Twin cities

The latest Mott MacDonald Masterclass explains why developing a digital twin for transport will set us on the road to fully integrated smart cities

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Our cities and their transport networks are highly complex systems, consisting of many autonomous, interrelated and interdependent parts that are not governed by simple rules. Each city is unique, reflecting the influences of climate, geography, culture, development, and wealth. Complex systems at this scale can appear chaotic with complexity appearing at both macro and micro levels, making the development of smart cities (adding further complexity to the system) a major challenge.

Transport systems are prone to uncertainty for at least four reasons:

- Transport is vulnerable to disruption caused by accident or technology failure. In a typical city there may be multiple such instances every day
- Transport users do not follow physical laws that can be easily modelled. Users face complex choices and may make seemingly illogical or unexpected decisions
- In most cities, transport is constrained by supply-side scarcity, so increases in supply may release suppressed demand rather than resolving shortages
- While transport users make choices based on current travel conditions, in the long run supply-side opportunities and constraints drive demand-side change.

Transport models have been developed for many decades with increasing sophistication, but these can be expensive to build, slow to run and usually based on historical data. Given the complexity of most transport systems, it is not surprising that progress towards a tool able to apply a smart city approach to transport provision has been slow.

Defining "smartness"

This is not to say that today's cities and their transport networks are not smart at all. Many cities have some aspects of 'smartness', with the increasing use of technology to control traffic signals and other functions well established, but even the smartest cities must continuously innovate to remain in step with the pace of technological change.

The 2018 edition of the Cities in Motion Index (CIMI), published by IESC Business School University of Navarra[1], evaluates cities' levels of development in relation to nine key areas: economy; human capital; social cohesion; environment; governance; urban planning; international outreach; technology; and mobility and transportation.

The CIMI undertakes an evaluation of 165 cities from more than 80 countries. Yet many other diagnostic assessments of the world's cities result in very different rankings. This smartness is multi-faceted and it is difficult for any city to optimise all or even the majority of its individual systems. This tends to support the authors' observation that, with few exceptions, we have delivered pockets of smartness rather than integrated smart cities.

An effective way of aligning a sector to collaborate for technology maturity is to use a maturity model, (see for example the now widely adopted model for connected and autonomous vehicles, published by the Society of Automotive Engineers[2]). The International Data Corporation (IDC) has recently published a similar maturity model for Smart Cities[3]. Honing in on the transport sector, we would suggest the following expansion (see table) to measure how smart the network is.

At best today's cities reach level 2 or possibly level 3. Level 5 will not be achieved for some time, but for many cities in the near term, progress towards level 4 is possible.

LEVEL	MATURITY	EXAMPLE
0	None	All transport operated based on immediate choices of operator
1	Smart city strategy developed	Smart city policy in place
2	Some smart transport solutions in place	Solutions such as real-time passenger information implemented
3	Some smart transport solutions integrated into smart city	Solutions such as real-time passenger information implemented and integrated into key destinations
4	Real-time smart transport	All elements of transport driven by co-ordinated data system
5	Full real-time smart city integration	All elements of city driven by co-ordinated data system

Digital twins are key to developing smart cities

One solution to the smart city challenge is the concept of the 'digital twin'. This is a digital model in which real-time data feeds allow for analysis and decision making, and can be applied at any scale, from individual objects to entire cities or even countries.

In fact, the National Infrastructure Commission sets out that, over a 10-30 year timescale, a digital model of our national infrastructure "will be able both to monitor our infrastructure in real-time, and to simulate the impacts of possible events, for example, a natural disaster, or a new train line"[4].

Developing digital twins for transport networks is a key step in enabling smart cities, and we already have some examples of digital models in our sector which – with some development – could become viable digital twins:

- Transport models are well established, but encompass limited elements of the transport system, usually based on historical data
- Urban traffic management and control (UTMC) systems collect real-time data from internet of things (IoT) sources and process that data to inform travel choices
- Land-use and transport interaction (LUTI) models reflect the interface between transport demand and land-use, highlighting the way transport influences (and is influenced) by spatial form.

However, developing true digital twins for transport networks means facing two key challenges:

- Transport systems must be integrated to create a digital twin capable of assessing short-term implications of changes in transport supply on demand and long-term implications of these changes on urban form. Machine learning (ML) is needed to assess both historical trend data and real-time data feeds.
- Integrated transport systems must use a LUTI interface to share data across the smart city. Such an interface must be a two-way process with potential for iterative analysis.

Mott MacDonald developed Merlin, a digital transport management tool, as an approach to this challenge. Developed for the 2012 London Olympics, the platform fuses a number of systems and applies basic intelligence to respond to incidents and make cities more resilient. However, Merlin does not provide all the elements of a digital twin, with two areas still to be addressed:

- Current transport models still don't run in real time. Software suppliers such as PTV[5] are developing real-time modelling and predictions while others rely on artificial intelligence (AI) to make short-term predictions based on sensor data. Cloud computing will bring real-time modelling closer to reality.
- The decision-making algorithms currently in place are generally conventional programs rather than AI/ML-generated. This is likely to evolve over the coming months and years.

Towards 'UTMC2'

Lessons can be learned from the development of UTMC[6]. This involved creation of a standard open system which all suppliers could utilise and which UK city clients could insist upon. The objective was to ensure 'plug and play' functionality.

Digital twins need the adoption of what we could refer to as 'UTMC2'; a new standard open source system that provides a clear framework for the industry, whether it's global IT specialists, infrastructure domain experts or innovative technology start-ups.

If we want to evolve a UTMC system into a smart city 'UTMC2' system we need to develop a framework based on recognition of three key principles:

- Success must be driven by collaboration – an open source platform which allows all industry players to contribute is essential.
- Models must be kept accurate through real-time data – transport is highly complex and driven by human behaviours which reflect multiple factors and imperfect decision-making; the models need to adapt.
- Data security and system resilience cannot be compromised – transport is an essential element of the city, so security and resilience must be 'baked in' to the overall design.

These are huge challenges, but transport is a sector where the use of models is well established. Developing digital twins in our sector will create a cornerstone of truly integrated smart cities, and accelerate progress toward maturity.

Footnotes

1 https://www.iese.edu/research/pdfs/ST-0471-E.pdf
2 http://tiny.cc/saeorg
3 http://www.idcsmartcitymaturity.com/
4 http://tiny.cc/NICreport
5 http://vision-traffic.ptvgroup.com/en-us/products/ptv-optima/
6 https://utmc.eu/

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