

## Digitalizing infrastructure

Juan Montero\*

*Infrastructure is being transformed by digitalization in a specific and distinctive way. Common experiences from different network industries show how digitalization reduces the costs of the design, construction, maintenance, charging and of the operation of infrastructure.*

**D**igitalization

The major technological transformation of our days is digitalization. Technology allows for the creation of a mirror image of reality. A data layer is being laid over the top of reality, which virtually recreates it. Algorithms can then identify opportunities to improve the organization of the system, increasing efficiency. The underlying reality can also be transformed and improved. This has clear applications for infrastructure.

Sensors can be installed in physical assets, sensors that capture and transmit data to the infrastructure manager. This data can recreate, in the data layer, infrastructure status (location, attrition, damage, collapse, etc.), as well as the use of infrastructure for the provision of services (capacity, traffic flows, payments, etc.).

Digitalizing infrastructure depends on the availability of underlying infrastructure: high-speed internet access particularly is a key enabler for other digital technologies. The development of 5G wireless networks across a given territory, not only in densely populated areas, but also in the remote areas crossed by infrastructure, is a fundamental challenge for infrastructure digitalization.

Algorithms allow for the full exploitation of Big Data (Domingos, 2015). Sophisticated algorithms are necessary to put the massive amounts of data created by sensors into order, and to make resulting data relevant. Furthermore, algorithms now incorporate machine learning tools, or “artificial intelligence”. They are no longer a set of fixed commands, rigidly linking a fact to a consequence. On the contrary, algorithms browse through the available data, learning from previous experiences and dynamically linking facts to consequences. Algorithms improve with each interaction, and they are becoming predictive (Agrawal, Gans and Goldfarb, 2018).

Algorithms are increasingly used for infrastructure management. They are used to create the virtual mirror image of a given piece of infrastructure, which is useful in reducing design, construction and maintenance costs. Furthermore, intelligent algorithms can predict and manage traffic flows (be it cars on roads, electricity in energy networks, etc.), as well as adapting capacity, optimizing the load factor and, therefore, reducing infrastructure costs.

Digitalisation, algorithms and automation can significantly improve efficiency. This means a reduction in the investment necessary for the construction and maintenance of infrastructure and, also, improvements in efficiency, as the ability to manage capacity and traffic flows grows.

### Cost reduction in the design & construction of infrastructure

Technology can reduce the cost of the design and the construction of infrastructure. Automated computer design can reduce design costs. Technology can further enhance design and construction methods by better coordinating all the participants in a network. Building Information Modelling (BIM) is described as “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle” (Succar, 2009).

BIM can reduce construction costs. In the case of roads, cost reduction through BIM technology in the design and construction of infrastructure has been estimated to offer 15% to 20% savings over the traditional design system (Blanco and Chen, 2014).

### Cost reduction in infrastructure maintenance

Technology can also reduce the cost of infrastructure maintenance. Traditionally, managers would plan the

\* Juan J. Montero, Part-time Professor, Florence School of Regulation & UNED University (Madrid), jlmontero@der.uned.es

necessary interventions in infrastructure based on the average life expectancy of each element (“preventive maintenance”). Managers would, then, intervene if a fault were detected (“corrective maintenance”); this intervention would naturally come too late if the fault had led to a collapse in the infrastructure.

Technology is transforming maintenance. The Internet of Things (IoT) allows for the installation of sensors in all elements in a given infrastructure. In this way, the infrastructure manager can monitor the status of these elements, and maintenance can be tailored to the real conditions of the infrastructure, making “conditions-based maintenance” possible for infrastructure. Intelligent algorithms can even make use of existing data to predict maintenance needs, enabling “predictive maintenance” (Daneshkhah, Stocks and Jeffrey, 2017).

Maintenance costs can be reduced. After all, interventions now take place when they are really necessary, rather than being based on a conservative theoretical analysis or costly break-downs. An example: for railways rolling stock, it has been estimated that “condition-based maintenance” can reduce costs from 10% to 15%, while predictive maintenance can reduce costs by a further 10% (McKinsey, 2016).

#### **Cost reduction in charging for infrastructure use**

Technology can also reduce the costs of charging for infrastructure use. Charges for infrastructure use are usually related to the volume of use of the infrastructure (the number and duration of telephone calls, the kilometres of highway used, the kilowatts of electricity employed, etc.). Metering infrastructure usage generates a cost. The cost is higher when measuring takes place on the periphery of the network, as is the case with electricity, gas and water networks. Meters have to be installed in each point of consumption and information has to be transferred to the infrastructure manager for invoice production. Furthermore, measuring and charging can disturb the traffic flow. Take, for instance, road tolls, which have traditionally obstructed traffic and created congestion at peak times.

Technology is reducing costs by digitalising meters. So-called “smart meters” are reducing costs for charging users in the electricity industry. Meters in themselves, and the associated communications technology, may have a substantial cost. However, they can significantly reduce meter-reading costs, as well as general maintenance costs and costs generated by electricity theft. The experience with water meters is somewhat different, as the low price of water does not always justify this kind of investment, other

than in areas with water scarcity. Smart meters can also reduce external costs. In Taiwan, it has been found that electronic tolling in road transportation can reduce congestion (-60.1%) and CO<sub>2</sub> emissions (-12.4%) (Tseng, Lin and Chien, 2014).

#### **Cost reduction in infrastructure operation**

Technology is not only about transforming the construction and maintenance of infrastructure. It also means transforming infrastructure operation and in particular the key feature in infrastructure management, namely the control of the load factor. Digital technologies allow infrastructure managers to have more control of demand, in the form of traffic flows, but also supply, in the form of dynamic capacity management. Efficiency can be increased as spare capacity is reduced while avoiding congestion.

Controlling demand to avoid congestion is a key element in infrastructure management. Infrastructure presents obvious network effects: the larger the number of users, the lower the cost for each of them as fixed costs are more widely shared pool for distributing the high-fixed-sunk costs of operating a given infrastructure set. As a network industry, infrastructure may also face negative network externalities, particularly in the form of congestion. Distributing traffic evenly across time and space (load factor) is one mechanism for reducing congestion without reducing infrastructure use.

Technology provides instruments for adapting demand to capacity. As infrastructure managers have new tools to predict traffic flows (e.g. predictive algorithms), they can incentivise the use of infrastructure in off-peak periods. Infrastructure managers have always tried to manage demand. The novelty now is that infrastructure managers can predict peak/off-peak usage in real time with far more accuracy, looking at time of the day and year, weather, specific events, etc. They can build more complex pricing schemes, based on metering and billing. For example, smart meters in electric networks are increasing the pricing sophistication of the service, with incentives being made to reduce consumption when demand is peaking.

Infrastructure managers can also respond to fluctuations in demand in real time through dynamic pricing. They can automatically adapt their metering and billing systems. They can also inform users in real time so that these consumers can make their own decisions. Infrastructure managers can reduce congestion, too, by distributing traffic across the network in ways that are more efficient. Discounts can be offered to users if they take alternative roads, or if they take alternative railway services, possibly with a

detour. This kind of network management is possible if the infrastructure manager has better knowledge in real time of how the network is being used; or if he or she is able to predict the same effectively and has the ability to respond in real time with new alternative capacity and new prices.

Digital technologies do not only allow for demand to be adapted to capacity, they also allow capacity to be adapted to demand. Software-Defined Networking (SDN) can dynamically adapt capacity to demand by virtualising infrastructure and by providing capacity as a service, rather than as a fixed asset.

SDN decouples the physical infrastructure layer from the control layer, and uses software to dynamically adapt the capacity in the physical layer to existing demand. If a customer demands more capacity, it is provided in real time. If a customer demands only a little capacity at a given time, the excess capacity is used to serve other customer. This is particularly useful in managing bandwidth in large data centres. In the same line, Deep-Packet Inspection (DPI) allows for the prioritization of traffic supporting critical applications over non-time-sensitive traffic. The “bandwidth on demand” services are already a reality (Kreutz et al., 2015).

The concept of SDN is being exported from telecoms, and it is expanding into other infrastructure industries such as electricity. It was originally employed with the provision of electricity to data centres, as a way to ensure the supply of electricity to critical applications. But SDN is now proposed as a solution to help dynamically manage electricity networks. For example, at times of low load, the voltage and operating frequency of the network can be reduced, lowering network operation costs.

The concept of SDN can also be exported to transportation. A smarter management of capacity can take the form of smaller vehicles to provide mass-transit services when demand is found to be low. Larger vehicles and a greater flow of vehicles can be dynamically assigned when a demand peak is identified in real time through sensors and predictive algorithms.

Greater control over the load factor allows infrastructure managers to adapt existing infrastructure capacity to cope with growing demand without congestion. This ability can also be used with unpredictable events, such as black-outs and accidents. Costs can be reduced very substantially.

### **Conclusion**

Technology can significantly reduce costs for the infrastructure manager. Even if the implementation of new technical solutions has a cost in itself, an investment has

been shown to pay off in many different contexts. Technology can reduce the cost of design, construction, maintenance and traffic charging. An example: it has been estimated that a 30% average reduction in CAPEX can be expected in the road industry from the implementation of the best technologies (Oliveira Cruz and Miranda Sarmiento, 2018).

Digital technologies enable infrastructure managers to achieve better efficiency by better matching capacity supply and demand. Technology provides new tools for dynamic pricing, empowering infrastructure managers to reduce peaks in demand. Technology even empowers infrastructure managers allowing them to adapt capacity supply to demand forecasts.

## References

Agrawal, A., Gans, J. and Goldfarb, A. (2018), *Prediction machines. The Simple Economics of Artificial Intelligence* (Boston: Harvard Business Review Press)

Blanco, F.G.B. and Chen, H. (2014), The implementation of building information modelling in the United Kingdom by the transport industry, *Procedia - Social and Behavioral Sciences*, 138(2014), 510-520.

Domingos, P. (2015), *The Master Algorithm. How the Quest for the Ultimate Learning Machine Will Remake Our World* (New York: Penguin Books).

Daneshkhah, A., Stocks, N.G. and Jeffrey, P. (2017), Probabilistic sensitivity analysis of optimised preventive maintenance strategies for deteriorating infrastructure assets, *Reliability Engineering & System Safety*, 163, 33-45.

McKinsey (2016), Huge value pool shifts ahead – how rolling stock manufacturers can lay track for profitable growth, Report September 2016.

Cruz, C. O., and Sarmiento, J. M. (2018), Maximizing the value for money of road projects through digitalization, *Competition and Regulation in Network Industries*, 19(1-2), 69-92.

Succar, B. (2009), Building information modelling framework: A research and delivery foundation for industry stakeholders, *Automation in construction*, 18(3), 357-375.

Tseng, P. H., Lin, D. Y. and Chien, S. (2014), Investigating the impact of highway electronic toll collection to the external cost: A case study in Taiwan, *Technological Forecasting and Social Change*, 86, 265-272.