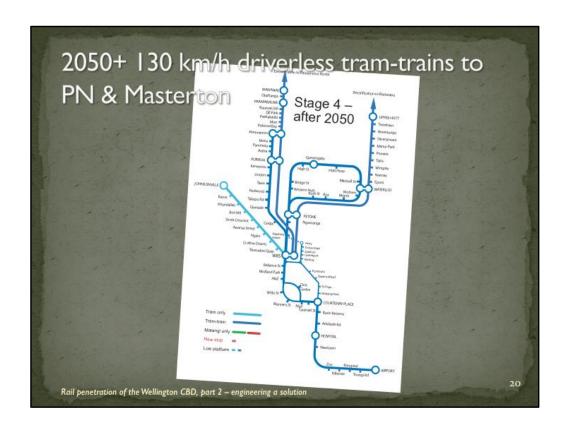
If it hasn't already happened, extension south to the Regional Hospital would also take place within this period.



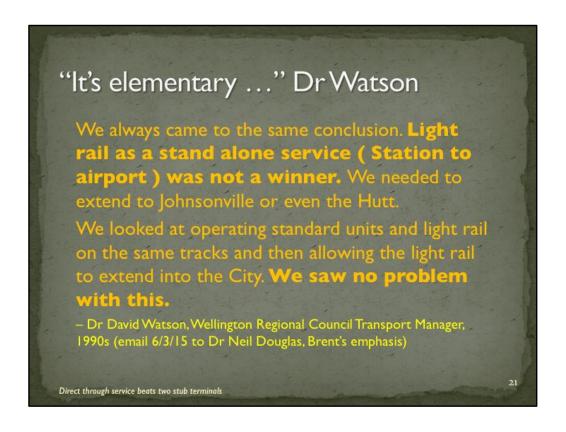
The big changes in the Stage 3 scenario are extension to Wellington International Airport via Mt Albert and runway tunnels, replacement of the life-expired Matangis by driverless tram-trains and the adjustment of the remaining station platforms for low-floor level boarding.

Express operation from the outer region and the addition of more stops is also probable.

Also quite possible is tram-only extension to places like Miramar and Island Bay, not shown here.

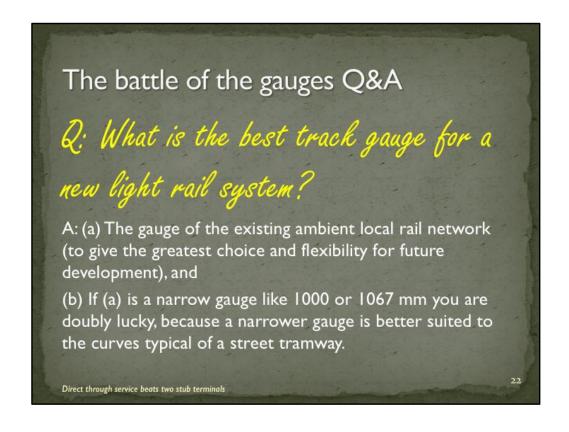


And finally, it is probable that automated tram-trains running up to 130 km/h could take over as far afield as Palmerston North and Masterton, replicating the sort of interurban electric railway service seen in America 100 years ago.



Gauge compatibility and eventual light and heavy rail integration of the Wellington network has been the standard assumption from the earliest days and was particularly strong in the 1990s. It was even explicit in the 1993 Waterfront Tramway proposal put together by Neil Douglas.

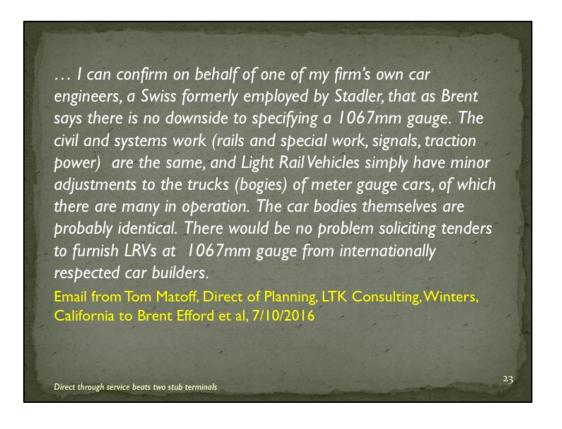
Former Regional Council transport manager Dr David Watson, who supervised many of those studies, put it like this, in an email to Dr Douglas.



It is apparent in Auckland, and you also heard it in the previous lunchtime presentation, that there is a hankering for standard gauge for new light rail construction.

This of course would rule out tram-train, which may be the reason – a dubious desire to limit options for the future on the basis of a current superstition.

In fact, there are big advantages to our gauge in an environment where sharp curves are required, which is why it has been the NZ 'standard' since 1870.



The idea that standard gauge trams are churned out cheaply while narrow gauge is an odd special order so humungously expensive that the cost would outweigh the benefits of an integrated rail system, is persistent in NZ.

This comment from my friend Tom Matoff, of LTK Consulting in California, one of the most experienced light rail experts in the US, is revealing.

I'm sure that CAF, suppliers of Auckland's EMU fleet, who routinely supply trams for gauges from Lisbon's 900 mm to the Iberian broad gauge of 1668 mm of the Cadiz tram-train line, would concur. And it is worth noting that recent car orders for metregauge systems in Europe have had a per-car cost no more, and in some cases less, than would be expected for standard gauge trams.

In 2013, incidentally, Tom did a pro-bono report for us on light rail from Johnsonville to Courtenay Place, a far more expert document than was being produced for the Public Transport Spine Study here at the same time.

Tram-train implementation challenges Signaling: ATP is essential – ETCS I likely to be implemented well before t-t anyway. Platform height: low-floor and level boarding is already the norm for light rail and must be achieved for every station on the system. A substantial cost item; can be achieved by track raising, platform lowering, split platforms or building new low platforms.

We can be confident that track gauge is not an issue impeding light rail and tramtrain, but it is clear from conversations with railway people that there is still a great fear of trams getting onto KiwiRail metals.

Well, don't panic! Except for the very youngest of you, implementing tram-train will never be an issue.

But for the future engineers there will undoubtedly be some challenges. However, with light rail already running through the Railway Station and sharing the EMU depot well before the Matangis retire, those challenges will be surmountable and solved incrementally.

(Ad lib from the slide.)



The productivity, convenience and social equity advantages of this ease of roll-on, roll-off boarding are so great that it is worth spending many millions to ensure that the low-level platforms match the car floors.

No fold-out ramps or staff involvement here, or indeed anywhere on light rail in the UK. People on wheels, whether pensioners or toddlers, board as quickly as the fleet of foot.

- Operational issues: tram-trains will operate similar to Matangi performance parameters or better, in trains of 1 or 2 units (or 3 or 4 if split at WRS).
- Regulation: a constantly changing environment, anyway.
- Automation: by 2045, driverless operation will be well-established, if not the norm, for many transport modes, with rail leading the way. Direct through service, not two stub terminals, will be particularly productive with automation!

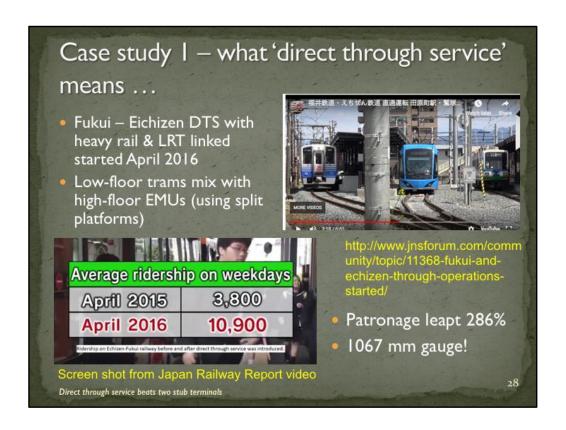
Direct through service beats two stub terminals

26

The taxonomy of tram-train A. Tram-Trains run on the tram tracks in mixed operation with conventional trams and on the heavy rail track in mixed operation with conventional heavy rail trains. B. describes a system in cities without an existing tramnetwork. Therefore the Tram-Trains do not run in mixed-operation with trams on the center city network C. includes other systems, for example if the Tram-Train has its own exclusive tracks in the city center or the regional area

A 2012 academic paper by Naegeli, Weidmann and Nash, attached to the website version of this presentation, attempts a categorization of tram-train systems. – A, B and C.

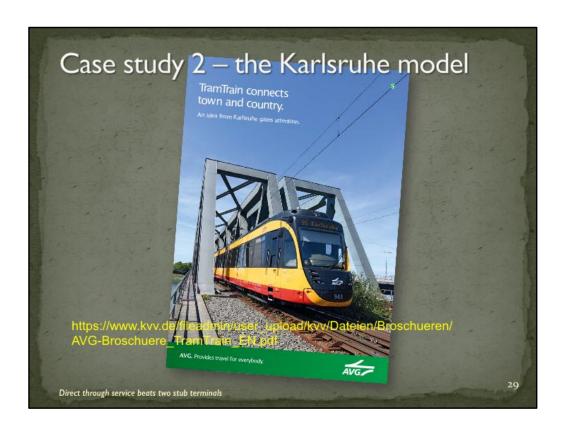
By these definitions, Wellington would be a Type A system, since a tramway to Johnsonville and through the CBD would already be established before tram-train as such came to pass. By contrast, the 1990 plan for Auckland energetically promoted by the then Railways Corporation would have been Type B.



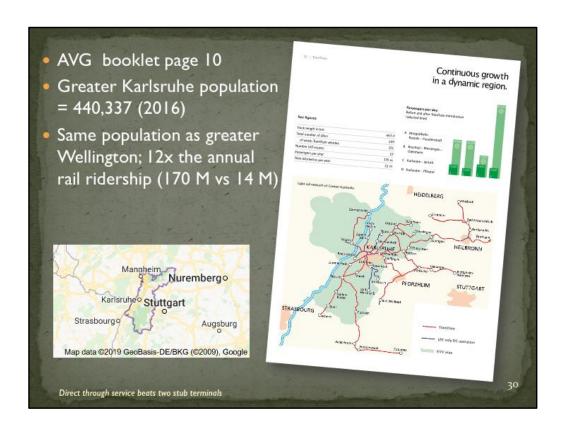
Let's have a look at two tram-train operations – one small and recent, one large and pioneering but both with special lessons for future politicians, planners and engineers.

The phrase 'direct through service' puts the concept so elegantly. It is a translation of the slogan which launched a new service in Japan only about three years ago.

It resulted in a near-tripling of patronage from a relatively simple connection of two formerly separate operations — a suburban railway end on to a tramway. It illustrates the advantage in building your tramway to the ambient railway gauge, even if the integration of the two systems isn't immediately intended —

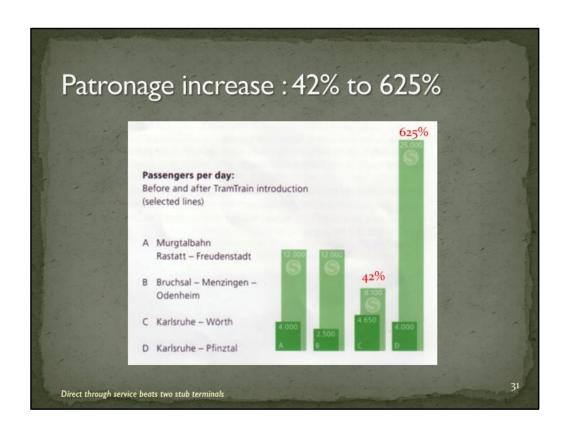


At the other end of the spectrum, the Karlsruhe Model, as it is widely known in the railway world, has been developing since 1992, and is well covered in the PDF booklet linked in the notice for this meeting.



One factoid not given in the booklet is greater Karlsruhe's population, which Google confirms is breathtakingly close to Greater Welington's, minus the Wairarapa. And yet look at their rail system ridership – 12 times ours!

As the map indicates, there are many rail corridors linking into central Karlsruhe, versus our single one nibbling at the edge of the CBD. That, cultural, and other factors, will explain much of the disparity ...



... but the introduction of tram-train has also played an enormous part on the lines affected.



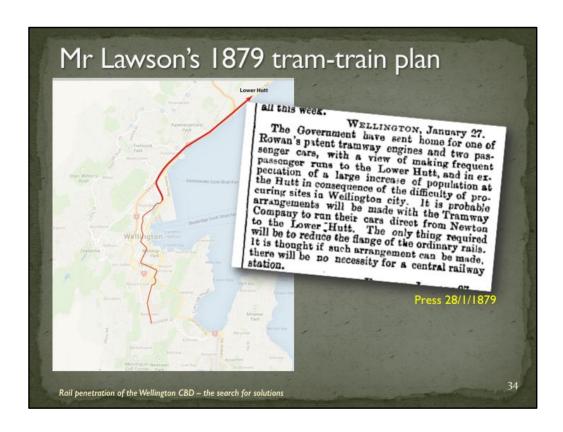
A point also to note is that tram-train operation under railway rules only applies on key lines, always double track, shared with heavy rail services.

On lines used only by trams (be they tram-trains or city trams) then light rail rules and operating procedures apply. This is made clear on the map. This would be expected here if, say, the Johnsonville Line was converted to light rail.



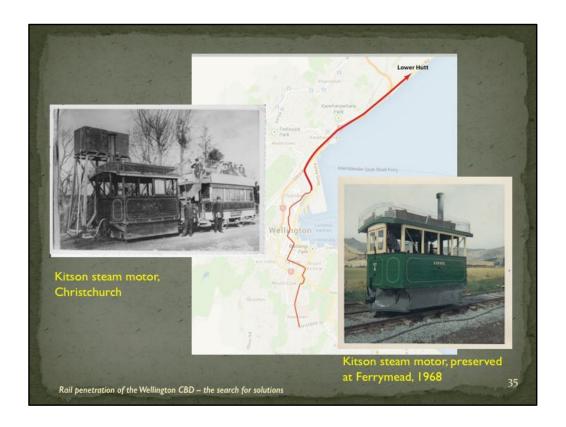
Tram-train goes back a long way. The very first urban rail transit line in the world, the New York and Harlem Railroad in 1832 started as a horse-drawn street tramway in lower Manhattan and became an orthodox steam railway further north.

In the interurban era of the early 20th century it was common for mainline steam railroads, interurban electric railways and streetcar lines to be connected and share trackage, particularly for freight. California, Chicago and many localities in the mid-West hosted such operations, some of which survive as diesel shortlines today.



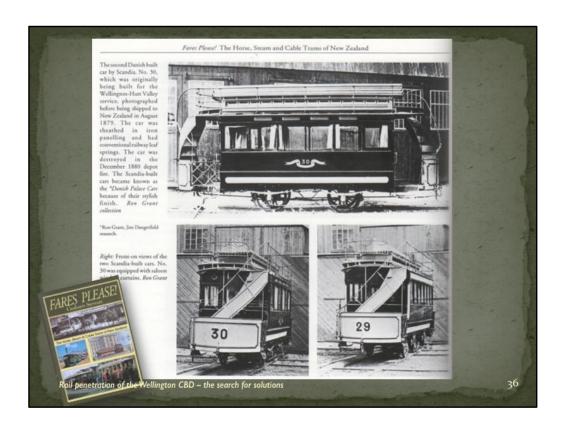
The tram-train concept got off to an early start in New Zealand, too.

In 1879, the Commissioner for the North Island railways, Mr Lawson, ordered a steam tram locomotive and two double deck carriages, intended for a direct service between Newtown and Lower Hutt. Using both the street trackage and the main line railway, it would have been a true steam tram-train.



Called a 'Rowan engine', the locomotive was the first steam tram engine produced by Kitson of Leeds, England. It was the prototype for the steam trams manufactured soon after for the Christchurch tramways. One survives at Ferrymead.

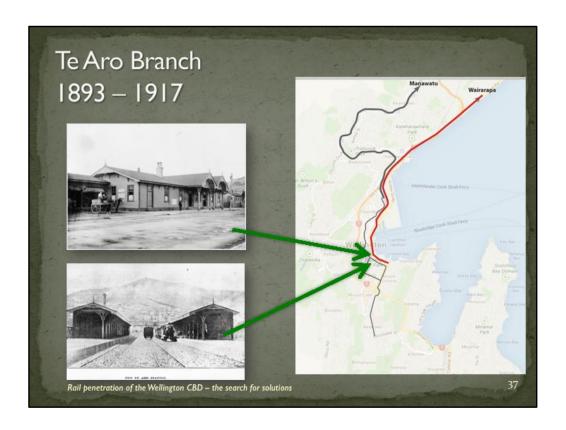
I regularly drove it there in the 1970s and can vouch for its unsuitability for travel over any distance. The top speed was only about 13 km/h. Even by the languid speed standards of the Vogel era, taking almost an hour just to skirt Wellington Harbour would have been quite unacceptable.



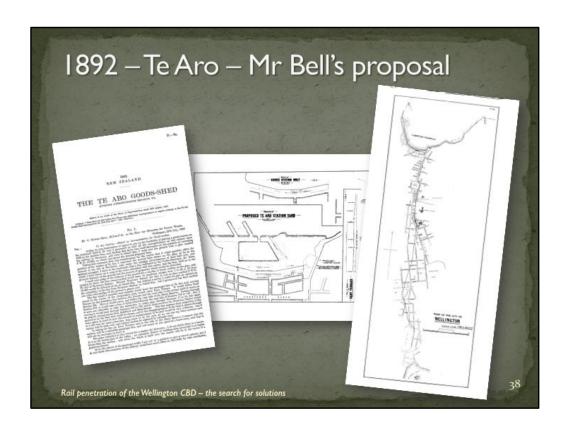
Even more bizarre in concept were the two double-deck trailers built in Denmark. Conceivably it could have been a leisurely and scenic way to view the harbour – on a good day!

For whatever reason, this steam era tram-train service never happened. The Kitson steam engine and the double-deck cars ended up in Dunedin to start tram services there.

Wellington Tramway Company Merryweather steam engines were tried out on the Hutt railway in the early 1880s but with no lasting outcome. They were replaced by horse trams in 1882.

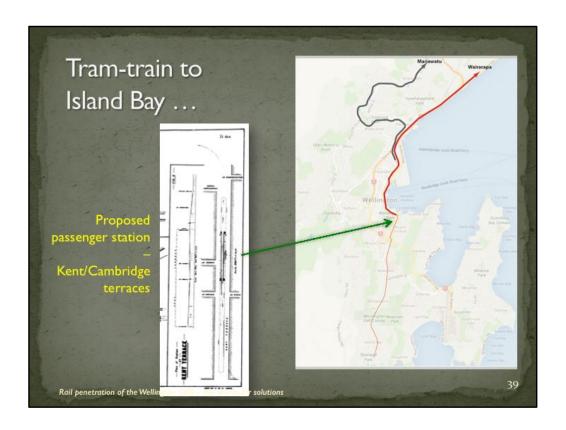


Demand that rail services should reach through the centre of Wellington and beyond made sense, given that was where the flat land and growth potential lay. In fact, such a connection was started, in the form of the Te Aro Branch which opened in 1893.



It was proposed that the line would later be extended to Island Bay, then open country.

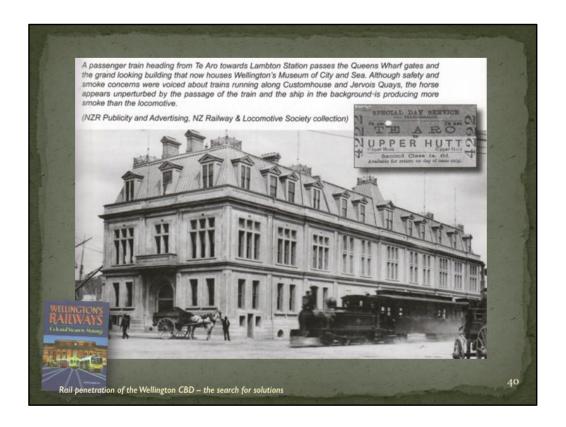
Before construction started there was an investigation as to whether, and if so where, a goods shed would be provided. A consulting engineer, C Napier Bell, prepared this proposal – addressing also the desired extension to Island Bay.



Mr Bell proposed that the goods handling would be done where the passenger station was eventually located, opposite where Te Papa now stands, and passengers would use short platforms between Kent and Cambridge Terraces, opposite Lorne St near Courtenay Place.

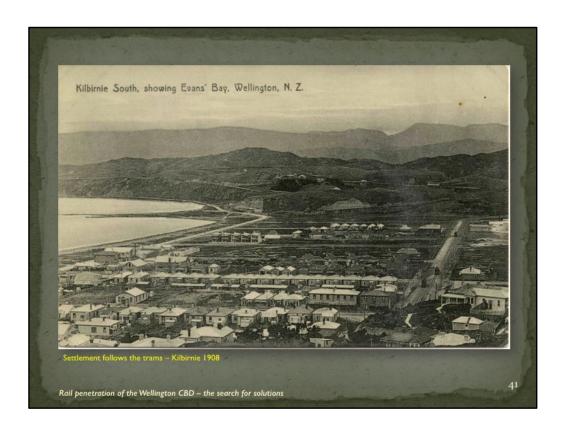
The line south would run in or close to the main streets and include sharp curves and steep gradients, requiring tram-type vehicles to operate. It would, in essence, be a tram-train service via Newtown, rather like the 1878 proposal – and very close to the optimum route for light rail to Newtown today.

But the railways management rejected the proposal, citing the evils of carrying mainline steam rail traffic through the streets.



In the event, the Te Aro branch did not carry bulk freight and its passenger traffic was only the slow last mile of long-distance trains from Napier and Masterton.

At the end of the 19th century there was comparatively little daily rail commuting from what we now call greater Wellington into Wellington City.



But what the Te Aro Branch did do, apparently, was put the frighteners on the Wellington City Council regarding a possible takeover of their planned electric tramway by central Government.

At the turn of the 20th century, Wellington, like every substantial city, was looking to the electric tram to expand its urban boundaries. The City Council purchased the NZR-gauged horse tramway operation in 1900 and set about planning new lines to the open country beyond the Town Belt.

In those pre-motorised days, having an electric tramway was regarded as a rates-reducing income generator which the City Council wanted for itself.

Even though the railways to Newtown and Island Bay had failed to materialize in the 1890s, who knows what ideas might be re-kindled in the minds of a Seddon administration very partial to the promotion of state enterprise, if the track gauges remained the same?

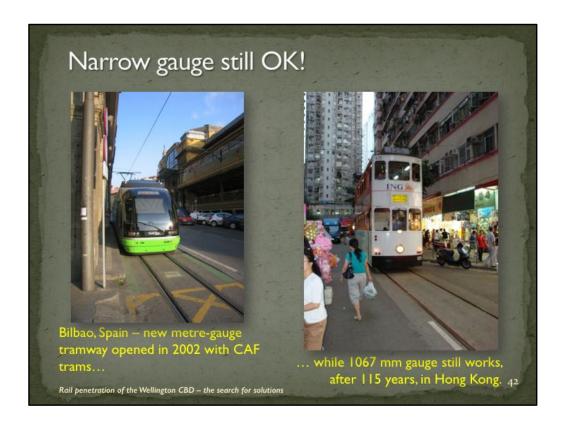
The prospect of a Government railway takeover milking the tramway cash cow was potentially very real. Such fears were common overseas and produced many tramways deliberately constructed to be incompatible with the local railway – the very opposite of a sensible policy these days.

Mr Wright, the City Council engineer designing the electric tramways, obligingly provided a technical justification for selecting the odd four foot gauge for the new trams.

In a memo to councilors in 1901 he said that narrow gauge as used for the horse tramways was unsuitable for electric trams, that motors and brake gear of adequate power could not be fitted inside narrow gauge trucks and that the four foot gauge was becoming the popular alternative to standard gauge in the tramway world.

That was an outright lie, of course, but it provided the council with a seemingly valid technical reason not to stick with the same gauge as the NZR when horse trams were replaced.

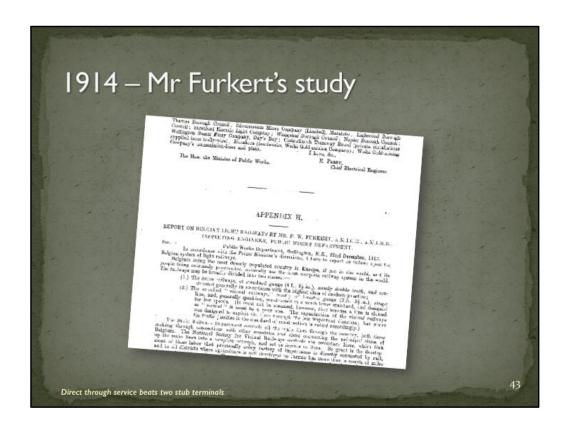
In the real world, the 3'6" gauge was widely used for electric tramways by 1901 – Hobart was the first electric tramway in the southern hemisphere and opened using that gauge in 1893. In Los Angeles, Denver, Portland, Perth, widely in Japan and in many other cities it also prospered.



Metre and 1067 mm gauge trams are widely used in the 21st century, whereas the four foot is only found in museums like MOTAT and Queen Elizabeth Park.

Mr Wright's recommendation would not be the last time that technical truthstretching served anti-tram-train political ends.

The enforced incompatibility of tram and train systems was one of the two crippling mistakes in Wellington rail transit planning which has prevented rail penetration of the CBD. The other mistake was made in our own time ...

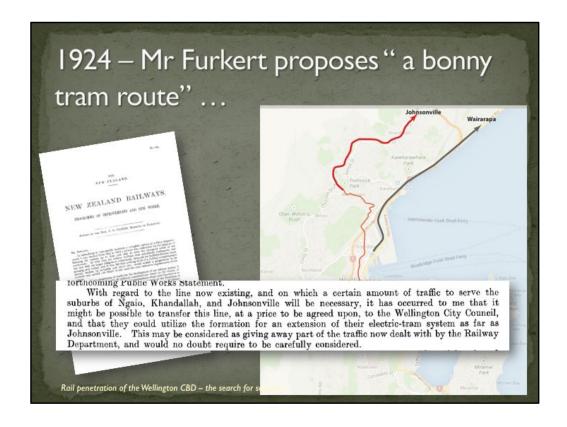


The name of Frederick William Furkert is well known to students of NZ engineering history.

He managed the completion of the North Island Main Trunk in 1908.

He became Inspecting Engineer of the Public Works Department and in that role delivered a report on his 1914 study tour to Belgium to report on the Vicinal system of light railways there, with a view to using rural tramways to extend the NZ railway system rather than the more expensive heavy rail branches which were demanded all over the place.

Of course, WW1 that year wrecked much of Belgium and, with its accelerated development of motor transport, eliminated the justification for rural tramways in NZ. The decline of the American interurbans also started with WW1.

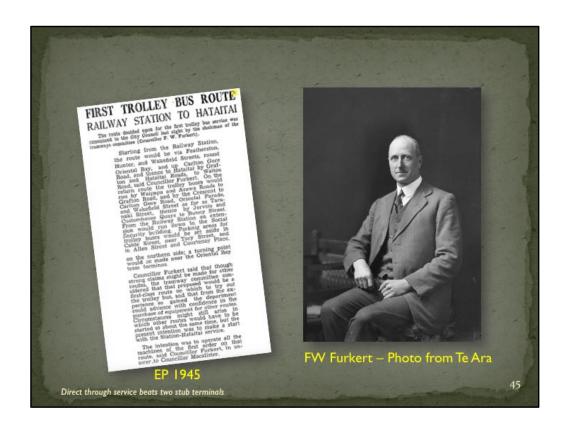


By 1924, Mr Furkert was Engineer in Chief of the Public Works Department. In a report on the proposed Tawa Flat Deviation, he suggested that the steep and winding line up to Johnsonville should become part of the Wellington tramway system, to serve the growing northern suburbs.

The Evening Post said editorially in 1931 that "... the rail track, unsatisfactory from a railroad point of view would make a bonny tram route ...".

This obvious suggestion had one decisive bugbear: the cost of converting the railway to a different gauge.

This was additional to electrification and building new trams of adequate power and speed. The Depression-era City Council just couldn't surmount that financial obstacle. In 1935 the Government approved the Johnsonville electrification with heavy rail EMUs, which opened in 1938.



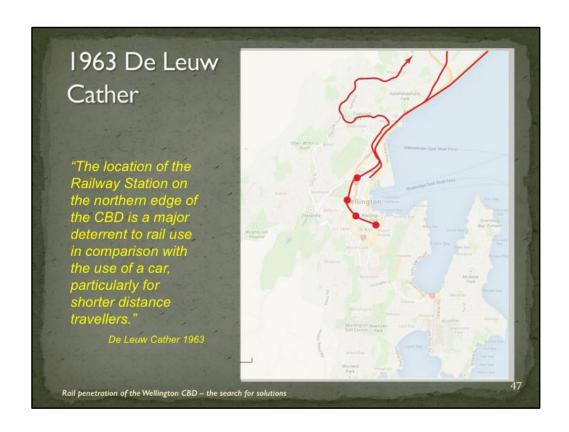
An amusing footnote is that towards the end of his life Mr Furkert became a Wellington City Councillor and head of its Tramways Committee. He started the movement to replace the trams with trolleybuses.

I wonder if he ever reflected on how things might have been different if the City Council's shortsighted tramway gauge decision in 1901 had not frustrated his 1924 Johnsonville Line "bonny tram route" recommendation.

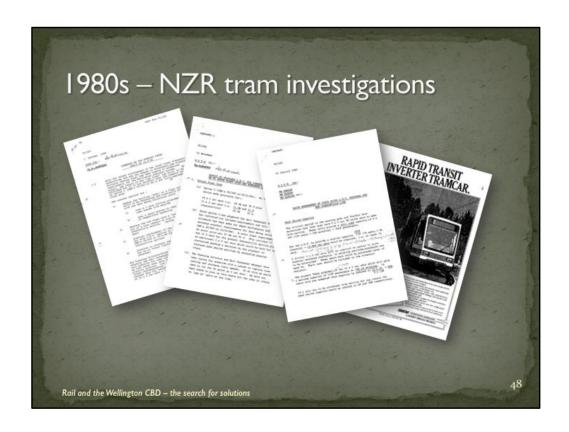
But lest we get smug about it, remember that there are those urging that we make exactly the same mistake today!



The desire for 'rail penetration of the CBD' intensified as the city started a new phase of high-rise growth in the 1950s. A proposal by the Railways and the Ministry of Works for a subway extension to John St in 1959 ...



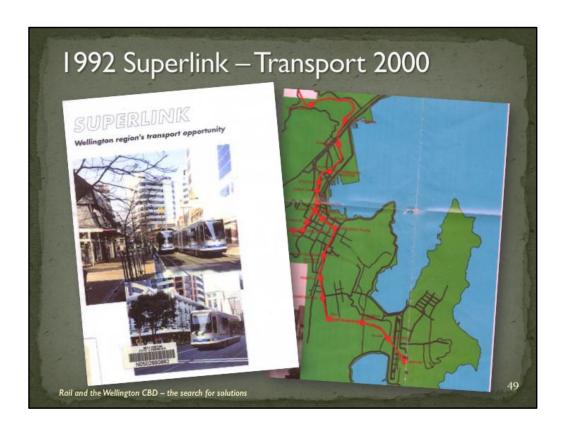
... and the De Leuw Cather modification of the plan in 1963 were not tram-train so are not really part of this story – but the observation in the De Leuw Cather report is the basis of the case for tram-train.



Official railways interest in the use of trams appears to have started with a memo from the assistant General Manager, the late Euan McQueen, to his boss, the GM Kevin Hyde, in 1979, suggesting that trams were better suited than EMUs to the rigours of the Johnsonville Line.

In the 1980s and early 90s NZ Railways made intensive investigations of the use of modern trams as replacements for the aging English Electric units on the Johnsonville Line.

Later Dr Francis Small, who had became the CEO of NZ Rail, even went as far as to say that the future of the whole Wellington rail system was light rail.



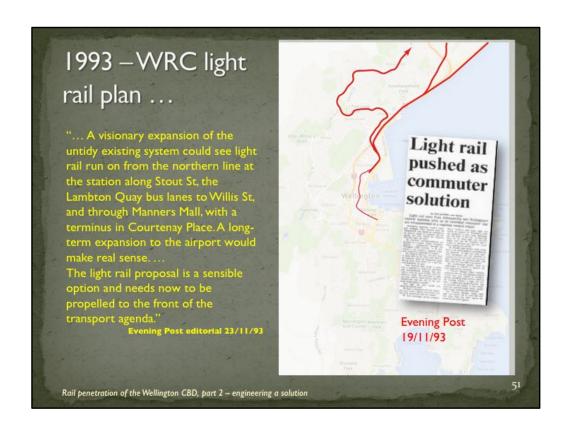
Meanwhile, various individuals and community groups were making suggestions and submissions to the Regional and City Councils stressing the potential of light rail transit (LRT) following its revival in North America and Europe.

The most detailed and publicised of these civil society attempts to advance rail access was Transport 2000's Superlink proposal in 1992 which was promulgated in booklet and pamphlet form

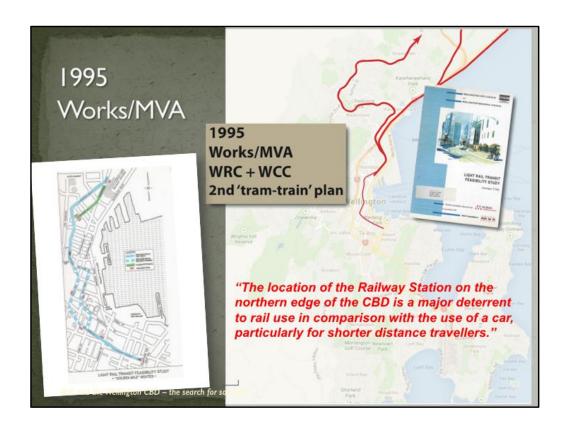
It proposed the conversion of the Johnsonville line to light rail and a line along the Golden Mile and a future extension to Wellington International Airport, via Newtown and a new Mt Albert Tunnel from the Zoo to Kilbirnie.



It was greeted by local business houses, some politicians, and on the front page of the Evening Post.



The next year, Dr Watson of the Wellington Regional Council, announced a light rail plan which was also welcomed by the Evening Post.



That was followed by the landmark study which provided the model for light rail in Wellington: the Works/MVA report of 1995, commissioned jointly by the City and Regional councils.

The report proposed a light rail route from WRS along the Golden Mile to Courtenay Place.

It would be an extension of all suburban rail lines, sharing tracks with heavy rail, so was definitely a tram-train proposal.

Note how, once again, the lack of rail penetration of the CBD was highlighted as the problem.

"The Wellington proposal to re-equip the
Johnsonville line with light rail vehicles and to
connect through to the airport was seen to be an
excellent plan. The Johnsonville units were very
aged, a matter which had to be addressed very
soon. NZRL would like to take part in any plan
such as light rail developments."

Summary of a speech by Ed Burkhardt to the Chartered Institute
of Transport in Wellington,
14 February 1995

Rail and the Wellington CBD - the search for solutions

Even the new private owners of TranzRail approved:

"The Wellington proposal to re-equip the Johnsonville line with light rail vehicles and to connect through to the airport was seen to be an excellent plan. The Johnsonville units were very aged, a matter which had to be addressed very soon. NZRL would like to take part in any plan such as light rail developments."

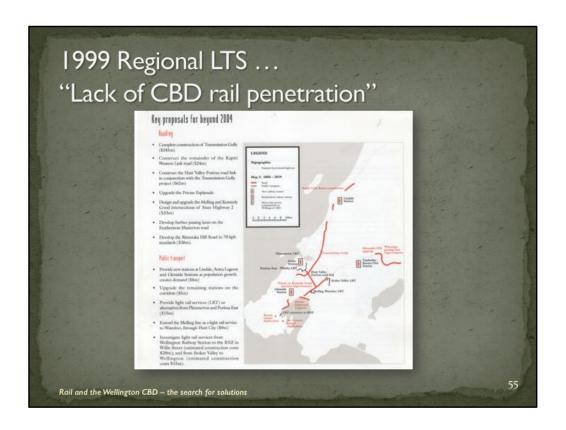
(Speech by Ed Burkhardt to the Chartered Institute of Transport in Wellington 14 February 1995)



An associated proposal was a heritage tramway on the waterfront, a la the line that has proven so valuable in Christchurch.

The initial study for the line was done by Dr Neil Douglas, with advice from a number of individuals, in 1993 and it was announced as a definite project in 1994. It was intended to be integrated with the Golden Mile leg of regional light rail.

Part of the reason for the project's ultimate failure was the City Council getting distracted by an incompatible Parry Peoplemover alternative at a crucial time – rather similar to the urgings for an incompatible gauge being heard nowadays.



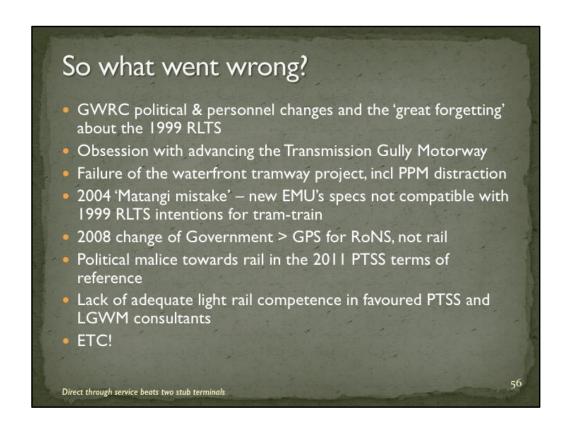
As of the end of the 90s the Regional Council was fully on board with light rail as its ultimate intention and it featured in the 1999 Regional Land Transport Strategy which envisaged extensive deployment of tram-train throughout the region in the 2004-19 period.

"Lack of rail penetration of the CBD" was highlighted as a problem to be solved.

It even went as far as proposing light rail lines to Stokes Valley, Whitby and from Melling to Woburn through central Lower Hutt.

The Hutt City Council followed up with a detailed report on the latter from SKM Consulting in 2000.

It was to illustrate this cross-Valley link that I commissioned the two paintings of a Queensgate-bound tram-train at the start of this presentation.



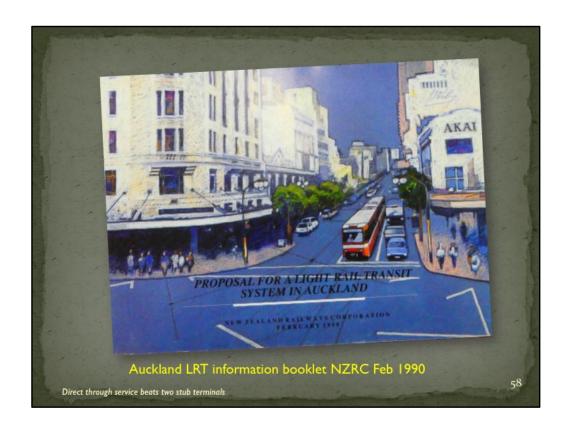
The failure of the 1990s plans to advance to realization was due to a 'perfect storm' of negative factors.



NZ Rail was also involved in detailed light rail plans for Auckland which resulted in a big promotion of tram-train in 1990.

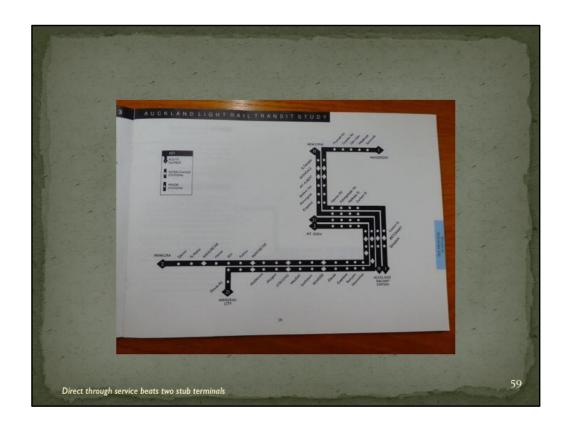
It envisaged conversion of existing lines – the ones now electrified – and the construction of a new tram line from Mt Eden Station and down Queen St to what became Britomart. When Britomart was built there was provision made for light rail track from the tunnel entrance to the surface in Tyler and Galway streets.

The 1990 plan was the surface light rail equivalent of what is now being built as the City Rail Link.



The Railways Corporation put considerable resource into this promotion, to the extent of commissioning a slick professional video as well as a comprehensive report with engineering drawings and detailed specifications, as well as this booklet for general public information.

Nothing came of it, of course, but its significance for us is the degree of confidence in, and acceptance of, the tram-train concept displayed by the railway authorities of the day.

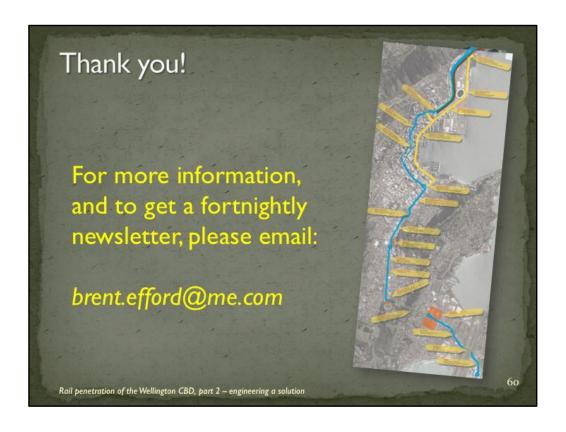


By contrast, the current proposed light rail lines to the airport and west Auckland have no tram-train intentions, even to the extent of planning for standard gauge.

This is less crucial in Auckland, which is big enough to support two incompatible parallel rail systems through the CBD, than it is in Wellington, where it would be crazy. But it is still a potential missed opportunity.

For example, an integrated system would overcome the disquiet over using light rail all the way to the Auckland CBD from the Airport. With an integrated system, cheaper tramway construction could be used for the track from Onehunga to the Airport, including Mangere Town Centre, while the speed advantage of using the existing railway from Onehunga to the CBD could still be realized.

There are other areas where new track built to light rather than heavy rail standards would be economically advantageous.



In the Wellington context, tram-train makes the most sense if it enables a light rail system which links the region to the Golden Mile and the activity centres to the south.

In my opinion, the FIT light rail proposal presented to you at the previous lunchtime session here is severely deficient in regards to its deliberate lack of a regional rail connection and dysfunctional aspects of their proposed route south of the Railway Station. It is what Dr Watson in the 1990s concluded is 'not a winner'.

But I am out of speaking time, so I invite you to consult the remaining slides in this presentation online when it is put up, to get a picture of the default design of new light rail construction using the studies done in the 1990s.

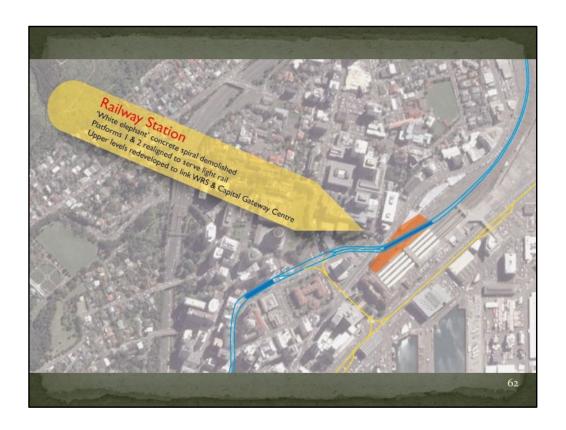
The following PDF pages, not part of the 14/2/19 presentation, are attached for your online information:

• Details of proposed new light rail construction from WRS to the Airport

• Ditto for the waterfront tramway

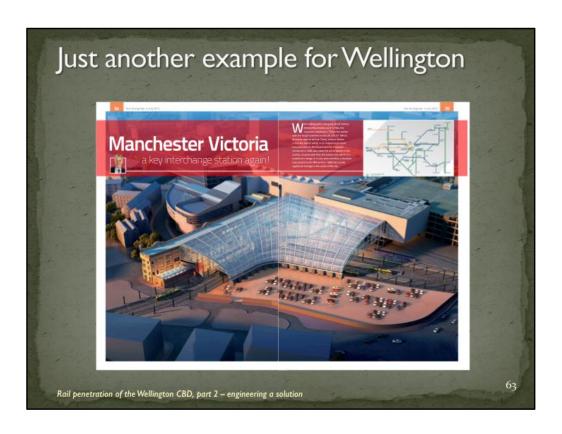
• The Naegeli et al paper 'A Checklist for Successful Application of Tram-train Systems in Europe'

• The LRTA submission to Lets Get Wellington Moving



Key, of course, is Wellington Railway Station.

Even if a first stage was to be just a street tramway with no revenue running on heavy rail, there are huge convenience, access, and future opportunity advantages to having the light rail platforms within the same array of platforms, on the same level, as heavy rail. This is done routinely throughout the world: of the systems I have visited, Los Angeles, Dallas, San Diego and Manchester Victoria are all arranged this way. It also make future expansion on the existing network, and depot access, easy. Demolishing the white elephant concrete spiral and instead developing some of the most valuable real estate in Wellington on the west side of the station is the obvious way to go. This would include new platforms 1 and 2 for the light rail.



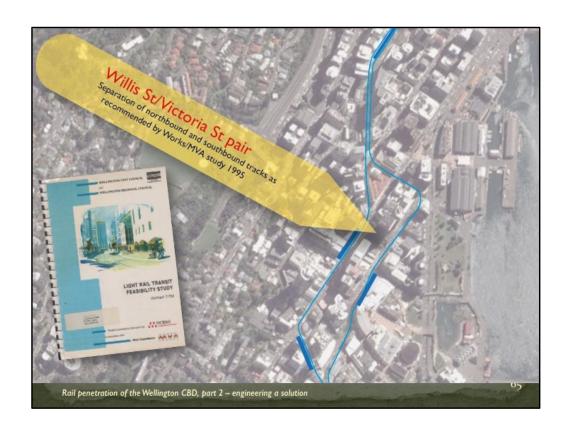
Leading the new light rail out the side of a long-established station is what happens in Manchester Victoria. This station has recently been completely redeveloped.



From there it is a simple matter to lead the tracks through the existing bus parking area and down the west side of Lambton Quay.

The idea is obvious and has been around for a long time. It would enable several traffic signals to be dispensed with.

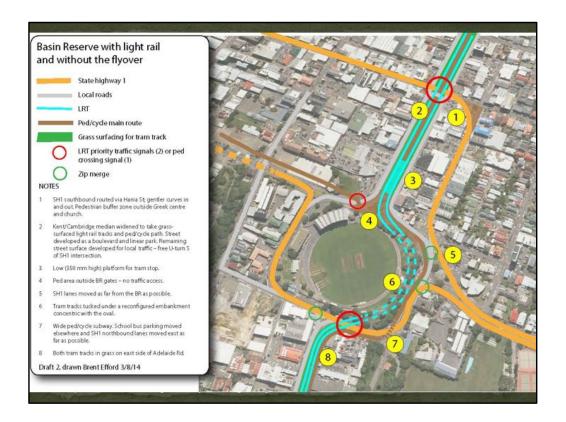
Road vehicles would enter Lambton Quay, if at all, only via one-way round-the-block loops fed from Featherston St. Without frequent cross-streets to worry about, tramtrains as long as two Matangi sets and 100m long platforms would be quite feasible.



At Hunter St the directions would separate as the buses do now. The 1995 Works/MVA report recommended southbound trams travelling via Victoria St and showed this on the cover of the document. As with the buses, northbound trams would travel via Manners and Willis Streets.



From Manners St to Courtenay Place the road widens, and there is room for a station, maybe an interim terminus, while still retaining some other vehicle access. Reversing and stabling should take place in the wide median around the corner. Note the junction with a waterfront line; we will come back to that shortly.

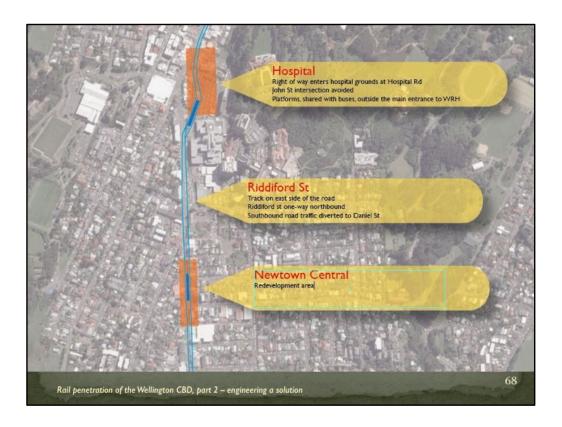


Between Courtenay Place and the Hospital, the line would cross State Highway 1, but only at right angles at prioritized signals. However, assuming the hated flyover plan is buried for good, there are some wonderful urban design opportunities which light rail is uniquely able to facilitate.

Southbound SH1 traffic should be redirected into Hania St, a three-lane-wide street already dominated by the motor trade. This gets the state highway lanes further away from the Basin Reserve. There would be gentler turns for road traffic and most importantly, the old Canal Reserve – Kent and Cambridge Terraces – could revert to its intended role of a linear park or boulevard.

Here light rail would shine, because the tracks would be surfaced with grass and landscaped to blend in with the rest of a very wide median, which would also feature trees and a cycle and walk way.

The tracks would pass the Basin Reserve in a sweeping curve concentric with the cricket oval. The embankment or, I would suggest, a stand or pavilion could be cantilevered over the tracks.



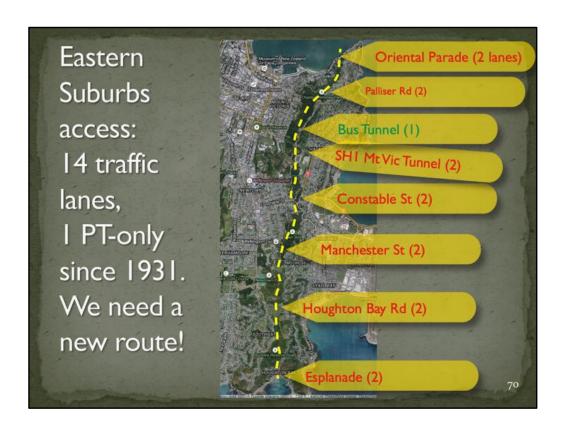
The tram line should avoid the John St/Adelaide Rd/Riddiford St intersection entirely – and it can, easily. Simply by using the area between the existing old shops and the Cancer Centre. This section would end up in a station in front of the main entrance to the Hospital which would include platforms shared with buses. That would be a logical interim terminus in a staged rollout of light rail.

Extending further south, through Newtown we start getting into some bigger engineering challenges. To provide an exclusive right of way for public transport through the dense shopping area, the southbound traffic lane in Riddiford St and the associated parking lane has to be used.

The City Council needs to bite the bullet and route southbound traffic into Daniel St and make the east side of Riddiford St a pedestrian cum tram way, similar to the proposal for Lambton Quay.

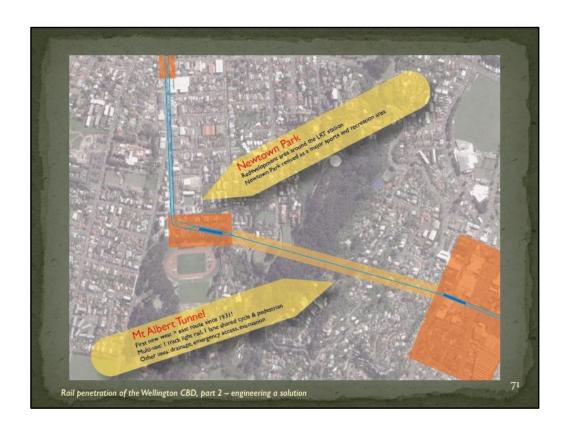


Having reached the shops we face the issue of extending to Kilbirnie. Remember that we are sticking to a single spine, not indulging in a stupid and deliberately dysfunctional second line via Mt Victoria, as theorized in the Spine Study. Some have been pushing for the Constable Connection, using the old tram route via Crawford Road, opened in 1915. However that winding and steep route, with significant restrictions once the line gets to the Kilbirnie Shops, is riven with problems.



One of the issues that needs to be confronted is that there have been no new routes for either public or private transport between inner Wellington and the Eastern Suburbs built since the Mt Victoria Tunnel was opened 84 years ago. No new lanes, even. The pressing need is for a new route for sustainable transport modes, not yet more traffic lanes.

The official answer is a second Mt Vic tunnel for SH1 – two new lanes but no new route to provide more diversity and security. And most crucially, no exclusive right of way for public transport – buses are simply to be squeezed in with SH1 private traffic, the worst situation possible for any PT mode.



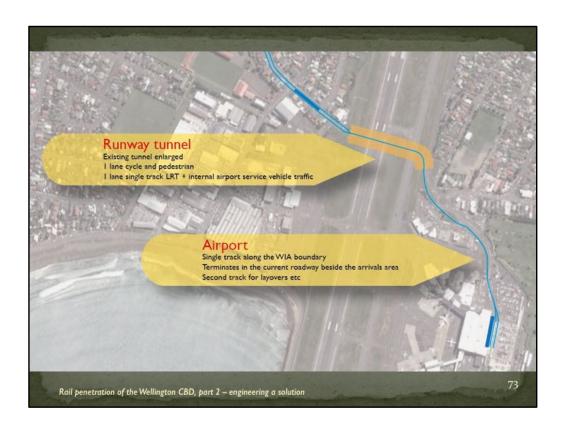
The answer was proposed in the 1992 Superlink proposal: a Mt Albert Tunnel for trams from the Zoo to Coutts St. This tunnel of about 800 metres on a 4% grade could serve a single-track tram line – not a big restriction over such a distance – and walking and cycling beside it.

Not only does this tunnel – unlike the 2nd Mt Vic tunnel – route public transport well away from conflict with traffic on and off the state highway, it also keeps all the big traffic centres on a single line – and that line is largely straight and would provide speedy access to the Airport. For the first time since 1907 it would provide a transport link not configured primarily for motor traffic, and for the first time ever would facilitate all non-motor modes.

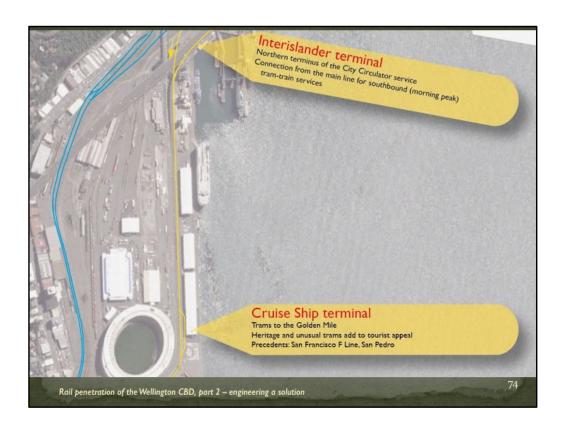
The City Council has actually already tunneled in the area, for drainage purposes in the 1980s, and that work involved the use of a construction tram line. Being a new route straight between the Kilbirnie Shops and southern Newtown, the tunnel could also be a lifeline for tsunami evacuation and other emergency purposes and could also accommodate utilities and drainage.



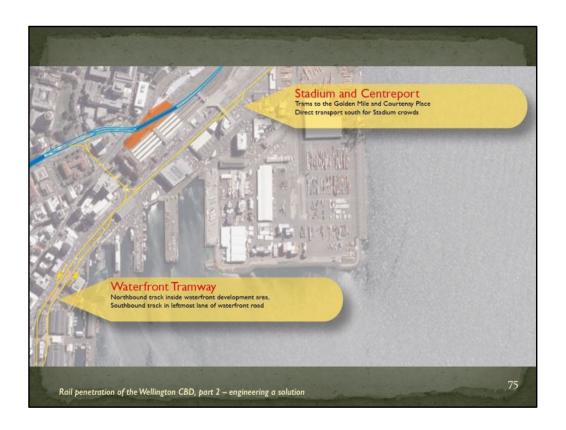
Exiting straight onto Coutts St – the original tram route to the peninsula – provides a very direct route to the Airport, down a street wide and quiet enough to be suitable for mixing tram and motor traffic.



Then it is a matter of expanding the existing pedestrian and cycle tunnel under the runway to take both trams and airport service vehicles. A short run along the airport boundary beside the end of SH1 and we are at the terminal building – a common terminus for a regional rail spine in other parts of the world.



A single-track tramway from the Interislander terminal south along the waterfront would be very easy to engineer. A rail line still exists along Aotea Quay as far as the Centreport office park. Until recently it ended opposite the Railway Station. Reinstatement would be easy.



From Bunny St to Courtenay Place, a southbound track in the leftmost traffic lane would be on the line of the old Te Aro Branch. . A northbound track would fit inside the waterfront, where a clear right of way used by road vehicles exists from Frank Kitts Park to the Bluebridge terminal.



It would hop inside the waterfront land outside Te Papa



Christchurch Tramway experience is that street trackage will cost about \$5,000 per single track metre to build. Double it to allow for utilities diversion and traffic engineering, \$20M per double track km is a good budget ballpark.

Which compares very favourably with urban arterial highways of equivalent capacity. Add another \$20M for access to the EMU depot, and the complexities of a Courtenay Place interim terminus and an inner-city starter shuttle line infrastructure for \$70M is feasible – exactly what was predicted by Works/MVA in 1995.

Add the Waterfront line for another \$76M and a downtown circulator track is complete for \$125M. Plus the trams – costing much the same as buses on a per passenger per year basis.

The big property development on the western side of the Railway Station is not included in this – that is a commercial opportunity which should be self-supporting. Just like the new development opposite Britomart which is starting the Auckland CRL

A CHECKLIST FOR SUCCESSFUL APPLICATION OF TRAM-TRAIN SYSTEMS IN EUROPE

Lorenzo Naegeli (corresponding author) Swiss Federal Institute of Technology (ETH) Institute for Transport Planning and Systems (IVT) Wolfgang-Pauli-Strasse 15 8093 Zürich Switzerland

tel + 41 44 633 72 36 fax + 41 44 633 10 57 e-mail lorenzo.neageli@ivt.baug.ethz.ch www http://www.ivt.ethz.ch/people/lnaegeli

Prof. Dr. Ulrich Weidmann Swiss Federal Institute of Technology (ETH) Institute for Transport Planning and Systems (IVT) Wolfgang-Pauli-Strasse 15 8093 Zurich Switzerland

weidmann@ivt.baug.ethz.ch http://www.ivt.ethz.ch/people/ulrichw/index EN

Andrew Nash Vienna Transport Strategies Bandgasse 21/15 1070 Vienna Austria

andy@andynash.com http://www.andynash.com/about/an-resume.html

words: 5,188 figures: 6 tables: 3

ABSTRACT

Tram-Train systems combine the best features of streetcars with regional rail. They make direct connections between town centers and surrounding regions possible, by physically linking existing regional heavy-rail networks with urban tram-networks. The Tram-Train approach offers many advantages by using existing infrastructure to improve regional transit. However using two very different networks and mixing heavy rail and tram operations increases complexity and often requires compromise solutions.

The research surveyed existing systems to identify key requirements for successfully introducing Tram-Train systems. These requirements include network design, city layout, population density, and physical factors (e.g., platform heights). One of the most important factors is cooperation between many actors including transit operators, railways and cities. Tram-Train systems are complex, but can provide significant benefits in the right situations. The paper describes Tram-Train systems, the key requirements for successful systems and conclusions.

1. INTRODUCTION

To be successful transit must be attractive to customers and efficient to operate. Rail-based transit is efficient and attractive, but, partly due to competition from automobiles, in the 1950s many cities began removing rail track from city streets and consolidating regional rail services in stations that were inconvenient for passengers. This combination decreased transit competitiveness leading to service reductions and a downward spiral for transit in many cities.

Karlsruhe (Germany) faced a similar situation. The city's main rail station had been relocated, motorization had taken hold and transit was becoming less effective. However, transport planners had an idea: why not connect the city's tram tracks to the regional standard rail network and run through trains? These trains would use the tram tracks in the center city and the regional network in the surrounding area. After much planning the first line opened in 1992 and was a great success. Since then the approach has been successfully implemented in other cities and is sometimes called the "Karlsruhe Model" [1].

The research goal is to identify the key strategic planning factors necessary to make the Tram-Train approach successful. The research analyzed existing Tram-Train systems and reviewed transport planning theory. The result is a checklist for determining when Tram-Train systems make sense and implementation recommendations.

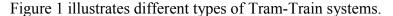
2. SYSTEM DEFINITION AND SCOPE

The term "Tram-Train" is a hybrid expression that has been used to define several different types of transport service. In this research, a Tram-Train system is defined as "a railway system that produces a direct connection between the regional area of a city and its town center. In the city it runs on tram tracks (partially on road space) and follows tram regulations. In the region, it runs on conventional heavy rail tracks and follows the regulations for heavy rail (with additional requirements)". This means that Tram-Train vehicles share tracks with trams in the city and with heavy rail trains on the regional tracks. One main goal of Tram-Train service is maximizing use of existing infrastructure.

Three different types of Tram-Train service were defined:

- Type A Tram-Trains run on the tram tracks in mixed operation with conventional trams and on the heavy rail track in mixed operation with conventional heavy rail trains. Examples include Karlsruhe and Regiotram Kassel (Germany).
- Type B describes a system in cities without an existing tram-network. Therefore the Tram-Trains do not run in mixed-operation with trams on the center city network, but do operate in mixed operation with heavy rail trains on the heavy rail tracks. An example is the Saarbahn in Saarbrucken (Germany).
- Type C includes other systems, for example if the Tram-Train has its own exclusive tracks in the city center or the regional area and therefore does not run in mixed-operation in one

or both of these areas. Examples include the line T4 in Paris and the Randstad Rail in The Hague.



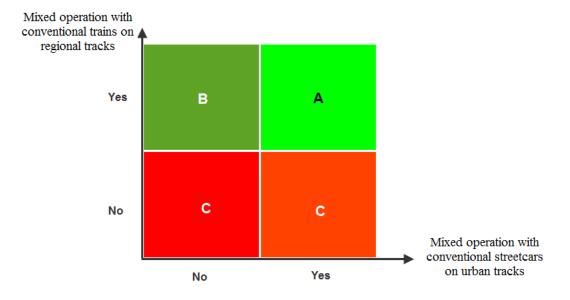


FIGURE 1 Tram-Train classification schema.

The research focus was on Tram-Train systems that share right-of-way with other forms of rail transport (types A and B), and therefore the paper only considers these systems.

3. DEMAND FOR TRAM-TRAIN-SERVICE

Travel time and comfort are two key factors influencing passenger mode choice. Unfortunately, conventional commuter rail systems in many cities lack direct links between their suburban rail network and the city center – thus requiring people to transfer between regional and urban transport-systems, reducing comfort and increasing travel times.

The Tram-Train approach is designed to solve this problem by linking urban tram and regional heavy railway infrastructure. This linkage provides a direct connection between the city-center and its suburbs helping reduce travel time and increase comfort, leading to higher patronage and efficiency. The benefit of this direct connection depends on the current situation for reaching the city center.

Since Tram-Train-systems normally operate on existing infrastructure in both the urban and rural areas, the investment costs are reduced. Furthermore the lightweight vehicles are cheaper to operate than conventional trains.

Initially, given these advantages, many believed that Tram-Train systems were the right solution for all cities with underutilized railway tracks in their suburbs. But the relatively low number of

projects built since Karlsruhe's successful application shows that they may not be appropriate in every case.

Successful application of the Tram-Train approach means carefully balancing the advantages against the physical and institutional difficulties of implementing a system that connects two very different rail infrastructures.

4. RESEARCH METHODOLOGY

Figure 2 illustrates the research methodology used in this project.

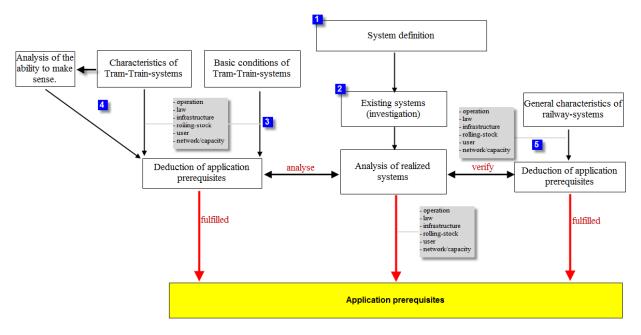


FIGURE 2 Research method.

5. HISTORY AND EXPANSION OF TRAM-TRAIN SYSTEMS

Following Karlsruhe's great success many cities implemented or considered implementing Tram-Train systems. Figure 3 shows the locations of Tram-Train systems in Europe.

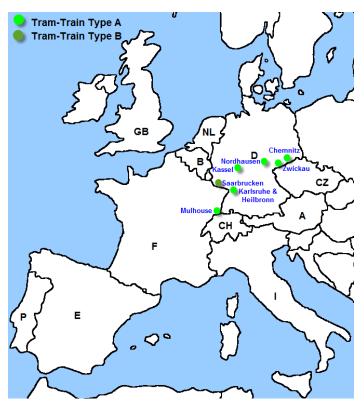


FIGURE 3 Tram-Train systems (type A&B) in Europe (map [2]).

There are several similar systems operating in the United States including the Capital Metro Rail Austin, and the Riverline in New Jersey. However under US regulations these systems operate under time separation: trams use the tracks during specified hours and standard railroad vehicles use the tracks at other times. Many US cities are interested in the Tram-Train approach, but it has been difficult to implement due to very strict rail car design requirements [3].

The history of Karlsruhe provides important clues to the success of the Tram-Train approach. Originally, the city was served by a tram-network, regional trains operated on the standard gauge German national railway and a narrow gauge private regional railway called the Albtal-railway.

In the early 1910s, Karlsruhe's main station was relocated outside the center city and the Albtal railway's terminal station was also moved to the new location. In the 1950s, this peripheral location and increasing traffic congestion on the surrounding streets made transferring between trains and trams difficult, which reduced ridership and caused increasing economic difficulties for the Albtal railway.

To avoid closing the Albtal railway, Karlsruhe decided to change it to standard gauge and connect it with the city's (standard gauged) tram-network. This provided a direct connection between town center and the suburbs, and led to a substantial increase in ridership.

After the success of the Albtal line, Karlsruhe has expanded Tram-Train service by adding through services on more regional lines. Today, the network has a length of approximately 500 km (311 mi) [1], [4] [5].

Interestingly, since ridership is so high, Karlsruhe recently decided to build a tunnel under its center to increase capacity and reduce the impact of Tram-Train vehicles on the city's popular pedestrian area [6].

The history of the Tram-Train system in Karlsruhe provides some preliminary lessons on conditions that make such systems successful. The next sections outline these conditions.



FIGURE 4 City center Karlsruhe (left); Regiotram Kassel meets heavy rail (right) [7].

6. KEY FACTORS FOR SUCCESSFUL TRAM-TRAIN SYSTEMS

6.1 Basic Conditions

6.1.1 Speed and Network Coverage

The maximum speed of Tram-Train vehicles depends on physical characteristics and safety requirements. Tram-Train vehicles have much lower body stiffness than standard heavy rail vehicles and do not meet the UIC stiffness requirements [8]. This reduces the passive safety in a crash situation. (Stiffness is referred to as "buff strength" in the United States.)

With reduced passive safety in the railcars, the system's active safety must be increased to reach an acceptable level of safety in mixed operations. Therefore special rules for mixed operation must be followed ("LNT-guidelines" / guidelines for lightweight rapid transit railcars). These rules were published in Germany after implementation of Karlsruhe's system. The rules set the maximum speed for Tram-Train-vehicles at 90 km/h (56 mph) (or 100 km/h (62 mph) if additional requirements are satisfied) [8].

The average speed of a Tram-Train system is around 35-45 km/h (22-28 mph), because the system combines features of conventional regional trains and trams. Since people generally have a fixed travel time budget, a transit line's average speed helps determine its effective network coverage. Assuming that the maximum commuting time per day and direction is one hour, then the maximum system radius is approximately 35-45 km (22-28 mi) from the city center.

6.1.2 Capacity and Capability

In center cities the Tram-Trains operate on streets and interact with other vehicles. Therefore they are subject to the same regulations as trams. The German "Bau- und Betriebsordnung für Strassenbahnen (BOStrab)" regulations are a typical example [9]. According to BOStrab the maximum dimensions of Tram-Train-vehicles are 75 m (246 ft) long and 2.65 m (8.7 ft) wide. Other countries have similar maximum dimensions.

Considering passenger comfort, a Tram-Train-vehicle's capacity is about 112 passengers (based on occupying 95% of seats and 20% of standing room) [10]. When these vehicles are operated in double traction (to reach the allowed maximum length of 75 m) the capacity is about 225 passengers. A typical example is the Alstom Regio Citadis illustrated in Figure 4.

In the suburbs, the operating capacity on the heavy rail track is limited by the other traffic and technical design of the tracks. Assuming that the maximum frequency of the Tram-Trains is 10 minutes (considering factors such as available slots on heavy rail tracks, infrastructure capacity, etc.), then the maximum traffic load profile for the system is about 1,400 passengers per hour and direction. A Tram-Train system type A&B can therefore not be applied on lines expected to serve very high passenger volumes. A Tram-Train system of type C, which uses separated independent tracks in the region can provide more capacity.

6.2 City Characteristics

6.2.1 City Size

Most of the European cities where Tram-Train systems have been successfully implemented have populations from 100,000 to 300,000. The typical Tram-Train-city functions as a regional metropolis and the surrounding region is strongly oriented to the city for employment, shopping, recreational facilities, hospitals, government and higher education. This centralizes traffic flows between the city center and surrounding areas.

Often these cities are too small to provide standard regional rail service (i.e., which requires transferring to local transit at a central station), since passenger volumes on specific corridors are too low.

The combination of lower costs (due to lower capacity requirements) and more attractiveness (due to direct central city service) make these markets very attractive for Tram-Train systems.

A type A Tram-Train system is possible in cities with an existing tram-network (many European cities with 100,000-200,000 inhabitants still have tram networks). In cities without existing tram-networks a type B Tram-Train system could be introduced by building a new tram track in the center city. In this case the regional connection means that more passengers can be attracted

to the city tram and justify construction of the new track. This is well illustrated in the city of Saarbrucken (Germany).

Countries outside Europe have different city size benchmarks depending on existing transit use patterns. For example, the Capital Metro Rail of Austin serves a city of approximately 800,000 people [11].

6.2.2 Existence of suitable Center City Tram Corridors

An important success factor for Tram-Train systems is the existence of a suitable corridor for operating Tram-Trains from the heavy rail track to the city center. Most importantly this corridor must have a good connection and offer adequate space. Since Tram-Train vehicles are often larger than city trams the corridor must be wide enough.

Furthermore, the track should have as much exclusive right of way as possible to provide high reliability. Reliability is especially important for Tram-Trains since they are assigned specific slots on the heavy rail network. If Tram-Trains are not reliable, they interfere with regular railway operations or have to wait for the next available slot. In the case of a type B Tram-Train, the selected corridor must have adequate space for building a new tram line and ensuring that it can be operated reliably.

Another important consideration for the center city tram corridor is capacity to operate Tram-Trains. If traffic on these corridors is already high, adding Tram-Trains with longer vehicle lengths than existing trams can be difficult and controversial. This is even true in transit malls or pedestrian zones where Tram-Trains can block pedestrian flows and traffic on cross streets. Therefore the corridor must be very carefully designed.

6.2.3 Activity Centers

Providing a direct connection to the city center only makes sense if there is sufficient transport demand (in other words most suburban passengers are going to the town center). If the traffic flows are dispersed throughout the city, a Tram-Train-line will not serve many passengers and a conventional radial tram-network might be a better option.

Therefore the most suitable cities for Tram-Train systems have a distinct main town center with a high level of activity including employment, shopping and educational institutions. Alternatively, the city could have several sub-centers but these would need to be served efficiently with the same central city tram track. Having both a high activity center and smaller sub-centers along the route is the best possible situation.

This criterion is related to city size: cities with a pronounced main center are often medium-sized (100,000-300,000 inhabitants). These cities often have a city center with a high density of activity but are too small to have several separate activity centers.

Figure 5 illustrates a typical corridor in Karlsruhe and the town center of Kassel.



FIGURE 5 Corridor between town center and railway station in Karlsruhe (left); city center of Kassel (right) [7].

Finally, it should be noted that the Tram-Train line could also positively influence center city development. For example, in Karlsruhe approximately 300 new shops opened in the city center between 2003 and 2006 [12].

6.2.4 Distance between Railway Station and Activity Centers

A key factor for Tram-Train systems is the distance between the heavy rail station and the city center.

If a city's main activity center is located near the railway station, a direct connection via Tram-Train does not produce much additional benefit: people can already reach the center by foot and do not have to take the tram.

On the other hand, a Tram-Train can be very beneficial if the city's main activity center is located farther away from the railway station (many railway stations are located outside the city center, and many railway stations in smaller cities are being moved further outside of the city to better connect with high speed rail lines that divert around these smaller cities). In this case the railway station is located far enough away that people would normally take a tram or bus to the city center (e.g., > 1 km (0.62 mi) or 10-15 minutes walking time).

As part of this research the distance between the railway station and the town center in existing Tram-Train-cities was measured using Google-maps and confirmed in field visits. Table 1 summarizes the results of these surveys.

TABLE 1 Distance between Railway-Station and Town Center (Center of Activity) and Estimated Walking Time

(a) Cities witl systems	h Tram-Tra	in	(b) Cities currently or formerly planning Tram-Train-projects			(c) Comparable Cities but without Tram-Train-projects		
City	Distance ^a [m]	Time [min]	City	Distance ^a [m]	Time [min]	City	Distance ^a [m]	Time [min]
Karlsruhe	1900	24	Nantes	1400	17	Mannheim	800	10
Zwickau	1800	22	Leiden	>1000	12	Hannover	750	8
Chemnitz	1100	14	Adelaide	1100	14	Augsburg	750	9
Kassel	700	12	Braunschweig*	2100	26	Magdeburg	600	7
Mulhouse	1000	12	Strasbourg*	1000	12	Hagen	300	4
Saarbrucken	800	10	Rostock*	1700	21	Leverkusen	200	2
The Hague	1000	12	Lubeck*	1300	16	Oberhausen	500	6
Heilbronn	1100	13	Kiel*	1100	14	Osnabruck	800	10
(Austin)	1800	22	Bordeaux	2500	30	Mainz	900	11
(Kassel: different elevation above			Grenoble*	1100	13	Hamm	750	9
sea level; distance to Kassel Wilhelmshöhe > 2 km) (Austin: similar system)			(* Project considered but rejected/postponed due to lack of funds / alternatives)					

Cities with Tram-Train systems (part (a) on Table 1) have railway stations located away from the city center or at a different elevation (walking time normally > 10 minutes). The cities currently planning or which previously considered Tram-Train-projects (b) show the same conditions. Cities without a Tram-Train or planned projects (c) have relatively short distances between the railway station and town center.

The distance between the railway station and town center is a key indicator of the benefit offered by a direct Tram-Train connection. This applies especially for type A Tram-Train systems. For type B systems one of the main incentives is to stimulate the reintroduction of urban tram service (e.g., Saarbrucken) so the distance between station and city center is not as important.

6.3 Regional Characteristics

6.3.1 Orientation to the City

A key success factor for Tram-Train systems is strong regional orientation towards the center city. This means that the suburban areas should feature largely housing and most of the regional population should work and shop in the city, focusing traffic flow towards the center. If there are other large activity centers or cities nearby (as is often the case in large metropolitan areas), the

 $^{^{}a}$ 1,000 m = 0.62 mi

regional traffic flows would be more dispersed and therefore more difficult to serve with a Tram-Train system.

6.3.2 Population Density

The Tram-Train system is a hybrid suburban transit system serving a niche between buses and regional rail. Since Tram-Train vehicles operate on city streets their capacity is limited. Therefore, the population density should not be too high or the system will have insufficient capacity to meet demand. If the density is too low, a Tram-Train system is also inappropriate.

The researchers estimated population density on existing German Tram-Train lines to develop density criteria for Tram-Train systems. Population density was calculated by summing the number of people who lived around each station for the entire line (the catchment area of a station was assumed to be 750 meters (approx. ½ mile)) and dividing by the length of the line. This provided a population density per linear km of corridor length. Table 2 summarizes the results. Note this only includes the suburban sections of the Tram-Train route (i.e., the portions operated on the heavy rail network).

TABLE 2 Population Density and Reachable Inhabitants along Tram-Train-Line Corridors in Germany

Regional Track	Length [km]	Reachable Inhabitants	Persons/km	Frequency [min]
Saarbrucken Brebach-Sarreguemines	14	27,400	1,960	30
Saarbucken Malstatt-Walpershofen	8	19,100	2,390	15
Saarbrucken Malstatt-Limbach	19	39,400	2,080	15
RT3 Kassel Vellmar-Warburg	36	35,000	980	30
RT4 Kassel Oberzwehren-Wolfhagen	25	29,400	1,180	60
RT5 Kassel Oberzwehren-Melsungen	20	30,000	1,500	60
RT9 Kassel Vellmar-Treysa	52 *	47,000	900	60
550 Chemnitz-Stollberg	16	26,100	1,630	30
Zwickau Maxhuette-Zwotental	48	36,100	750	60
Zwickau Maxhuettte-Plauen	40	46,200	1,160	60
S1 north, Hochstetten-Karlsruhe Neureut	11	27,300	2,480	20
S1 south, Karlsruhe-Rupuerr-Bad Herrenalb	18	42,100	2,340	30
(* >45 km)				

The number of persons per kilometer (p/km) provides an index about the population density in the region, but this value cannot be considered alone. For example, a Tram-Train-line with a length of 45 km could not serve a density of 2,500 p/km since it would have insufficient capacity. Therefore it is also necessary to consider the absolute number of inhabitants along the entire line.

The researchers also calculated this for existing German Tram-Train corridors. The results show that the number of reachable inhabitants lies between 19,000 and 47,000 persons, but is mostly around 25,000-35,000.

Finally, it is also important to consider the standard gravity model indicating that the number of passengers increases towards the center of activity. This means that, in areas with equal population densities, more people will use the Tram-Train system from stations near the center than farther away from the center.

In summary, Table 2 shows that a population density of approximately 2,500 p/km is normally combined with a number of reachable inhabitants of 20,000-30,000 for a short corridor, while longer corridors with lower population densities (750-1500 p/km) can serve areas with up to 50,000 reachable persons. It should be emphasized that these rules of thumb are very closely tied to local conditions such as modal-split characteristics and specific operating characteristics of the Tram-Train service. Therefore these values should only be considered as benchmarks for a rough analysis.

If the distance between stations is approximately 1-2 km, lightweight Tram-Train-rolling stock can be used. These vehicles can accelerate fast and their energy consumption is lower than conventional trains. Generally the Tram-Trains stop at all stations on the rail line and inner city tram tracks. Having the tram-trains stop at all stations makes it possible to use true regional trains to provide express service on the same line. The subject of station spacing and stopping patterns for Tram-Train systems is an excellent topic for further research.

6.4 Technical Issues

6.4.1 System Change Area and accessible Network

Since type A and B Tram-Train vehicles operate on both the city tram network and the standard gauge railway network, they need to be designed to operate using two different types of power supply, signaling systems, physical profiles etc. Consequently the Tram-Train rolling stock is generally more complex and expensive than standard trams or comparable regional rail trains.

One aspect of operating using different systems is that a particular place where the Tram-Train vehicles change from the tram track to the heavy rail track is necessary. At this point power supply changes, a different rail profile is applied, and different rules and regulations must be followed (e.g. other safety standards).

The ease of making the changeover between the railway and tram networks is important for determining Tram-Train system feasibility. The first requirement is that there must be a suitable physical location where the networks can be connected. This means physical proximity and sufficient space for the transition infrastructure.

An important factor in Tram-Train system success is the extent of the network that can be reached with a single changeover area. The best case is when it is possible to reach the whole heavy rail network with just one interface. In contrast, if several changeover areas are needed and/or several different power systems are used on the heavy rail system, the situation is not

optimal. Therefore, a good indicator of Tram-Train system feasibility is the ratio between ease of building the changeover area and the reachable network.

All the existing Tram-Train systems in Germany have a good ratio of these factors. In Zwickau for example, the system uses an old siding track at the main station. In Karlsruhe the Albtal railway terminal was located directly adjacent to the city tram tracks and could be rebuilt quite easily into a through station for Tram-Trains (Figure 6).





FIGURE 6 Karlsruhe Albtal-railway-station [7].

6.4.2 Existing Tram and Heavy Rail Track Technical Standards

The technical standards of the existing tram and heavy rail systems have a significant influence on the ease of implementing a Tram-Train system. The main advantage of Tram-Train systems is that they can operate on existing infrastructure, if large infrastructure investments are needed, then the cost benefit ratio for a Tram-Train system is reduced.

Some key technical standards that help determine feasibility include handicapped accessibility, platform heights, the gap between rolling-stock and platform, structure gauges and rail profiles. Tram-Train vehicles must be able to operate on both the existing tram and heavy-rail stations and track. If the networks are incompatible, the system needs new infrastructure. Examples include new station platforms or third rails in the case of rail gauge differences. In both cases the new infrastructure will increase capital costs and operating complexity. In Zwickau, where the inner-city track is quite short, a three-rail track was an acceptable solution.

The power system changeover is a good example of the complexity involved in changing between the standard railway and the tram network. Normally the electric power supply changes, for example from 750V tram system to 15 kV 16.7 Hz AC or diesel. This difference is generally addressed by using dual mode Tram-Train vehicles. However, it is also possible that a region can have several types of power used on the standard gauge rail lines. For example, in Kassel the Tram-Train system uses two different types of dual-system rolling stock (electric/electric, electric/diesel). In this case the added complexity of having two types of rolling stock was less than the cost of electrifying the rail line. In Saarbrucken (a German border city where it might be

possible to extend lines on both the German and French national rail networks), the decision to build a Tram-Train system was likely made more to support reintroduction of the tram since the three different electrical power systems will make future extensions complicated.

The important point is that planners must carefully consider how the infrastructure and rolling stock will work together when considering the feasibility of a Tram-Train system. More complex systems reduce feasibility.

6.5 Quality of Existing Connections

The benefit of a direct connection depends on the current situation for reaching the city center. If the railway station is near the city center there is little need for a Tram-Train system, because regional rail passengers can simply walk to the city center.

If passengers need to transfer between regional trains and inner-city transport systems, planners must consider specific qualities of the transfer process including distance, level changes, and scheduling. The main criterion is transfer time. If there is a good and fast existing connection with a harmonized timetable, the benefit of a Tram-Train system will be limited. If there is a bad connection, the benefit of a Tram-Train system can be high, reducing travel time and increasing comfort and passenger demand.

Therefore an important part of analyzing the benefit of a Tram-Train system is evaluating the possibilities for improving the existing transfer between regional rail and city transit. Karlsruhe's experience is typical: the Albtal-railway station and the main station were quite far from the city center and transfer conditions were poor. Directly connecting the regional lines to the tram network was shown to be the best solution.

6.6 Institutional Complexity

In addition to being technically complex, Tram-Train systems are institutionally complex. The service operates in both cities and suburban areas – two different areas, with somewhat different interests. On an operations level, the vehicles run on several different track infrastructures with (generally) different owners and other operators. This means, for example, that train drivers must be trained on several networks. It is easy to see that the system involves many actors all with their own interests. Furthermore, in addition to different transportation actors, a Tram-Train system can only be realized in coordination with cooperative city planning.

Implementing such a complex system requires very good cooperation between the different actors. Finding common ground can be difficult, but is essential.

An important factor in the development of Tram-Train systems is prior experience. If a country has experience in planning Tram-Train systems it has experts in this domain and a legal basis for proceeding. This assists and accelerates Tram-Train-projects. This effect is shown clearly in Germany and France, where many new projects were started after the first system was realized.

As outlined above, even though a Tram-Train system uses existing infrastructure sometimes the investment cost can be high (depending on the existing technical conditions). Therefore, Tram-

Train systems need to have a certain "level of support" in the city for transit including financial resources. Many Tram-Train projects have been rejected due to lack of funds and/or political support.

6.7 Strategic Planning

Thinking strategically is important when planning a Tram-Train system. For example, planners should carefully compare Tram-Train systems to other solutions including alternatives such as extensions of existing systems and improving transfer possibilities at the railway station serving regional trains. Both are good ways to achieve similar benefits at lower costs. It is also important to consider how the Tram-Train system fits into the long range city/regional transport plan.

Strasbourg is an excellent example. The city originally intended to extend its existing tram network in a first step and then connect it with the regional standard rail network in a second step. Since the project required a very expensive tunnel for the system change area, it was postponed several times. Instead, Strasbourg decided to improve the transfer conditions at the railway station and make further extension to the city tram system.

7. CHECKLIST

The research goal was to develop a checklist for identifying optimal conditions for Tram-Train systems. This checklist was developed using the factors discussed in the foregoing sections. The checklist provides a rough analysis tool for planners to evaluate whether a city is suitable for a Tram-Train system. Table 3 presents the checklist.

Each criterion on the list should be evaluated on a sliding scale (for example 1-5 points). If, using the checklist criteria, a city seems suitable for introduction of a Tram-Train system, then a more detailed analysis should be completed. The first aspect of this detailed analysis is capacity. In analyzing capacity it is important to take into account that the higher level of comfort and the shorter travel time provided by a Tram-Train system can significantly increase the passenger volume.

TABLE 3 Checklist for Possible Tram-Train-Cities

Characteristics of the Cities Size of the city Regional metropolis Existence of a suitable tram-corridor Conversion of the corridor (monument conservation?) (only for type B) City too small for tram network/ bus used to capacity (type B) Existence of a main center of activity Further smaller centers of activity along the line Distance between railway station and center of activity **Characteristics of the Region** Orientation to the city (rural metropolis) 10 Settlement structure/ structure type of the region Settlement structure along the heavy rail (size, distance betw. villages) 11 12 Population density and reachable inhabitants Possibility to connect a bigger city at the end of the deployment radius Infrastructure and Technic Existence of a suitable corridor/elementariness for power system change area 15 Ratio between costs and reachable network Platform heights (tram/heavy rail), complexity for handicapped accessibility (for type A) 16 Technical parameters of the heavy rail tracks (equipment, decision between special rolling stock or conversion of the track) 17 18 Technical parameters of the existing tram (gauge) (for type A) Possibility for dividing the project in several stages **Existing Connections** 21 Existing connections (quality, travel time, comparisons) 21 Completion to the overall system Capacity on the tracks with today's connections Capacity on the crossroads/stations with today's connections Circumstances of transfer process train/tram **Institutional Circumstances** Situation of the railway/tram companies (financial situation, organizational structure) 26 Cooperation between city and regional area 27 Politics/ strategy of the city Financial situation of city and region 28 Position of state adverse projects (financial support) Regulatory situation Experience of the country with Tram-Train-projects **Further Prerequisites** Acceptance (especially traffic in the city center) 33 Existing development plans Rough comparisons with possible alternatives: Costs and benefits (Other application areas, for example tangential connections (Tram-Train Paris)) **Basic Conditions** 36 Capacity and capability (verification)

8. DISCUSSION

Tram-Train systems can be excellent additions to transit in many cities, however they require particular conditions to be successful. The goal of this research was to identify those conditions.

Tram-Train systems involve mixed operations on tram and standard heavy rail tracks. This mixed operation and the many interfaces it creates, increases complexity and sometimes requires compromise solutions and changes to the existing networks. Furthermore, although Tram-Train systems are designed to operate on existing infrastructure, they can be difficult and expensive to implement. It's important to note that solutions found today in Karlsruhe or Kassel (inadequate handicapped accessibility) will not be accepted in future systems, thereby increasing complexity and costs.

Successfully introducing a Tram-Train system requires extraordinary good cooperation between many stakeholders. This requires time and good institutional cooperation. Tram-Train-planning must be integrated in the city and regional planning.

Under the right circumstances, Tram-Train systems can be very beneficial, increasing the number of transit passengers and improving the modal-split. Providing a direct connection to the city center increases comfort and reduces travel time. On the other hand, a good conventional regional rail system without a direct connection but with good transfer conditions and a well-coordinated schedule can also offer comfortable and fast connections.

A Tram-Train system can become the victim of its own success if ridership becomes too high. The system can quickly reach its capacity limit (a particular problem due to limited vehicle length). Operating trains more frequently can increase capacity, but increases operational costs and congestion in center cities and may not be possible due to a lack of capacity on the standard rail network. European experience shows that Tram-Trains can cause considerable disruption in central pedestrian zones, therefore very low headways may not be accepted. Expensive tunnels under the city center then become necessary, as the situation in Karlsruhe shows.

The checklist developed as part of this research allows planners to make a rough assessment of whether a Tram-Train could be a good option for a city. Carefully considering these factors early in the planning process could help reduce the number of unrealistic projects and save time.

The number of Tram-Train projects in planning or under construction shows that the expansion of this hybrid transit mode is not over. There are still cities that offer great conditions for a Tram-Train system. In short, Tram-Train systems have a future.

REFERENCES

[1]

Karlsruhe Model, Transport Technologie-Consult Karlsruhe GmbH (TTK), Karlsruhe, www.tramtrain.org (Accessed July 20, 2011).

[2]

Map background: Blank Digital Map of Europe, http://www.youreuropemap.com/ (Accessed July 20, 2011).

[3]

Phraner, S. D., R. Roberts, et al. Joint operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads, TCRP Report 52, TRB National Research Council, Washington D.C., 1999.

[4]

Cervero, R. The Transit Metropolis – A global inquiry. Washington, D.C., Island Press, 1998.

[5]

Annual Report 2010, Page 14/15, Albtal-Verkehrs-Gesellschaft mbH, Karlsruhe, http://www.avg.info/fileadmin/user upload/avg/pdf/GB/AVG GB 2010.pdf (Accessed July 20, 2011).

[6]

Die Kombiloesung, KASIG - Karlsruher Schieneninfrastruktur-Gesellschaft mbH, Karlsruhe, http://www.diekombiloesung.de/kombiloesung/projekt.html (Accessed July 20, 2011)

[7]

Pictures: Lorenzo Naegeli, 2010

[8]

Leichte Nahverkehrstriebwagen (LNT) der AVG auf dem Netz der DB AG, Transport Technologie-Consult Karlsruhe GmbH (TTK), Karlsruhe, http://www.tramtrain.org/de/framework/lnt/lnt01.html (Accessed July 20, 2011).

[9]

Verordnung über den Bau und Betrieb der Straßenbahnen (Straßenbahn-Bau- und Betriebsordnung - BOStrab), Bundesministerium der Justiz Deutschland / Juris GmbH, http://www.gesetze-iminternet.de/bundesrecht/strabbo 1987/gesamt.pdf (Accessed July 20, 2011).

|10|

Alstom Regio Citadis, Alstom Transport, France, http://www.bus-tram.de/Datenblatt_RegioCITADIS.pdf (Accessed July 20, 2011).

[11]

Demographics, City of Austin, Texas, United States, http://www.cityofaustin.org/demographics/(Accessed July 20, 2011).

[12]

Entwicklung der Karlsruher City, Page 7, Wirtschaftsförderung Karlsruhe, http://www1.karlsruhe.de/Stadtentwicklung/afsta/Stadtentwicklung/download/ZukunftInnenstadt_2007.p df (Accessed July 20, 2011).

Let's Get on With It!

LRTA submission to Lets Get Wellington Moving

18/1/18

This is the submission to Let's Get Wellington Moving by Brent Efford, NZ Agent, on behalf of the Light Rail Transit Association. See 8.1 and 8.2 below.

1 Executive Summary

- A completed rail spine is essential if we are really going to get Wellington moving more efficiently.
- Lets Get Wellington Moving has failed to take into account the role of the rail system, which serves 75% of the regional population, shoulders 70% of the public transport load in greater Wellington and covers 92% of the transport corridor.
- Although the congestion issue is felt most keenly in central Wellington City, the traffic is generated regionally and alternatives to it must take a regional perspective as well. This LGWM fails to do: the non-motor transport modes proposed for development (walking, cycling and buses) as in Scenario A only service the needs of Wellington City south of the Railway Station (< 100,000 population), whereas big investments in roading, particularly various grade separations for SH1 traffic as in Scenarios B, C and D, are proposed to deal with car traffic originating throughout a metropolitan region of nearly half a million.
- LGWM has been criticised by the new Government for its lack of ambition and failure to
 properly incorporate rail transit into its thinking. If it is not to be a 'wasted exercise',
 LGWM needs to adopt a more rail-friendly approach and draw on the information
 which is readily available both in Wellington and overseas.
- Wellington is 'made for light rail' in terms of any of the metrics which indicate success
 factors for LRT internationally. Paradoxically, however, Wellington is unique in having a
 rail transit system which covers the suburbs competently but which does not penetrate
 the metropolitan CBD. This is the reverse of the pattern for developing rail transit
 internationally.
- The optimum design of a light rail line to extend rail south of Wellington Railway Station and to the Airport is a single route clearly indicated physically, intuitively and by numerous studies carried out over past decades. The route is the same as the Growth Spine designated by the Wellington City Council.
- The main civil engineering required would be an overdue new link between inner
 Wellington and the eastern suburbs in the form of a Mt Albert Tunnel between the Zoo
 and Kilbirnie. It would carry pedestrian and cycle traffic as well as light rail and would
 also improve resilience to natural disasters.
- A shorter tunnel, expanding the existing cycle/pedestrian tunnel under the Airport runway, would also be required, and would also have multiple uses.
- The idea of a waterfront tramway as planned by the City Council in the mid-1990s should be revived and expanded to cover major new inner-city traffic nodes and act as a relief line for the regional light rail to bypass the Golden Mile if required.
- It is probable that within a few decades urban transport will be fully automated i.e. driverless. In this scenario, private car ownership will be replaced by small electric

- autonomous vehicles (AVs) operating on-demand taxi-type services. These will replace conventional buses on fixed routes and schedules. However, along the very dense corridors typically served by rail transit, the AVs required to move equivalent passenger numbers simply will not fit. Fortunately, rail transit is readily automated and will continue to be the backbone of urban transport in dense cities.
- In other words: expansion of inner-city highway capacity a la LGWM scenarios B, C and D to accommodate the current large volumes of one-person-per-vehicle privately-owned cars could well turn out to be a redundant stranded investment, whereas completing the rail system using light rail will continue to be of value even into a fully driverless future.

2 Rail-aversion puts LGWM on the wrong track

2.1 The Minister of Transport, Hon Phil Twyford, has criticised the four scenarios presented by LGWM for public consultation:

... They have also been criticised by the Transport Minister, who said new proposals to fix Wellington's traffic problem are lacking ambition.

Phil Twyford says he's committed to working with Wellington but seems unimpressed

Phil Twyford says he's committed to working with Wellington but seems unimpressed with its road-focused approach.

"We have a Government that is committed to building up the role of public transport, and investing in modern rapid transit in our cities to make them work better, to reduce congestion and give people a much better alternative to being stuck in traffic."

(http://www.newstalkzb.co.nz/news/wellington/transport-proposals-accused-of-lacking-ambition-environmental-focus/ 17/11/17)

- 2.2 None of the four scenarios offer an alternative, non-congesting, choice of transport mode to most urban commuters i.e. the 75% who live north of Wellington Railway Station and whose predilection for driving (for many, this is because the 'lack of rail penetration of the CBD' makes public transport unattractive) is the main cause of the inner-city congestion which LGWM is meant to cure.
 - It offers no solution to greater Wellington's unique public transport deficiency the rail transit system which serves most of the population does not penetrate the CBD and beyond where most regional travel destinations lie. Normally rail transit development worldwide starts along an inner-city corridor and expands outwards. No other city in the world has such an incomplete rail system and is happy to perpetuate that situation indefinitely.
- 2.3 Nor does the LGWM approach support a rapid transition to a zero-carbon transport system surely a critical requirement nowadays. Nor does it deal with the land use, urban sprawl and CBD parking demand issues by offering such minimal incentives for current car drivers to switch modes. This is particularly egregious considering that the RONS program of multibillion dollar projects which will make long-distance car commuting faster and **more** attractive (at least as far as Ngauranga!) Transmission Gully et al is now well underway.
- 2.4 Also noteworthy is that copious information supplied by myself and my colleagues in Trams-Action, including evidence of previous studies and overseas experience relevant to Wellington, appear not to have been taken on board judging from LGWM

- representatives' answers to questions at the 15 November scenarios launch and the 29 November presentation by WSP-PB.
- 2.5 This situation implies an agenda on the part of LGWM to smother demands for rail transit, despite rail's dominance of existing Wellington regional public transport, and concentrate potential large transport infrastructure investment proposed in scenarios B, C and D purely on roads. This mimics the previous Public Transport Spine Study sponsored by the same parties. It has led LGWM to make a number of methodological errors and false assumptions:
 - a) **Disparity of approach:** The need to deal with car traffic originating in the wider region i.e. that which enters inner Wellington City via SH1 and 2 is acknowledged in the high-cost highway improvements proposed in scenarios B, C and D but the non-highway improvements (walking, cycling and busways) proposed in scenario A will only be used by local (inner-Wellington City + maybe eastern suburbs) residents, a minority of the regional population.
 - b) The role of the current rail system, the PT spine for 75% of the population, carrying 70% of total regional PT passenger/km and covering 92% of the SH 1 & 2 corridors, as an alternative to car commuting is ignored.
 - c) The lessons of previous studies and investigations stretching back decades but particularly concentrated in the 1990s, have also been ignored. Only the poorly-framed 2013 Public Transport Spine Study on which international expert Professor Peter Newman commented ..."There is little science behind this study and a lot of politics as it appears to clear the way for motorway spending. I don't think I have seen a study quite so crudely apparent in its anti-rail politics. It should be dismissed."

 (Copied from an email 20/8/13.) is drawn on as a reference.
 - d) Where 'mass transit' is mentioned in LGWM it is confused with 'bus rapid transit', which automatically precludes extension of the dominant rail system, or else as 'light rail' in the form of a local tram system better than just buses but still not part of the regional rail system.
 LGWM claims to deal with the 'Ngauranga to Airport Corridor', over which the mass transit spine for greater Wellington in the form of the Metlink rail system operates on the Ngauranga to Thorndon (WRS) sector. However, when 'mass transit' is considered in LGWM, only the Thorndon Airport sector, the 8% of the regional corridor over which rail does not currently exist, is considered!
 - e) Where 'light rail' is mentioned, it is only posited as a disconnected system operating purely south of the Wellington Railway Station and still requiring an interchange essentially the same as the current one to bus services for regional passengers arriving at WRS. Historically, except for the PTSS, the concept of 'light rail' as proposed in Wellington has **always** meant an extension of regional rail services by integrating street-running modern trams with the existing rail infrastructure (known as 'tram-train' in modern transit industry usage).

 To quote the former Transport Manager of the GWRC, Dr David Watson in regard to the 1990s investigations: ... "We always came to the same conclusion. Light rail as a stand-alone service (Station to airport) was not a winner. We needed to extend to Johnsonville or even the Hutt. We looked at operating standard units and light rail
 - f) Unable to ignore the clamour for light rail entirely, LGWM engaged the WSP-PB consultancy to report on the mode. However, the consultant's brief was clearly limited and contained all the errors and false assumptions mentioned above, and only the PTSS

no problem with this." (Email 6/3/15)

on the same tracks and then allowing the light rail to extend into the City. We saw

was used as a reference. At the 29 November report-back to sustainable transport advocates, the consultants were clearly uncomfortable and apologetic, and admitted that the bifurcated route structure was 'not ideal'.

Their endorsement of the discredited Public Transport Spine Study model of 'light rail' in the LGWM scenarios – including a bifurcated route structure, a badly-located extra tunnel under Mt Victoria and a zig-zag, technically unsuitable, branch route to Kilbirnie rather than a single, simple, 'string of pearls' route linking all nodes – did not reflect 'world best practice'. Or even common-sense local practice.

3 To summarise

- 3.1 It is evident that the Lets Get Wellington Moving project is a left-over from the former Government's RONS (Roads of National Significance? Roads Only, Not Sustainability? Rail's Of No Significance?) policy, coupled with the current Greater Wellington Regional Council's distaste for expanding rail transit and the desire of the majority of regional councillors for 'four lanes to the planes' as the next big transport thing now that the Transmission Gully Motorway is assured.
- 3.2 Three of the four scenarios which the LGWM team have laboured for many months to develop are simply traffic engineering alternatives to the failed Basin Reserve Flyover, the rejection of which kicked off the whole LGWM exercise.
- 3.3 One scenario A de-emphasises the traffic engineering in favour of walking, cycling and PT. A is the best of the options and is a starting point, but critically does not propose the public transport infrastructure necessary to complete the rail system and attract the majority of citizens onto sustainable, high-density modes. For the commuter from Porirua, Kapiti or the Hutt, better walking and cycling facilities in the Wellington CBD won't do a lot to induce a shift from car to rail.
- Only a city rail link can do that and light rail in the form of tram-train is the only practicable means of providing that CRL for Wellington, something that was readily acknowledged by regional and city councils, the railways, consultants and advocacy groups, the daily media and even the Government in the many studies and proposals prior to 2008.

4 A way forward – use our existing strengths

- 4.1 Wellington is clearly 'made for light rail' in the form of tram-train due to the synergy of the following factors:
 - a) The metropolis of 'Wellington' has a population of nearly half a million which, although distributed over a number of satellite cities and districts with strong sub-centres, is very highly focussed on a single central business district containing about 50% of regional employment and the focus of most other travel-generating activities.
 - b) The overall population of Wellington and its distribution is truly at the 'Goldilocks' spot for light rail development. We are not 'too small' for light rail, the familiar canard of the rail-haters (how to explain the existence of the heavy rail system, which would cost many billions to build today, if that is the case!) but nor is the region large enough (1M+) to support an underground railway as was planned in the 1960s. A single integrated surface rail system using light rail is 'just right' for our size.
 - c) Half of the region's employment and most of the tertiary education, cultural, entertainment, professional sporting, tourist, healthcare and central government activity – and the highest density and fastest-growing residential development – takes

- place within a strip about five blocks wide and five km long a better rail corridor would be hard to imagine!
- d) The region's electric rail PT spine covers about 92% of the transport corridor represented by state highways 1 & 2, but the greatest density of regional travel destinations and population is in the non-rail 8%.
- e) About 75% of the total regional population is in the catchment of the rail spine. Reducing inner-Wellington congestion means getting more of this 75% to use rail and this will not happen if rail does not penetrate the densest destination corridor.
- f) The rail spine terminates at the edge of the regional CBD. Worldwide, this situation the main or only rail transit system **not** offering a seamless ride into and through the CBD seems unique to Wellington. Only Auckland, that I know of, currently shares this crippling deficiency in its PT. And there \$3bn is being devoted to constructing their City Rail Link! World experience dating from the very first tram lines in New York (1832) and New Orleans (1835 and still going!) is that **CBD penetration is the main reason you build rail transit in the first place!**
- g) The Wellington rail system carries only about 40,000 passengers a day (11M pa) well below a typical new light rail system, or even many individual on-street tram lines in cities like Melbourne. Even if rail patronage was to double as a result of introducing integrated light rail a quite likely outcome the traffic would be easily handled within conventional LRT parameters.
- h) The **current rail system is quite 'light rail-like'** in a number of important respects: the 2.7m wide x 43 m long Matangi EMUs have the floor area and hence capacity of a modern articulated tram; short trains generally only one unit off-peak; maximum half-hourly headways; one of the lines is ill-suited to EMUs compared with trams (in 1931 the Evening Post observed that the Johnsonville Line would make a 'bonny tram line'!). A staged introduction of tram-trains replacing the Matangi EMUs as the latter wear out would be quite straightforward.
- i) Within the modern era, **light rail as an extension of the rail system was studied/planned in 1992** (Superlink), **1993** (Travers Morgan an imminent start on CBD light rail was even announced by Dr Watson and praised in the Evening Post 23/11/93), **1995** (Works/MVA), **1999** (Regional Land Transport Strategy, slated for 2004 19 implementation), **2000** (SKM report for Lower Hutt City Council) and **2006** (North Wellington PT Study). The concept was also studied and endorsed by the railways management at various times from the 1980s onwards, including the decade of Tranz Rail private ownership, and acknowledged by Hon Dr Michael Cullen, Minister of Finance, at the time that he rejected a Johnsonville rail-to-bus conversion in 2006. All this has been covered in reports and presentations already supplied to LGWM.
- j) A show-stopper for any light rail which is **not** integrated with the suburban rail system with its current facilities (the EMU depot opposite the Stadium) is the **provision of a suitable stabling and maintenance depot** somewhere along the likely route. The smallest size of depot for a small light rail system with articulated trams is represented by **Adelaide's Glengowrie facility**. (I visited it in 2012 as part of a tram conference. We were shown the special provisions they had made to squeeze the stabling and maintenance of their tram fleet into the limited space it is the very minimum size that a modern tram depot can be. But look it up on Google Earth and consider where on earth a site even of that modest size could be obtained in southern Wellington anywhere near a sensible tram route unless hundreds of millions is to be spent just on the depot, and community resistance to the loss of housing or Town Belt overcome.)

5 Design of Wellington light rail

- 5.1 The most common question asked about light rail in Wellington seems to be "where would it go"? In my view, the answer is so obvious and traditional that detailed consideration of alternatives is hardly merited. The Golden Mile Courtenay Place Basin Reserve Adelaide Rd Riddiford St route:
 - Was the obvious 'main street' of Wellington from the first drawing of the settlement in 1840
 - from 1878 was the route of the first steam tramway (which was almost connected to the Hutt Railway to form a steam-age tram-train operation)
 - Was the main line of the electric tramway system for 60 years, and as a result ...
 - Was the spine around which the city grew and densified
 - It is the main part of the Growth Spine, designated by the Wellington City Council to encourage densification along a high-capacity public transport route
 - Is level or nearly so, and has few significant curves
 - Can be engineered to be largely free of conflict with motor traffic
 - Much of the route can be pedestrianised, grass surfaced or exclusive right of way
 - Until Newtown Park is reached, requires very little property purchase and no significant civil engineering
 - Can provide a stop, or even a temporary terminus, right at the front door of the Regional Hospital, a major travel focus.

The total route from Wellington Railway Station to the Airport is summarised on the attached Wellington City Rail Link drawing. The previous studies which have covered elements of the drawing are listed on it.

- Wellington Railway Station: even if there is full adoption of tram-train-only electric rail 5.2 decades hence, there will always be a need for heavy rail:LRT interchange at WRS, and there should also be physically better interchange with buses, too (although, as noted in 6 below, bus services as now constituted may well disappear in 30 years or so). A likely first stage would see LRT operating only south of WRS, or just to Johnsonville, but having crossplatform interchange with heavy rail would still be of benefit to passengers on all lines. Having light and heavy rail platforms on the same level and sharing the same pedestrian circulation area is a common design feature of major stations around the world. Of systems I have visited, San Diego, Dallas, Los Angeles, London (Wimbledon) and Manchester (Victoria) all share that feature, which makes for the easiest possible physical interchange. Achieving that situation at Wellington is quite straightforward, as suggested in the 1995 report. It would involve realigning Platforms 1 and 2 and leading the LRT tracks into Lambton Quay via the current bus parking area. Removing the existing concrete pedestrian spiral ramp – little-used and a safety hazard – and instead developing commercial space at the first-floor level over the LRT tracks would be part of the package.
- Lambton Quay: From there it is a simple matter to lead the tracks down the west side of Lambton Quay. It would enable several traffic signals to be dispensed with and would be an ideal facility for a substantially pedestrianised Quay. Any road vehicles entering Lambton Quay would do so via one-way round-the-block loops fed from Featherston St. Without frequent cross-streets to unduly limit platform length, tram-trains as long as two Matangi sets (84m) would be quite feasible.

- Central section: the 1995 report recommended the separation of north and south-bound lines into Willis and Victoria Streets respectively. This will allow full-width (2650 mm wide) articulated trams, and 25m minimum radius curves (the international light rail norm) to be used. This one-block separation of tracks in narrow areas is very common on overseas systems.
- **Courtenay Place:** as the 1995 report noted, Courtenay Place has ample room for an interim terminus, though parking the trams around the corner on grass in the median might help operations.
- right of way is available simply by converting the parking strips beside the median to grass-surfaced tram track. Both tracks should be located on the east side of the Basin itself, with the embankment or a stand cantilevered over. Southbound SH1 traffic should be diverted to Hania St, simultaneously easing the turns that traffic must make, improving traffic flow and improving the environment of the Kent/Cambridge boulevard. Note that both crossings of SH1 would be priority signalled this is the only interface with SH1 that the light rail line would have under this proposal.
- 5.7 NOT the Ruahine St branch! Missing from this submission is any support for a bifurcated LRT route structure the simplicity of a single 'pearls on a thread' route coinciding with the designated Growth Spine is a big plus for light rail. And if there was a case for a second line, via a second Mt Victoria Tunnel and alongside SH1 via some sharp curves and in an area with limited on-line passenger demand would be the very worst place to put it! Moreover, such a way of reaching Kilbirnie, let alone the Airport, involves more total track length than directly from Newtown to Kilbirnie via a Mt Albert Tunnel, would be slower, have more traffic conflicts and higher operating costs. It breaks all the 'rules' of good LRT practice. And it offers no direct connection between the eastern suburbs and the important Newtown and Hospital destinations.

The proposal for a branch via Ruahine St arose part way during the PTSS development process. Clearly it was because 'light rail' on the single traditional route was starting to look like an attractive and cost-effective option and there was a political motivation to create a model of LRT which could be written off as too costly and unattractive. This tactic worked for the PTSS but it is inexplicable – unless you ascribe ulterior motives – that it should be repeated by LGWM.

- **Adelaide Rd and Hospital:** Adelaide Rd is already designated as a growth area for future densification. The road-widening designation creates a convenient margin for grass-surfaced track from the Basin Reserve to Hospital Rd. At the latter, it is possible to create a right of way within the hospital grounds behind the shops fronting John St (which should be retained) to platforms for a stop (and maybe temporary terminus) outside the Hospital main entrance.
- **5.9 Riddiford St:** The Newtown shopping area has a very high pedestrian density likely to grow as residential density increases. The high-density transport mode light rail should have priority over through car traffic. The through LRT line needs to have an exclusive RoW in Riddiford St, perhaps with shared pedestrian space in the shopping area. Road traffic in at least one direction needs to be redistributed into adjacent streets such as Daniel.

- and sufficiently light to enable sharing with modern trams without too much inconvenience just as the trams which used to operate here did until 1964. The Roy St/Newtown Park area would be a prime candidate for transit-oriented development when the regional rail spine reaches it. Housing densification, better use of Newtown Park and improving the profile of the Zoo are all possibilities. For a minimal impact, the line could be in Roy St and have a station at the former tram/bus terminus; a higher impact development would see the line within Newtown Park and removal of the existing houses on the south side of Roy St.
- 5.11 Mt Albert Tunnel: this tunnel was first proposed in 1992 as part of the Superlink report. It would be instead of a transit tunnel via Mt Victoria. There is no dispute that there is justification for more access between the inner Wellington basin and the eastern suburbs no new traffic lanes of any sort have been created since the opening of the Mt Victoria Tunnel in 1931 87 years ago! The last, and only, exclusive, single, public transport lane is the Hataitai Tunnel, opened in 1907 111 years ago. But both those tunnels are badly located as far as achieving a single easy and fast rail connection to the eastern suburbs and Airport is concerned (see 5.7 above) whereas a direct line from Roy St to Coutts St is an ideal location.

The Mt Albert Tunnel would be created to serve many functions, not just light rail: a shared cycle and pedestrian route, drainage and other utility and tsunami evacuation, for example. And the spoil could go towards a runway extension or raising parts of the south coast ahead of sea level rise.

Andre de Groot, a Trams-Action trustee and a professional consulting civil engineer with experience in Toronto and Auckland as well as on the Arras Tunnel has provided this technical comment on the proposal:

I have now had a look at both ends of where a Mt Albert Tunnel could go, walking along the Kilbirnie side yesterday. I have attached a pdf showing it on a map showing a route going from Roy St to Coutts St, which is the same route as shown by Brent's overall route map.

As to how it would be built, I expect construction would be similar to the Northern Gateway Tollroad Johnstone's Hill tunnels. I was a part of the wider project team and got to observe the construction. These tunnels were ~13m wide, 340m long and built by using a 'road header' which is basically a giant drill bit. First the roof is constructed by excavating the roof with the road header and installing rock anchors with shotcrete. No people are allowed under sections without the shotcrete so this work is done by remote controlled equipment to reduce the chance of construction accidents. Once that is done, the job of digging down was quite simple by using a road milling/planing machine. Then a concrete lining was added for aesthetic reasons. This road header approach is more economic for shorter tunnels. Twin 340m long tunnels were built plus multiple bridge, 4 million cubic metres of dirt shifted and 7 km of motorway all of \$360 million a decade ago.

As to the question of tunnel width of the Mt Albert tunnel, I have the following thoughts. I estimate that at 30km/h it would take 100 seconds for each LRV to pass

through, 60 seconds at 50 km/h. At this headway either single or double tracked could be done. If using a road header, I think a wider tunnel would be easier for using conventionally trucks to remove the spoil and generally to create less confined workspaces. Usually a walkway is provided for escape. If it were double tracked plus with pedestrian and cycle lanes then it would give another cycle route. So single or double tracks are both options to be chosen during the design phase. (Email 10/1/2018)

- 5.12 NOT the Constable Connection! There have been suggestions of a light rail 'Constable Connection' i.e. re-using the old tram route over Constable St and Crawford Rd to get to Kilbirnie instead of the Mt Albert Tunnel. This would save capital cost though maybe only a little but has some egregious defects which should rule it out:
 - The route would have to share with fairly intense car traffic, limiting speed and productivity
 - The turn at the Riddiford St/Constable St corner is sharp, maybe requiring property purchase for mitigation
 - The narrowness of Constable St would almost certainly entail property purchase and widening to acceptably accommodate both current traffic and a double-track tramway independent of traffic
 - Crawford Rd built in 1915 to accommodate the slow trams of 100 years ago is too sharply curved to allow acceptable speed and capacity for modern articulated trams.
 Property purchase and civil engineering could mitigate this, but probably at a cost equal to a tunnel without its co-benefits
 - When the bottom of Crawford Rd is reached the line meets the most congested non-SH1 intersection in the eastern suburbs: at Bay and Rongotai Roads. There is no obvious way to separate trams and traffic at this point, other than by further capital-intensive rebuilding
 - Getting from there to the fastest and most direct route to the Airport Coutts St would involve two more 90° turns, again replicating former tram lines but unsuitable for modern requirements
 - The potential co-benefits for pedestrians, cyclists, tsunami evacuation, Newtown Park TOD, etc of a Mt Albert Tunnel would not be available.
- **5.13 Coutts St:** the original tram connection to the Miramar Peninsula, Coutts St is wide and quiet enough to accommodate modern trams without unduly impacting motor traffic and cycling although banning parking on at least one side might be necessary.
- 5.14 Airport Tunnel: to reach the airport terminal building complex, a tunnel under the runway is necessary for speed and efficient operation. (The proposal to route light rail around the north end of the runway, squeezed against SH1, just to avoid a tunnel, is so slowing, inefficient and technically inappropriate that it hardly merits further analysis.) Fortunately, the existing cycle and pedestrian tunnel from the end of Coutts St is available on the optimum route to act as a pilot tunnel, reducing the time that the runway would be unavailable due to construction work.

As with the Mt Albert Tunnel, a runway tunnel would be multi-use, serving not only LRT but also cyclists and pedestrians and airport service vehicles. Single track through the tunnel and within the Airport boundary beside the end of SH1, with two tracks just at the terminus beside the baggage claim area inside the terminal building, would be all that is necessary.

Another comment from Andre de Groot:

As to a tunnel under the airport runway, while it would be challenging to do so, with construction windows of around 6 hours, I think that it is achievable. A pair of walls could be constructed as secant walls using the Continuous Flight Auger (CFA) technique. CFA pile rigs are incredibly fast, able to install several piles per hour. Precast concrete panels could provide the roof. The tunnel under the runway could be tendered as a separate design and build tender, to allow for innovative tender designs. The tenders could then be judged against the estimated benefits of the more direct route that avoids state highway traffic.

- 5.15 Miramar extension: the expansion of the movie industry and its tourist spinoffs in Miramar make an extension of light rail past the Airport worth considering, if it can be constructed cost effectively. This extension isn't shown on the current version of the attached infographic but is conceptually simple enough: a triangle junction with the Airport line at the intersection of Broadway and the end of SH1, then generally follow the old tram route up Hobart St and Park Rd and terminate at the intersection of Park Rd and Camperdown Rd the 'heart of Wellywood'.
- 5.16 The Waterfront Tramway: also shown on the attached infographic is a waterfront tramway the yellow line. This is proposed as envisaged by the City Council in the mid-1990s, as an urban circulator connecting the waterfront and the Golden Mile but integrated with the regional light rail line. It draws on the 1993 report by Dr Neil Douglas, but with the route extended to include subsequent major developments such as the Stadium, Te Papa, cruise ships, etc.

It would be able to provide a bypass of the Golden Mile if the latter is blocked by parades, emergencies etc, and also provides a morning relief line for tram-train services at the 'peak of the peak' if travel growth ever increases to the extent that this is necessary.

6 Anticipating automation – future-proofing light rail

- 6.1 Occasionally suggestions are made that the advent of autonomous vehicles will make rail transit redundant, and it is predictable that other submissions to LGWM will follow that line. Reflection suggests that the opposite is likely to be the case: the flexibility of small autonomous vehicles serving low density areas is a direct competitor to scheduled bus services on fixed routes but the space footprint of small vehicles, whether autonomous or manually-steered as now, makes them completely unsuitable for high density corridors such as the PT spine through central Wellington.
 - Autonomous vehicles will be a very good fit for 'last mile' services between the rail spine and final destination, and developments to this end by transit agencies are already underway in the US, sometimes using Uber as an intermediate step.
- 6.2 The most important point, though, is that rail is well suited to driverless operation, and some leading rapid transit lines have been automated for decades. Off-street light rail is already automated in some locations like the Muni Metro subway in San Francisco or London Docklands and extending driverless operation to the on-street environment, or to mainline heavy rail, is a matter of applying technology already developed.
- Overall, automated operation of all urban transport is only a matter of time. It will bring many efficiencies to operations and reduce car ownership and car numbers in favour of

shared on-demand taxi-type services. Thus the demand on road space is likely to actually reduce but the need for automated transport along the highest-density spine will continue to increase. If future-friendliness is important to Let's Get Wellington Moving, NOT developing further highway capacity increases but instead completing the rail infrastructure to cover 100% of the regional transport spine should be the priority.

7 Let's get on with it

- 7.1 'Light rail' as a concept has been studied to death in Wellington over past decades. In the same time, light rail lines have been introduced and extended in hundreds of cities overseas, dozens of industry conferences and other information exchanges have taken place and the LRT information available on the internet and from personal travel has increased exponentially.
 - Paralysis by analysis must be avoided we have had enough 'whether' studies of light rail in Wellington; any further studies must concentrate on 'how' and even that is pretty obvious, given work already done by the GWRC in more enlightened days.
 - Other than for completing the engineering design, there is no justification for further 'investigations' prior to the political decision.
- 7.2 Light rail is not new technology or high risk every Wellington situation I can think of has already been considered and solutions found and proven elsewhere in the world. Calls for 'further studies' only seem to mask a desire by the anti-rail lobby to delay progress until a rail-unfriendly Government is again elected. A political go-ahead decision now is required.

8 Who are we?

8.1 Introducing the LRTA: The Light Rail Transit Association was formed in the UK in 1937 and ... "is the world's leading organisation concerned with the achievement of better public transport through light rail, tramway and metro systems in towns and cities world—wide." (http://www.lrta.org/)

The Association is a partnership between civil society advocates (such as myself) and professionals within the public transport industry.

The main activities of the LRTA are:

- Information provision and advocacy through submissions such as this one
- Publication of the monthly industry-and-enthusiasts' magazine Tramways and Urban Transport; T&UT is available online, by subscription, and also retail in some magazine outlets like Magnetix in Wellington.
- Sponsorship of major UK light rail industry events such as the annual Light Rail Awards and a separate annual industry conference.

Although remaining UK-based, the LRTA has a world-wide reach, including agents such as myself in a number of countries. One of its most notable achievements was the provision of information about modern tramways which informed and led to the establishment of light rail in San Diego, opening in 1981 – the first new-generation LRT system in the United States and the progenitor of several dozen new systems now operating there.

8.2 Introducing Brent Efford: I am the New Zealand agent for the LRTA – a relatively recent appointment compared with my total light rail experience ...

•	1963	Joined the Tramway Historical Society, Christchurch (the resource centre for the current Christchurch Tramway), starting a life-long interest in tramway heritage and rail transit, leading to
•	1979	Started investigating modern tramways for Wellington, at the request of the late Cr David Bull, chair of the WCC Transport Committee and my manager at the time.
•	1980s	Light rail specialist within Transport 2000
•	1992	Co-author of 'Superlink – Wellington's transport opportunity'
•	1999 – 2006	PT/pedestrian/cycle or 'environmental sustainability' representative, Wellington Regional Land Transport Committee
•	2000	Delegate to UITP 'Light rail for liveable cities' conference, Melbourne
•	2001	(Unsuccessful) candidate in Wellington City Council elections, mainly advocating light rail
•	2003	Winston Churchill Fellowship – WELLtrack light rail study tour to the US
•	2003	APTA/TRB light rail conference, Portland, Oregon
•	2004	Towards Sustainable Land Transport conference, Wellington – presented paper 'Wellington rail and the sustainable vision'
•	2006	Member, reference group, North Wellington Public Transport Study
•	2009	WELLtrack Mk II – return visit to cities visited in 2003
•	2009	APTA/TRB light rail conference, Los Angeles
•	2010	CORE – rail engineering conference, Wellington
•	2012-13	Reference Group, Wellington Public Transport Spine Study
•	2012	Council of Tramway Museums of Australasia conference, Adelaide
•	2013	Commissioned report by Tom Matoff, LTK consultants, Davis CA on the Johnsonville Line
•	2014	NZ Rail 2014 conference, Auckland – presented paper 'Rail penetration of the Wellington CBD – the search for solutions'
•	2015	NZ Rail 2015 conference, Wellington – presented paper 'Rail penetration of the Wellington CBD – engineering a solution'
•	2003 – date	Publisher of scores of emailed newsletters in email and PDF format detailing light rail developments around the world and their relevance to Wellington.

All of the papers and presentations mentioned above have been supplied as PDF files to LGWM during the consultation process.

Brent Efford

NZ Agent, Light Rail Transit Association PLC

1 Boston Tce

Aro Valley,

Wellington 6021.

brent.efford@techmedia.co.nz

Submitted 18 January 2018