Wellington Cable Car and its Engineering Heritage

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Abstract
Wellington's iconic Cable Car is a fully functioning funicular railway that carries in excess of 1,000,000 passengers per annum. It serves a dual purpose as a vital transport link between Lambton Quay and Kelburn, and as the second most popular tourist attraction in Wellington. It first opened in 1902 and has recently been the subject of an application for an Institution of Mechanical Engineers Heritage Award. It was designed by James Edward Fulton who, assisted by Maurice O'Connor, constructed the 785 metre (m) system, rising over 119m at an average incline of 1 in 5. At the time, it was a major engineering achievement for New Zealand and the railway track passes through three tunnels and over three viaducts. Despite being commonly referred to as a Cable Car, the original system used to operate the ascending and descending cars was in fact a combination of a cable tramway and a funicular. In 1978, the original system was extensively modified and the drive system and passenger vehicles were replaced with the current Garaventa-designed system. The original twin railway tracks were replaced with a single track plus a crossing loop. The drive system was replaced with a variable Direct Current (DC) electric drive and the track length was reduced slightly to 610m. The Cable Car reopened in 1979 and has run in its current form since then.

1. Introduction

This paper is a synopsis of a recent application to the Institution of Mechanical Engineers (IMechE) for an Engineering Heritage Award for Wellington's iconic Cable Car that has proudly and reliably served Wellingtonians since 1902. [1]

Wellington Cable Car Limited (WCCL) operates and maintains Wellington's historic Cable Car (which is a funicular railway) and the city's iconic Trolley Bus DC overhead electrical network. WCCL is a Wellington City Council-owned Council Controlled Organisation, incorporated in 1991. [2]

This application was supported by the Institution of Professional Engineers New Zealand (IPENZ) Mechanical Engineering Group (MEG) national executive committee. The MEG is a Special Interest Group which also represents IMechE's interests in New Zealand.

2. Background Information and History

Wellington's iconic Cable Car is a fully functioning funicular railway. It carries in excess of 1,000,000 passengers per annum and serves a dual purpose as a vital transport link between Lambton Quay and the suburb of Kelburn, and as the second most popular tourist attraction in Wellington. It is often featured on promotional images gradually ascending towards Kelburn, with the central business district (CBD) laid out below. However, for many local residents and students, the Cable Car remains an important form of daily transportation.

The Cable Car has served the Wellington general public faithfully since opening in 1902 and was the brainchild of two Scottish immigrants, John Kirkcaldie and Lewis Henry Balfour Wilson, who were instrumental in many of the key buildings, and supporting infrastructure, constructed within the CBD. Further reference to their activities is documented in the Wellington City Council publication "*Wellington's Old Shoreline Heritage Trail*". In the 1890s, Wellington was the fastest growing city in New Zealand and was becoming increasingly crowded. Speculators saw the opportunity to develop new suburbs beyond the town belt, including Kelburn. [3]

They formed the Upland Estate Company which purchased the land on which the Cable Car was eventually built, and subsequently incorporated the Kelburn and Karori Tramway Company to design, build and run a funicular railway. This was intended to service the growing suburb of Kelburn, as well as what was destined to be the main campus of Victoria College (which is now Victoria University of Wellington).

Kirkcaldie and Wilson, assisted by a fellow Director, Martin Kennedy, engaged a brilliant engineer by the name of James Edward Fulton to design the Cable Car. It was his engineering skill and dedication, assisted by the construction skills of Maurice O'Connor who brought to life the Cable Car which, with some modifications, is still running today.

Fulton was associated with the Upland Estate Company from early in its history. His design was described as a complicated piece of work featuring

tunnels, viaducts, and retaining walls. Fulton also designed the necessary machinery and safety appliances for handling the traffic.
At the time of his death in 1928 Fulton was said to be one of the best known engineers in the Dominion and the Cable Car was seen as one of his biggest achievements. [4]

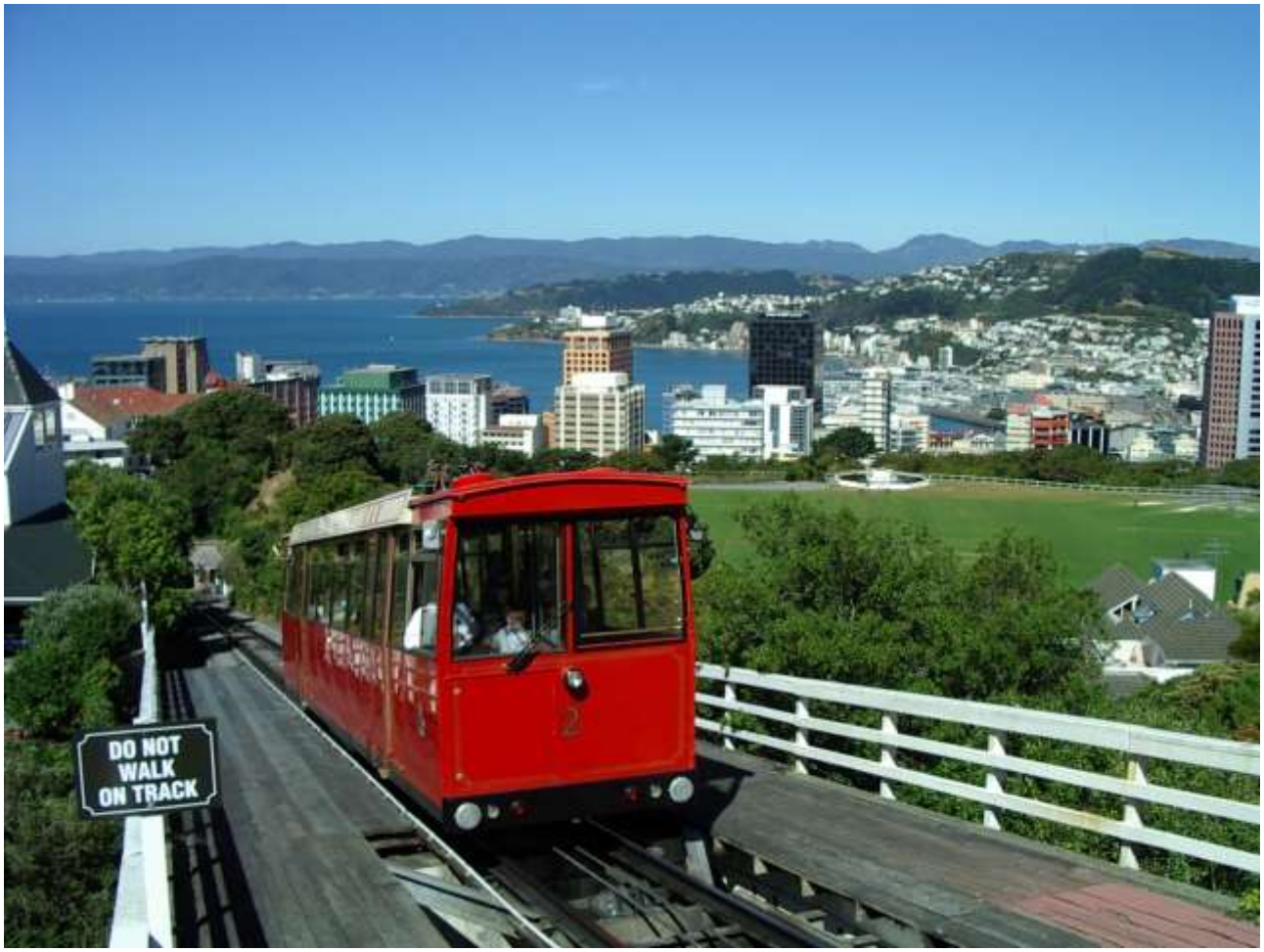

Figure 1: Wellington's Cable Car is the second most popular tourist attraction in the capital city after the Museum of New Zealand, Te Papa Tongarewa and carries in excess of 1,000,000 passengers per annum.

3. Geography and Geotechnical Conditions

Wellington's undulating geography and the requirement to pass over or under all existing roadways, allowing for uninterrupted passage, predicated a track length of 785m rising over 119m at an average incline of 1 in 5. At the time, it was a major engineering achievement for New Zealand and the railway track passes through three tunnels and over three viaducts. The Cable Car has five stations including the top and bottom terminals of Kelburn and Lambton Quay, plus the intermediate stations at Salamanca, Talavera and Clifton Terrace, and these remain in use today. [5]

A funicular railway is a good design option where the geotechnical conditions and topography, although challenging, are such that a railway track can be laid.

This gives the technical advantages of greatly increased payloads, a higher degree of lateral stability for the passenger vehicles and enhanced passenger safety in the event of a significant incident. The most common equivalent of a funicular railway in widespread use nowadays is the Gondola manufactured by companies such as Doppelmayr and Poma. These are most often found in ski resorts and tourist destinations. [6]

A significant amount of explosives blasting was the main technique utilised to carve the route for the Cable Car's three tunnels that are still in use today. Despite Wellington's close proximity to an earthquake fault line, the traditional tunnel construction techniques and tunnel portals have stood up extremely well to over 100 years of constant, low order seismic activity.
The tunnels are inspected annually for structural integrity and any change in alignment is detected by monitoring strain gauges fitted in the tunnels. The higher magnitude earthquakes that occurred in July and August 2013 had a negligible effect on alignment and nil damage was caused as a result.

For the viaducts, Fulton was innovative in his use of scaffolding techniques and deviated away from

the standard construction practices at the time, which was to build up from the bottom of the valley. He managed to save a considerable amount of programme time and expense by securing much of the scaffolding into the side of the hills, whilst still ensuring the safety of construction workers building the viaducts.

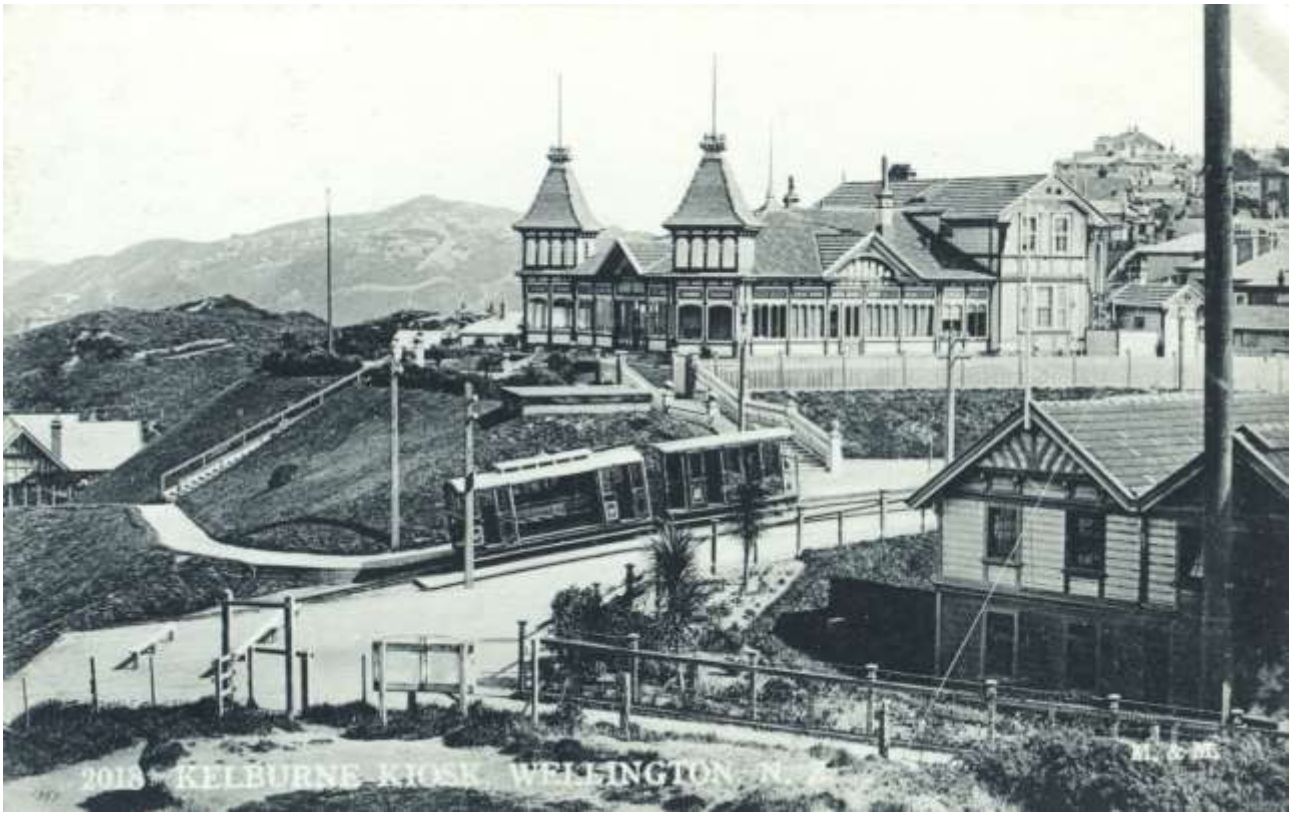

Figure 2: Kelburn Kiosk, Wellington, New Zealand, circa 1908, Wellington, by Muir & Moodie. Purchased 1998 with New Zealand Lottery Grants Board funds. Te Papa (PS.001360/02). Retrieved 04 November 2014, from http://collections.tepapa.govt.nz/Object/327307

4. Choice of Motive Power and Track Configuration

Initially the preferred means to power the Cable Car was using a water-balanced system (the Lynton and Lynmouth Cliff Railway in Cornwall is a surviving example of this). The system concept was for two counter-balanced cars, each with a large water tank. The car at the upper station had its tank filled with water allowing gravity to pull the lower car upwards as it descends. There were however, a number of drawbacks to this system and the idea was eventually scrapped in favour of a steam-driven power source. This lasted until 1933 when it was replaced by electricity to overcome problems caused by a lack of installed power and long-term increases in weight of the Cable Cars (and the passengers). To house the engine a two storey winding house, also designed by Fulton, was built at the Upland Road terminus. The smokestack would eventually become a Wellington landmark and its smoke plumes were relied on as an indicator of wind direction. [7]

The former Winding House is now a dedicated Cable Car Museum, housing some of the original system‘s equipment, and a car designed and built by Dunedin‘s tramcar specialist, Mark Sinclair. [8]

Despite being commonly referred to as a Cable Car, the original system used to operate the ascending and descending cars was in fact a combination of a cable tramway and a funicular. The system made use of two cables; the driving cable which would tow the descending car downhill and the tail wire which connected the two cars. The momentum of the descending car would haul the second car uphill through the connected tail wire. The term ‘cable car’ could therefore only be technically applied to the descending car as it was only on the downhill journey that the cars gripped the driving cable. [9]

Originally the line consisted of double track which ran along the route between the Lambton Quay terminus and the Upland Road terminus at a length of 785 metres (m). The tracks consisted of the New Zealand standard railway gauge of 1,067 millimetres (mm) and were set at 2.7 m centres. When the line was subsequently rebuilt in 1979, the tracks were changed to the common European narrow gauge of 1,000 mm. [10]

5. System Redesign and Upgrade in 1978

With the exception of the drive system and motive power, the original Cable Car system remained in service and largely unchanged until 1978. The

original passenger vehicles (which were nicknamed the “Red Rattlers”) were loved by generations of Wellingtonians as their open design allowed passengers to sit facing outwards and kick the tunnel walls whilst travelling through the tunnels. [11]

Figure 3: One of the “Red Rattlers photographed in 1973 stopping at Talavera station.

An increasing awareness of legislative responsibilities for passenger safety, plus technical obsolescence after 75 years of service meant a fundamental redesign was required. Despite an outcry from the general public, the decision was made in 1973 that an upgrade was essential to deal with acute obsolescence issues that were adversely affecting engineering support and reliability. In 1978, the original system was extensively modified and the drive system and Cable Car bogies and passenger cars where replaced with the current Garaventa-designed system. The original twin railway tracks were replaced with a single track plus a crossing loop at the midway station. [12]

The outside wheels of the bogies on the Cable Car vehicles are handed such that each vehicle always goes the same way on the crossing loop, eliminating the requirement for track points.

The drive system was replaced with a 185 kilowatt variable DC electric drive and the track length was reduced slightly to 610 m. The Cable Car reopened in 1979 and has run in its current form since then, although replacement of the electric drive and associated control and telemetry systems is planned for 2016 to, again, deal with long-term weight increases and obsolescence.

The “new” design was considered revolutionary at the time although its control system pre-dates the introduction of personal computers and the use of Supervisory Control and Data Acquisition (SCADA) systems to enhance the Human Machine Interface (HMI).

The current Cable Car passenger vehicles have a mass of 13 Tonnes each and carry a maximum of approximately 75 people per car (maximum loading of 7 Tonnes per car. The maximum velocity is 5 m/s and the Cable Car transit time is 7 minutes if it stops at all the intermediate stations. [13]

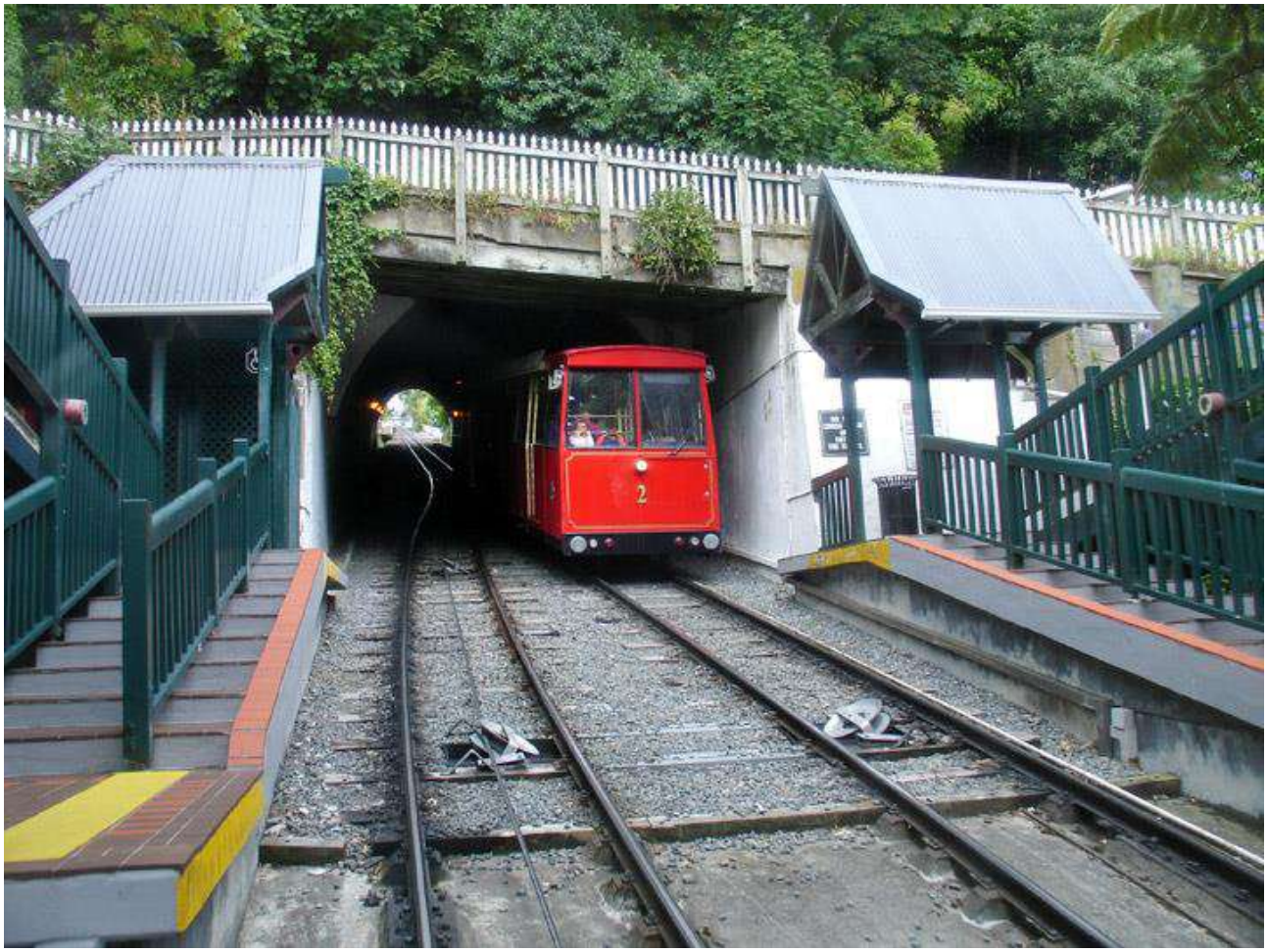

Figure 4: The redesigned crossing loop at the midway Talavera Station introduced in 1979.

6. Risk Management

WCCL, the modern day successor to Wellington City Transport Limited, risk manages the Cable Car by a variety of means, including legal as well as technical / structural and operational. WCCL is also subject to the provisions of the Health and Safety in Employment Act 1992 and the proscriptive regulations enacted under the legislation for passenger ropeways (which includes Cable Cars). [14]

As a fully functioning funicular railway carrying in excess of 1,000,000 passengers per year, WCCL is required to comply fully with the provisions of the Railways Act 2005. This requires the Company to present annually to the New Zealand Transport Agency a detailed and updated safety case. This demonstrates that the Cable Car is correctly maintained and that appropriate safe systems of work are in place to protect passengers and staff in the event of any incidents. Part of this includes an annual shut-down for maintenance, including a rolling passenger vehicle bogie replacement, and thorough testing of the various propulsion and braking systems utilising all the various modes of redundancy. [15]

From a technical / structural perspective, the continued safe operation of the Cable Car, including meeting our specified service standards and reliability targets are addressed by the Cable Car's asset management strategy and its associated asset management plan. This includes ensuring high engineering standards through a sensible and affordable balance of regular inspections, appropriate preventative maintenance, and replacement of capital items when required by service life or a condition based regime.

Finally, operational risk management is also enhanced by the deliberate policy decision to continue using Cable Car drivers instead of automating the operation (which would be relatively straightforward to do). This ensures that trained and experienced staff (who are also first aid trained) are immediately on hand in the event of a service stoppage or other incident, which is particularly important while the Cable Cars are transiting the tunnels. This also has a very positive benefit in terms of ensuring that good interpersonal contact is maintained with the passengers.

Figure 5: The new Kelburn terminus built in 2013.

7. Conclusion

Wellington's iconic Cable Car is a fully functioning funicular railway essential within the city's public transport network and one of the capital's popular tourist attractions. It has served the Wellington general public faithfully since opening in 1902.

The Cable Car is recognised as one of important engineer James Edward Fulton's major works. It conquers the challenging landscape between Lambton Quay and the hill suburb of Kelburn through a series of tunnels and viaducts and a combination of cable car and funicular railway. With some modifications, Fulton's Cable Car is still running today and, as at the time it was constructed, it is regarded as one of New Zealand's engineering achievements.

WCCL risk manages the Cable Car and is ensuring the retention of this piece of engineering heritage by a variety of means, including meeting regulatory and legal requirements. From a technical / structural perspective, the continued safe operation of the Cable Car, including meeting our specified service standards and reliability targets, is addressed by the Cable Car's asset management strategy and its associated asset management plan. Finally, operational risk management regarding service stoppages or other incidents is also enhanced by the deliberate policy of using specially trained Cable Car drivers, instead of automating the Cable Car operation.

Figure 6: The Cable Car runs over the viaduct at Salamanca near Victoria University of Wellington.

8. Acknowledgements

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[10] (Daisley, 2012).

[11] (Daisley, 2012)

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