Cracking Tales of Safety-Critical Cables



Wendy Owen provides a fascinating insight into the Lisbon Tram/Funicular accident. She describes the circumstances surrounding the accident, the reported causes and the impact and aftermath of the incident. Wendy and Jon Wiggins then provide a few similar case studies to show this is not an isolated case.

The first time I heard about the Lisbon Tram/Funicular accident (3rd Sept 2025) was on the BBC news. Witnesses described it as "out of control" and the whole incident happened in less than a minute.

A Review of the Lisbon Accident

The Glória funicular derailed and crashed into a building in Portugal's capital. 62 rescue personnel and 22 emergency vehicles attended the scene.

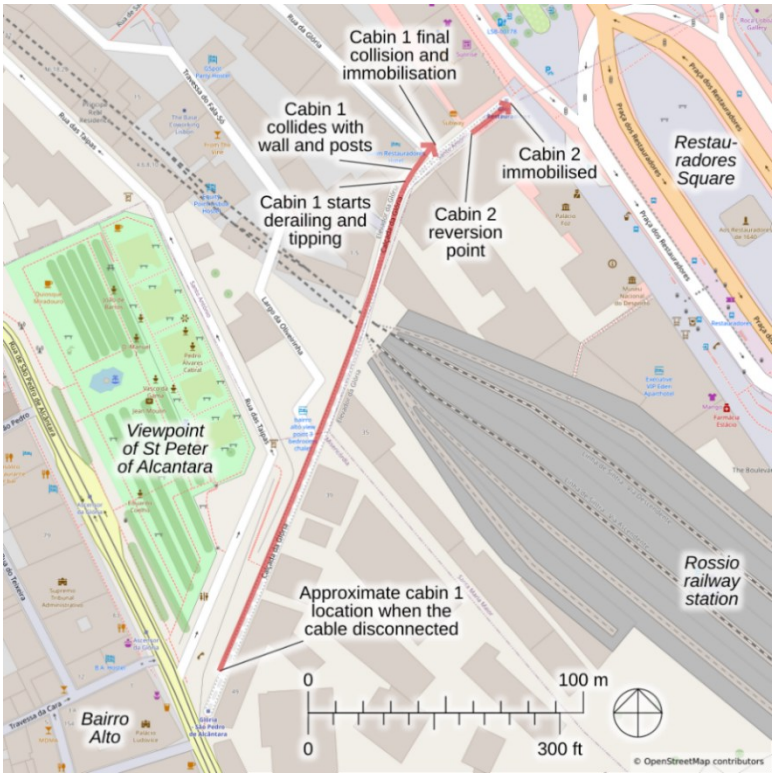
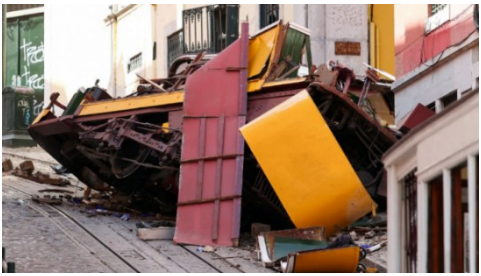


Figure: Map of the incident

Here's a map of the incident. The car at the top of the hill (lower left of the map on the figure) sped uncontrollably downhill before derailing and hitting a building near the bottom.

Not long after, news came in that three Brits were involved, including news in my local papers – David Young, 82, was a former customs officer and lifelong transport enthusiast [1], a Scot living on Anglesey. He was among 16 people who died (of twelve nationalities involved, all adults, including one hit by the railcar). Additionally, 23 people were injured. David's family said [2] it was a comfort that *"his final moments were in pursuit of the hobby which gave him so much happiness… In retirement he enjoyed visiting heritage railways and tramways around the world*". Cheshire Police confirmed the other two were Kayleigh Smith, 36, and her partner Will Nelson, 44. Llinos Medi, MP for Ynys Môn, sent her condolences to Mr Young's family and "*to those who have been affected*". Prime Minister Sir Keir Starmer said he was "*deeply saddened*" by the incident, "*His thoughts are with their families and those affected by this terrible incident*," said a spokesperson. There are many people like David who very much enjoy travelling on heritage transport.

About twenty years ago I was an independent safety reviewer for a new tram project. I am also more generally familiar with a few heritage funiculars in the UK. I'm particularly fond of old trams and funiculars, and I'd travelled on that now 140-year-old iconic funicular in Lisbon some years ago. I had travelled on a fantastic funicular in Bridgnorth not long before the Lisbon accident.



It was notable that those affected were often referred to as victims rather than fatalities or deaths. A crime had taken place, apparently. I really, really, wanted to know more about what had happened – was this a crime, an unpredictable mishap, or something else?

We didn't have to wait long to get some initial answers, only a few days [3].

Figure: Immediate aftermath of the derailment

Investigators determined the carriage was travelling at ~60km/h (37mph) when it hit the building and that a cable connecting two carriages had snapped, although the rest of the cable mechanism was functioning properly. They added that the driver (AKA brake guard) tried to apply the emergency brakes but failed to prevent the derailment. Although he activated both the pneumatic brakes and a manual brake when the cable came loose, at this early stage of the investigation it was not clear whether another – automatic - brake initiated as it was supposed to. Sadly, the driver was one of the deceased.

The cable was reportedly only 337 days into its expected 600-day operational life. Let's pause at this point – this is saying that the cable snapped at just over half-way through its expected lifetime, that its expected lifetime is not even two years, and this is also given that the trams perform a very frequent daily service.

A fuller report was due within 45 days, but again we didn't have to wait long, the larger report (by Portugal's Air and Rail Accident Investigations Bureau) was released on 10th October 2025 [4].



Figure: Immediate aftermath of the derailment, as seen from Restauradores Square, with dark yellow derailed car toppled into building on right.

Litany of Failings

This reported a "*litany of failings*"; for readability here, I have grouped these failings into five topics. A note that the words carriages, cabins and cars are loosely interchangeable.

Cable Failure Mode

- An underground cable – which acted as a counterweight between two carriages – was defective and broke, causing the crash
- After travelling only about 6 metres, the connecting cable between the two cabins failed at its attachment point to the upper car
- While a visual inspection of the scheduled cable was allegedly performed on the morning of the accident and did not show any issues, the section of the cable where it eventually failed was not accessible for observation.



Figure: Cable broken during the derailment. Bottom left: cross section. Right: unbroken cable inserted into the *trambolho*.

Cable Specification Issues

- The cable had never been certified for passenger transportation. The cable was "*not technically suitable*". It did not comply with the specifications in force at the CCFL [Lisbon's transport operator] to be used for the Gloria tram.
- Yet, the specific type of cable had been used on this funicular for about six years.

Braking System Issues

- The vehicle's speed could not be reduced, despite the pneumatic and hand brakes being applied immediately, once the driver lost the balancing force of the cable
- Activation of the emergency braking system failed to stop the derailment. This system, which the driver correctly tried to apply when the cable snapped, either did not function at all or did not function properly
- The emergency braking system was never tested in advance

Procurement & Installation Issues

- The cable was acquired in 2022 by Carris (who run Lisbon's transport system). There had been no oversight by Carris engineers
- The cable was not tested before it was installed

Maintenance Background & Inspection Issues

- Maintenance regimes of the Ascensor da Glória
  - It was last placed under general maintenance (held every four years) in 2022
  - Its most recent immediate maintenance (held every two years) was conducted Aug-Sept 2024
  - A routine daily visual inspection was allegedly carried out nine hours before the derailment

- There were several instances when the maintenance programme referred to "*non-existent, inapplicable or outdated standards*"
- The supervision and maintenance of the funicular (by a company outsourced by Carris) did not work properly. Apparently, the Glória funicular was given the all-clear on the morning of the disaster.

The preliminary report emphasised that the information gathered to date was "*incomplete*", with further tests and analysis needed. "*The guilt or responsibility of any organisation or person involved in the incident should not be presumed*".

Meantime, Lisbon's mayor reaffirmed that "*the unfortunate tragedy... was due to technical and not political causes*".

Orders to Operators

The investigation report concluded: "*At this point in time, it cannot be said whether the use of this type of non-compliant cable intervened, or what intervention it had, in the rupture... and it is certain for the investigation that there were other factors that had to intervene.*"



Figure: An operator's view from the cabin of car No. 1 in July 2023, showing the location of its fatal derailment.

It ordered/advised:

a) All Lisbon cable cars to be taken out of service until the necessary safety checks were in place
b) All braking systems to be reviewed. These need to be capable of immobilising the cabins in the event of a cable break
c) Carris to implement a new safety management system in line with European best practice
d) Closing a loophole whereby Lisbon's historic funiculars are exempt from legal and supervisory oversight that applies to other cable forms of transport

Carris issued a few statements in response:

- They had dismissed their head of maintenance of funiculars and trams
- Said it was *"not possible at this time to state whether or not the non-conformities in the use of the cable are relevant to the accident*"
- Noted that other cables had been in use on the Glória funicular for 601 days without incident [cue tut-tuts from the RAM engineers]
- The cables had been brought into use under the current board of directors, who took office in May 2022, but the acquisition process took place under a previous board.

What Else?

Other pertinent information that arose during the writing of this article not already mentioned above:

- A few hours after the disaster, Carris' CEO stated to the press that "*the maintenance protocol was scrupulously followed*" by MAIN and that it included monthly, weekly and daily inspections
- An incident had occurred in May 2018, when one of the cars derailed due to a lack of maintenance of its wheels. No one was injured. The outsourced contractor supplying maintenance at that time is not named.

The Aftermath

A full investigation report will take about 11 months to complete. A National Day of Mourning was declared following the accident. The historic tramway is out of action.

Lisbon municipal council formed a technical team of Carris engineers, university experts, Ordem dos Engenheiros and the National Civil Engineering Laboratory (LNEC) to develop new safety mechanisms and determine if, and when, the funicular is safe to reopen.

On the face of it, it does appear as a *"litany of failures*":

- Ultimately, no-one spotted that it was the wrong type of cable being installed and put into service. There are some big questions here about how and why it was not spotted.
  - It definitely was not the specified cable (assuming that the spec itself was correct), reflecting a lack of due diligence by both procurement and installation teams.
  - Maintenance also missed it, on many occasions, although there is some evidence that it wouldn't have been possible to spot this type of fault during a visual inspection.
  - It also wasn't tested post-manufacture or upon installation (as far as I can tell). Nor does it have a long lifespan.
- There's something seriously amiss with the emergency braking.

We shall wait and see what the technical team come up with.

Note: In the UK, funiculars require formal authorisation by an Approval Body and HSE/ORR (depending). In general, they are not classed as "light rail" but fall within the remit of the Cableway Installations 2018 (a post-Brexit version of an EU regulation).

To conclude this already fairly long article, here is a small collection of other cracking cable tales.

Case Study 1 (Jon): Post-Tensioned Concrete Tanks

The storage of large volumes of water or media is a common occurrence in the water industry. A cost-effective method of constructing and installing large volume tanks is therefore a requirement.

A common solution is to utilise post-tensioned Concrete tanks. In essence, these are pre-cast concrete sections arranged on a pre-cast base in a circle with a series of steel cables (or tendons) threaded through them and tensioned to allow the seals between the section to become watertight and remain so under the highest load conditions as illustrated below.



A common use is in storm diversion tanks. These tanks take the excess water which cannot be treated by a sewerage works during a storm and then later discharge through the works once the high flow has abated. As such, these tanks go through regular stress cycles with water loading and temperature variations causing expansion and contraction of the tendons.

There have been some notable cases of the tendons failing catastrophically causing localised damage and weakening to the tank and in extreme cases collapses, opening out like petals of a flower, a failure mode nicknamed "petalling" as illustrated below.

The implications of these "petal" failures are clear

- Potential for death or serious injury due to tendon ejection
- Potential for death due to tank collapse
- Potential for environmental and property damage from sewage leaking



The case-by-case failure mechanism can be difficult to pinpoint and studies into post tensioned structure failures have drawn several hypotheses.

Two common factors arise:

- Corrosion. Steel and water, especially sewage, is a mixture made for corrosion [9]. In addition, effects such as embrittlement and chloride ion corrosion have been postulated [10]
- Creep and stress cycling. Where structures are subjected to repeated loading/unloading cycles, the movements and loading patterns have been noted to cause cracking in the concrete structure, and creep and damage to the tendons.

The regimes to maintain and inspect these structures have varied, although a lack of maintenance and inspection may be seen as a contributory factor in failures. These structures require that tendons are maintained and inspected at regular intervals. Inspections are predominantly visual checks. Tendons may be removed for inspection and re-greasing alongside a tension check.

Other measures, such as the addition of secondary supporting cables (to prevent petal failures) and physical barriers to mitigate the risk of tendon ejection have additionally been installed. Awareness of the hazard and the need to carry out regular inspections is key to risk reduction and improvements.

Case Study 2 (Wendy): The Maverick Procurement Team

I have a tale about another cable where no-one spotted it was the wrong type of cable before it went into service. It was a very different type of cable to the above, no-one was hurt, it was during a trial, but there are some similarities. I have previously used this as a case study for training new RAMS engineers.

It happened during a step-change technology upgrade at a small regional control centre. I was called in on a fact-and-fault-finding mission on behalf of the manufacturer of the new technology. Something was awry with some readings, and after a few weeks no-one had been able track down the problem.

I sat there (remotely) for a day observing the operational data and talking to a few of the operators. The first sign of the problem was visual, on monitors and printouts. Sometimes it was fine, occasionally it was "wobbly", and even less occasionally it was blank. Whatever was happening was certainly erratic. They had checked and re-checked the monitors, the printer, the systems under control. Nothing, apparently. Eventually, after noticing something about the patterns on the printouts and the odd way the monitors looked at times, I asked them to double-check a few of the cables. Then I asked them to replace two of the cables, one at a time, then both together. The replacement cables looked slightly different if you looked very closely. I asked them to compare, contrast and triple-check the cables.

To cut a long story short, there was one "faulty" cable – it was supposed to be a high quality, high integrity EMC/EMI protectively sheathed cable, but it was not. This affected data transfer to/from the monitors and printers. The interference was being "set off" by various electrical equipment in the room, both permanent and transitionary/temporary equipment, and possibly mobile phones too. Someone mentioned the cables were procured in a rush prior to the trial and someone else mentioned getting them for a very good price. The receipt for the dodgy cable was eventually tracked down, revealing purchase at a local hardware shop.

A few months later, there had been no erratic behaviour, and the trial concluded. The system as installed is still in use today and there has, to my knowledge, been no more wobbles.

End Note

The day before this article was completed, there was widespread disruption on the UK rail network. It centred around a power outage at Leeds Station, reportedly from a *"defective cable*" [11].

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Wendy has over 35 years' experience in the field of safety and systems assurance. Approximately a third of her career to date has been in the transport sector, predominantly in rail. In the mid-00s, she was a co-author/editor of the UK rail sector's Engineering Safety Management guidance (AKA Yellow Book https://www.rssb.co.uk/en/standards-catalogue/CatalogueItem/YB-Iss-4), particularly the ISA sections. Yellow Book subsequently formed a basis for CSM-RA and the book itself transformed into an international version, iESM (https://www.intesm.org/), since used in many other countries. She spent a portion of her childhood in view of the funicular at Aberystwyth and is always delighted to see a tram.

Jon Wiggins (Functional Safety & Cybersecurity Technical Managed, DEKRA)



Working in a wide variety of sectors from Utilities to OEM automation system design, Jon has built a wide range of experience in the construction, design, maintenance and assurance of systems. As a chartered engineer and UK expert to the IEC and ISO Jon advises on the safety of systems and machinery as well as matters of cybersecurity. Jon is a serial author and advocate for improved safety and security throughout UK industry.

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