UCD Impact Case Study

How much traffic can this bridge safely take? A break-through in quantifying traffic loading on big bridges

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SCIENTIFIC · SOCIAL · TECHNOLOGICAL · ENVIRONMENTAL · ECONOMIC

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SUMMARY

Bridges are often key factors in transport, allowing us to get across landscapes efficiently. If a bridge fails, the results can be catastrophic for human life, for economies and societies and for the environment.

This is why bridges are monitored as they age, to estimate whether they can still safely bear expected traffic. But the processes that civil engineers use to do that on long-span bridges are limited. This could result in bridges being closed due to safety concerns.

Professor Eugene O'Brien and his team at UCD School of Civil Engineering have been using cameras to augment the data we can collect about traffic weights and patterns on long-span bridges.

They have developed a first-of-its-kind method to quantify the traffic loading on some of the world's biggest bridges – structures with clear spans of up to 2 kilometres. This means that engineers can now provide a more realistic measurement of bridge safety, thereby protecting human lives. The UCD-developed method should also help to prevent the unnecessary closure of economically important bridges, thus saving money and reducing disruptions to economies and societies and to the environment.

Bridging a gap in our knowledge of traffic loading

In August 2009, two spans of the Malahide Railway Viaduct in Dublin collapsed into the sea. Luckily there was no injury or loss of life, but commuter services were disrupted as the railway bridge was repaired. Other bridge failures have wrought far worse devastation, such as the Interstate-35 collapse in Minneapolis in 2007, in which 13 people were killed and 145 were injured.

As bridges get older they deteriorate, and they need to be checked periodically to ensure that they are still safe to carry the traffic that passes over them. That's where research by Professor Eugene O'Brien and his group in UCD School of Civil Engineering is bridging a gap in our knowledge to assess long-span bridges more reliably.

His work focuses on 'traffic loading', or the weight of the most critical combination of heavy vehicles that could be expected on the bridge. One way of capturing traffic-loading data is through Weigh-in-Motion (WIM) sensors, he explains: "These pressure-sensitive sensors embedded in a groove in the road surface can tell us the weight of every vehicle that passes and it does this in the milliseconds it takes for the tyres to cross the sensors."

But there's a particular problem for long-span bridges, where a critical case is when traffic is congested and the vehicles are stopping and starting. "In this situation, WIM sensors do not work and we have no way at present to either weigh the vehicles or measure the gaps between them," says Professor O'Brien. "This is a huge problem, because if we don't know what the loading is on the bridge then we don't know how safe it is. Civil Engineers will close down the bridge rather than risk it becoming unsafe. But this results in bridges being replaced, repaired or closed when, in many cases, they are in fact perfectly safe. It is a huge waste of public funds."

To more realistically assess traffic loading, the UCD team draws on WIM data from eight countries around Europe and 150 site-years of data from the United States, and they have come up with an eagle-eyed way to fill in the gaps in data by using overhead cameras to monitor congested traffic.

"From these images, we are extracting information about vehicle lengths and the gaps between them," explains Professor O'Brien, who is Professor of Civil Engineering at UCD. "Then we use WIM data from adjacent sites where traffic is free-flowing, in order to find the relationship between vehicle length and weight."

With good information on gaps and estimates of all the vehicle weights, they have finally been able to find the total loading in congested situations: "With some statistical calculations, we can go from there to the level of loading with one-in-a-million probability of over-stressing happening on the bridge, which is generally accepted as a safe threshold (it's about the same risk of being struck by lightning)."

Optimising bridge use saves lives, money and the environment

Professor O'Brien's research at UCD School of Civil Engineering has developed the first ever method to quantify the traffic loading on long-span bridges. This means that, unlike previously, we can now calculate the true safety of these bridges, which has benefits not only for **human safety** but also for **economics** and **traffic management**.

To widen the research's impact, Professor O'Brien is director and co-founder of Civil Engineering firm Roughan O'Donovan's subsidiary Innovative Solutions (ROD-IS), which has worked on numerous national and international **academic and commercial projects**.

In 2009, ROD-IS carried out an assessment of the Malahide Railway Viaduct for Irish Rail, and in 2011, the consultancy won €890,855 in EU funding to explore the lifespan of bridges – the project produced a computer simulation tool that allows engineers to 'play forward' 150 years into a bridge's likely future.

ROD-IS also produced a double-tuned mass damper to **reduce harmful vibrations on railway bridge cables** (and demonstrated a 20 per cent reduction of such vibrations on a bridge in Sweden), it undertook a structural health check of the Dursey Island Cable Car in Cork and it calculated the implications for pavements and bridges of a proposed change in the weight limits for non-regulated vehicles.

Professor O'Brien continues to apply the research findings to bridge construction projects, including the Ting Kau bridge in Hong Kong and the road bridge over the Firth of Forth in Scotland. "The main cables in the Forth bridge have deteriorated, so it is not as strong as when it was built in the 1960's," he explains. "As a result, a new bridge is under construction (at a cost of about £1.35 billion) with the creation of a new public transport corridor on the old bridge. Under the reduced loading of the HGV's and other motorway traffic using the new bridge the old bridge is expected to operate well into the foreseeable future. With our new approach, we will be able to accurately calculate the traffic loading on both bridges and **give the authorities the ability to make an informed decision**."

The Chacao Channel Bridge in Chile, which is being built to connect Chiloé with mainland Chile, is benefiting from the UCD research too, with Professor O'Brien's team assessing the safe level of trucks in traffic on the bridge, and suggesting how **trucks could be monitored and diverted if needed using data from road tolls**.

Optimising the use of bridges also has an **environmental impact**, notes Professor O'Brien. "Being able to assess bridge safety more accurately allows us to keep it open for longer," he explains. "In effect, we are **extending the working life of the bridge, without compromising the safety of the traveling public**. A bridge has a major carbon footprint – both concrete and steel are carbon-intensive materials. By extending the working life of a bridge, we are **getting more transport service for that carbon footprint**."

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