A Primer for Digital Twins in Transportation

By Peter Lindgren

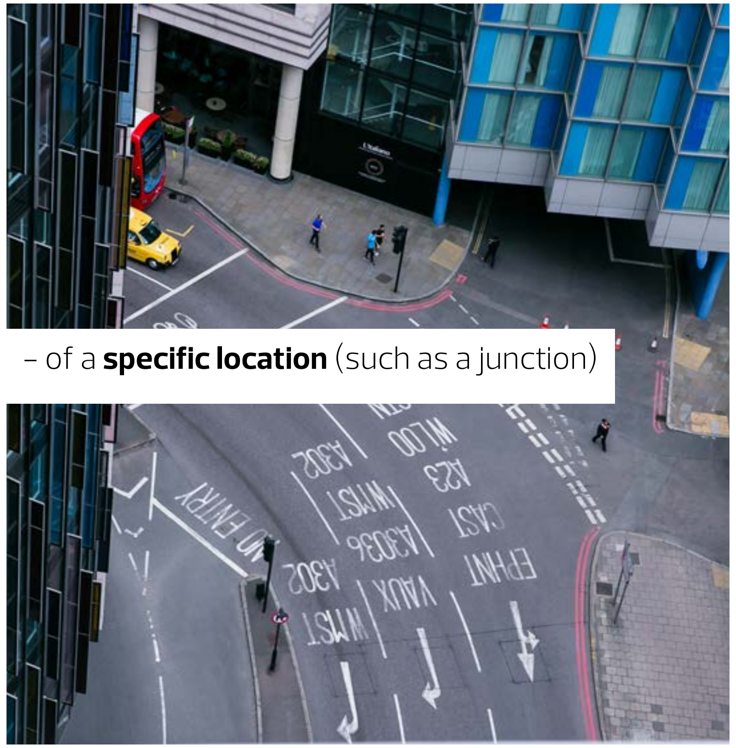
 www.trl.co.uk

Introduction

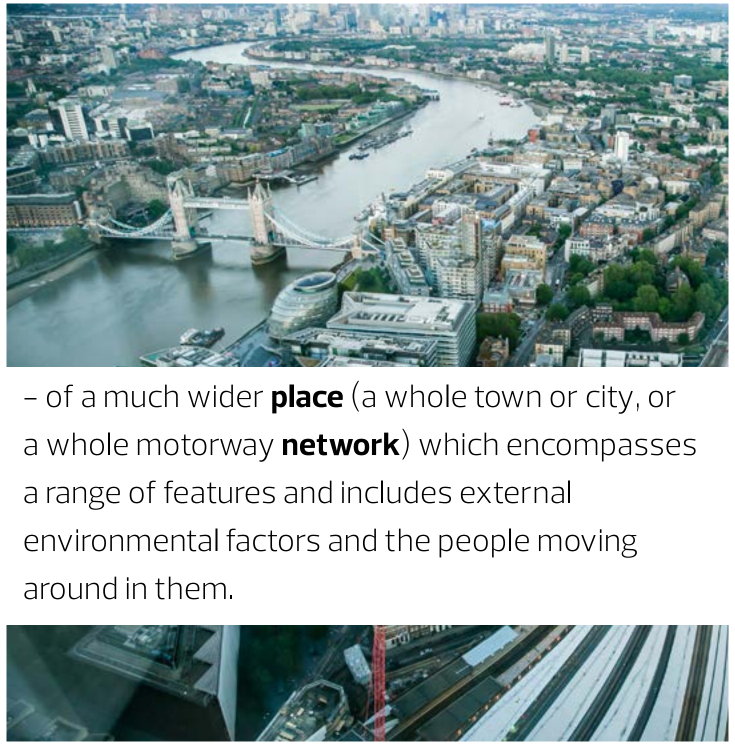
Digital twins are rapidly gaining attention in many sectors, not least transport. But there is a lot of confusion about what they are exactly, and how they might benefit the creation of a better future transportation system. As with any new field, terms are often used without a solid understanding, raising the risk of miscommunication, or exposing a gap in expertise. In this primer we will briefly explain three forms of digital representations and how they benefit innovators when developing a future transport system.

Digital representations can be

– of a **thing** (an object like a car)



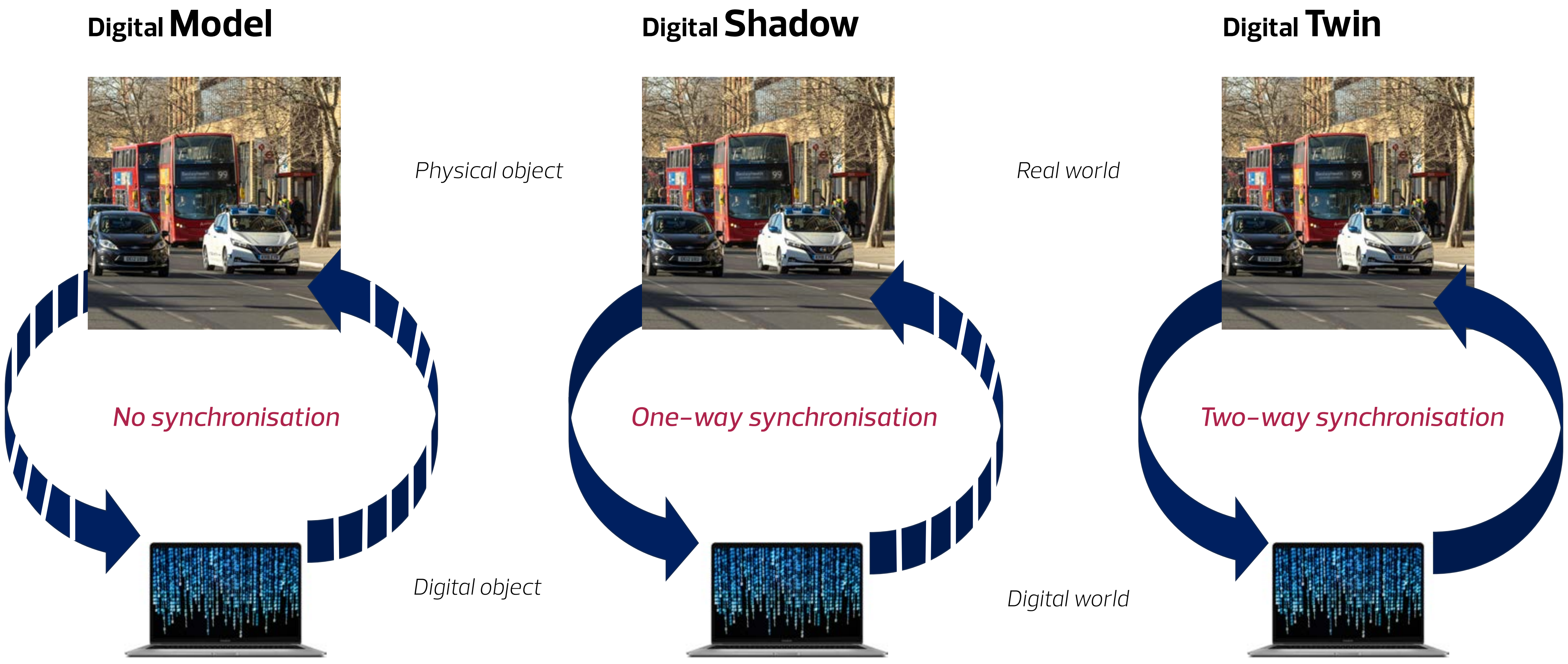
– of a **specific location** (such as a junction)



– of a much wider **place** (a whole town or city, or a whole motorway **network**) which encompasses a range of features and includes external environmental factors and the people moving around in them.

Digital representations

The differences between the types of digital representations are all about the input and output of data.



Data from physical object provides a snapshot. No implied data transfer from digital to physical.

Frequent or continuous data transfer from physical to digital. No implied data transfer from digital to physical.

Interventions in the digital representation are implemented automatically in the physical world.

The Digital Model

In a digital model, data is taken from the real world to create a digital replica of that physical thing.

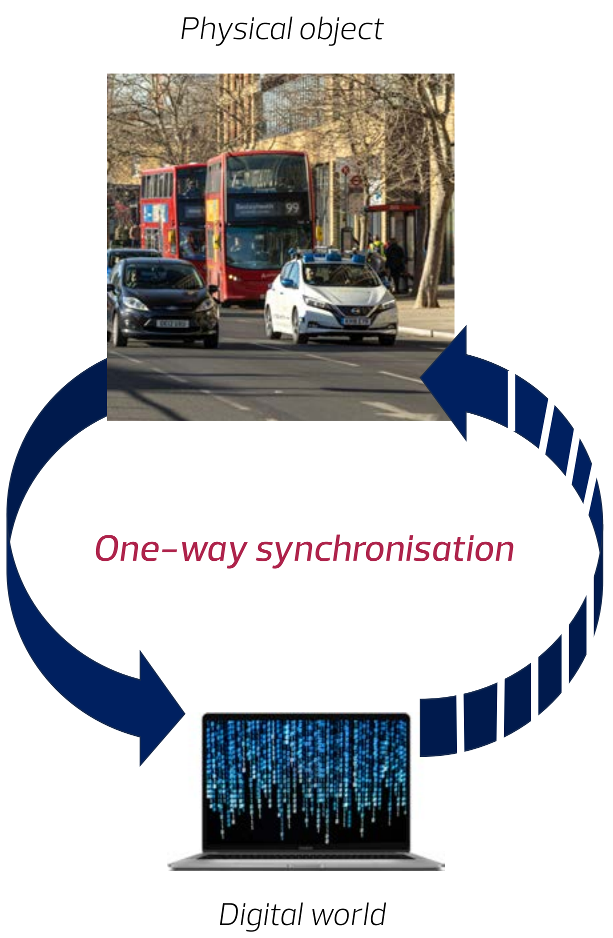
Typically, in a transport context, it would be a physical asset (a car, a bridge) or it could be a process (traffic flow control in a tunnel).

This digital model can be manipulated. But it is a snapshot, a still image of the real thing. It is altered or updated by inputting new data manually.

The digital model is most useful for working with or modifying things that by their nature are static, or repetitive, and do not change frequently. It can be thought of as a template.

There are many examples of digital models being used today for recreating things and processes, used by designers to develop new and improved stuff.

The Digital Shadow



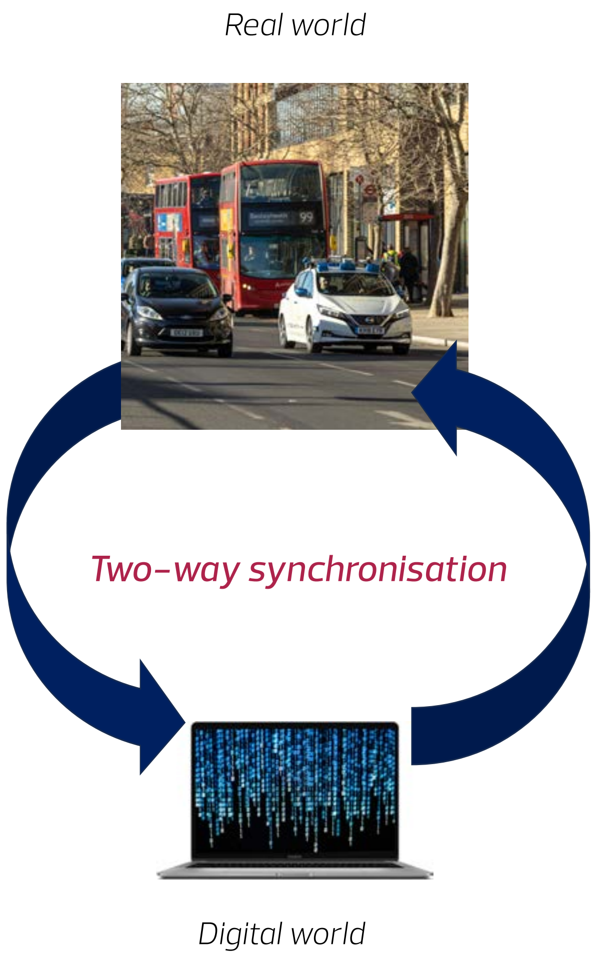
In a digital shadow, a live data link connects the physical thing and its digital representation, the fresh data is coming into the shadow automatically. This updating process is baked into the digital shadow so that it is now a synchronised version of the physical thing. The digital shadow is not just one snapshot, it's a living representation of the real world, akin to a live stream version of reality.

The utility of a shadow in a transport context is that by manipulating the digital shadow, testing changes to different aspects of it, the results can be used to manually alter or update the physical thing.

An example of this as a process might be a digital shadow of a bus operating on a fixed circular route. By analysing the digital shadow, operators might identify a more efficient drive cycle for the bus, resulting in a permanent change to the bus route or timetable.

In many instances, when people talk about a digital twin, they are actually talking about a digital shadow. While the same concept might be known by other names, its defining trait is the data flow coming in one direction only from the real world.

The Digital Twin



In the next iteration of the digital representation, a digital twin has another link, a live data flow from the digital version back into the real world. So it starts as a model, ingests data automatically from the real world, and now also injects data back into the real world, often in near real time.

One area where digital twins have potential to yield benefits are variable messaging signs (VMS), typically found on overhead gantries, informing drivers of a lane closure ahead or informing a reduction in speed.

Imagine now we have a digital twin of the whole motorway. The VMS system is part of a bigger system that is monitoring the traffic on the motorway. It detects a build up of traffic on a slip road some miles ahead. This real time information is fed automatically into the digital version of the motorway. The digital twin then runs various algorithms to decide how to respond to this new information, taking into account live data from other sources such as weather, visibility, time of day and predicted traffic volumes. Having concluded that it would be beneficial to the road users to affect their driving behaviours, the digital twin then runs a calculation to determine how far back down the motorway it should start warning drivers that there's a build up of traffic ahead, and once that is decided, which of the variable messages signs it will instruct to illuminate a warning and advised speed change. This is the digital version of the motorway instructing people in the real world what to do. The automatic data flow is coming from the real world into the digital version of it and going back out into the real world, in near real time.

Digital twins like this are a promising tool for systems level thinking: they allow the connection of one part of a system to another and allow the cascading of coordinated interventions across complex systems. Furthermore, the connections can often be achieved without having to expose or share the underlying data, overcoming privacy or commercial sensitivities.

The Future

Digital twins of whole transport systems are in their infancy. With evermore data sources, processing power or and more sophisticated decision making algorithms, a key challenge faced by digital twins is the homogenisation of many different types of data so that the twin can make use of the data. The CODEC project proved the principle of how this can be done, by establishing a common ontology for the "translation" of data types. TRIB in the USA has done a lot of work on a roadmap to assist developers in creating digital twins for transport.

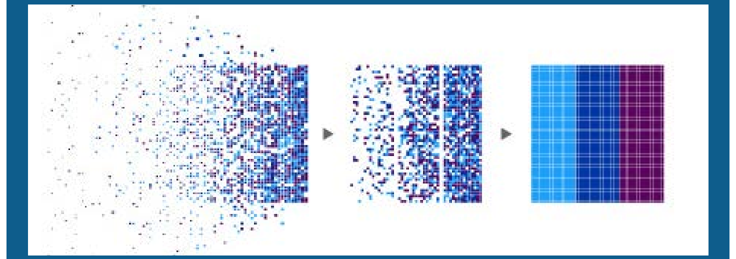
While the allure of the digital twin is its potential to mirror the real world in granular detail, a pragmatic approach is often to start with a well-defined, limited scope. Such a strategy minimises the inevitable implementation complexity and reduces the time until its utility can be evaluated through hands-on use. They can then be iteratively expanded or connected to other digital twins to augment their capabilities and purpose.

As their scope broadens and they become more sophisticated, digital twins will be transformative in the development of transportation because they afford not only greater confidence in predicted outcomes, but also offer rapid real-time optimisation of complex systems.

Ontologies are a method of structuring knowledge to provide a consistent and machine-readable framework for organising data.

Good exmples of ontologies successfully used to exploit disparate datasets to improve transport management can be seen in the practical digital representations built for the CEDR project CODEC.

https://www.codec-project.eu/



Validation

At TRL's Smart Mobility Living Lab, we have the know-how, digital infrastructure and real-world test lab to accelerate the development of digital twins. Our facility gives access to assured real world inputs that enable the construction of digital models, and then we can build specific content that affords the means to validate the purpose of a digital twin.

The digital components of the test route at SMLL can be adjusted for light and weather conditions.

See the SML simulated test environment in action in this video.