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Why digital twins are critical for climate change mitigation

Digital twins represent an enormous opportunity for governments to move towards data-driven and evidence-based climate change mitigation —both with regards to their own assets, as well as requiring other asset owners and managers to digitalise their planning and operations. Digital twins, as realistic digital representations of physical assets, systems and processes, can help not only collect and process data to produce insights regarding greenhouse gas emissions from asset operations and management, but can also provide a digital environment simulating the impact of various options to reduce these emissions, and monitor the impact of implemented measures. As such they can make a significant contribution towards building an information environment that can support policy and direct interventions to deliver on decarbonisation commitments.

In order for these benefits to be realised, digital twins however must be designed and implemented as part of digital strategies, rather than viewed as standalone technology 'fixes'. This means that the technical design and implementation of digital twins must be purpose- and challenge-driven, and informed by stakeholder and user requirements from the outset. In turn, governments taking such a strategic approach to digital twin development can influence industry and other influential societal actors, steering the advancement of digital twin technologies towards decarbonising the global economy.

Managing the Built Environment as a System of Systems

Our infrastructure and built environment systems combine to form a dynamic 'system of systems' defined by its complexity: not static and predictable, but dynamic and evolving. These systems are increasingly cyber-physical: composed of interacting digital, analogue, physical and human components, the digital elements supporting the functionality of physical infrastructure. That is one reason why coordination between those involved in the built environment has become more important than ever.

Infrastructure systems have always been interdependent to a degree, but today they are more interdependent than ever before. The growing popularity of electric cars and the integration of digital technology into roads and railways mean that transport infrastructure needs to be closely coordinated with the power grid. Much of our energy generation relies on water resources, for cooling and hydropower. Branches of the built environment that could previously be run relatively independently now have to be brought into alignment with each other.

Fortunately, disciplinary advances in systems engineering and complexity science, and technologies like digital twins, put the management of complex systems within our reach. The interdependencies between infrastructure systems can be modelled to predict likely impacts of new developments on existing stock.

To make the most of these advances, a strategy is needed for managing the complex system of systems that comprises the built environment. Such a strategy could help the construction industry to understand the interdependencies built into its projects, and improve their social and environmental footprint and resilience.

Thanks to developments in systems engineering, complexity science, information management and data science, we are now better placed than ever before to understand, manage and intervene effectively in complex interconnected systems.

Alternative materials

One major challenge in construction is the impact of materials. Materials have high levels of 'embodied carbon' – emissions caused by extraction, manufacture and processing, transportation, deconstruction, and disposal of the material. Taking all materials into account, embodied carbon in construction makes up 11% of global emissions. Steel and cement alone account for at least 8% of global CO_2 emissions. Until both can be reformulated, these materials will remain carbon intensive.

There are, however, new composites available with potentially lower embodied carbon, such as HempCrete (concrete made from hemp), mycelium (a material derived from fungi),and ferrock (a material made from recycled steel dust).[30] Governments can support their use by incentivising designers and builders, including in public

30 https://inhabitat.com/11-green-building-materials-that-are-way-better-than-concrete/

projects, to take 'a whole-life approach' to calculating impact and choosing materials – encouraging them to take into account not just emissions from a building, but also the manufacture and disposal of its materials. They can also encourage companies which upcycle waste. **Carbon Craft Design** (India), for example, has developed methods to convert waste products from building materials, including carbon emissions themselves, into useful materials.

Workflow Automation

The construction industry can also reduce the amount of waste it produces as well as its energy consumption by using workflow automation – digitalising the planning and execution of subtasks in a construction project. By notifying stakeholders when actions or approvals are needed, the process reduces paper dependency, and improves efficiency and cost-effectiveness. This kind of Building Information Modelling (BIM) can drastically reduce waste by eliminating the need for design changes to be made during construction.

GREENbimlabs (Germany) has developed software to produce a comprehensive simulation of a project, modelling the optimal use of materials during construction to avoid waste and for greater efficiency across its life-cycle. Teknobuilt (Canada) takes a slightly different approach, offering total workflow automation through an OS platform for better resource management. And Swapp (Israel) uses algorithms to devise building designs for the most efficient possible use of materials, reducing waste.

Monitoring and Managing Energy Consumption in Buildings

Buildings do not just emit greenhouse gases while they are being built. They also emit a great deal while they are being used, and even when they are demolished. At present, these account for 36% of emissions in the EU. The operation of buildings also account for about 50% of all extracted materials, 33% of water consumed, and 35% of waste.

Newer dwellings are already substantially more energy-efficient than older ones on average, which is a cause for optimism. But the older ones will be around for a long time, which means retrofitting them with energy efficiency measures will be vital to achieve net zero carbon by 2050. This is particularly important for governments to keep in mind, because government-owned building stock is disproportionately older than privately-owned stock.

Adding sensors and smart meters to buildings to monitor energy consumption and automatically manage environmental conditions helps to track and conserve energy usage. Infogrid (UK) and Worldsensing (Spain) offer versions of these sensors that are comparatively simple to install and offer automatic data reporting.

Governments have an opportunity to use the decarbonisation of their own old, energy-inefficient buildings to launch and promote public competitions to find and showcase efficient and effective methods of decarbonisation, and raise awareness of how it can be done.

The UK has quietly disbursed £932 million in grants for decarbonising public sector buildings, with a focus on energy efficiency and heat decarbonisation, following a competition in January 2021.[31] The European Union, meanwhile, is aiming for 35 million building renovations by 2030. It prioritizes funding energy efficient renovations, and will usher in binding energy performance standards for all EU buildings in 2021. To promote further innovation in this area, governments can link their own retrofitting with the broader project of integrating digital innovation into urban spaces and public services to create more liveable, integrated cities. The EU has done linked retrofitting with urban IoT schemes under the **Smart Cities and Communities** initiative, which 'aims to **improve urban life** through more sustainable integrated solutions and addresses city-specific challenges,' such as energy, mobility and transport.

Waste and the Circular Economy

Construction and demolition produce a huge amount of waste: they comprise the single largest waste stream in the EU, amounting to 374 million tonnes in 2016.[32] Some of this waste, especially from older buildings, is highly toxic: asbestos, lead, PCB caulking, mercury. Some smoke alarms even contain the radioactive isotope Americium 241.[33] This waste presents a serious hazard to the natural environment and human health.

To reduce the impact of construction and demolition on the climate, it is time to start thinking about the principles of the "circular economy" in construction. Within this model, all resources that are extracted are reused, and then their components recycled, for as long as possible to extract the greatest possible value from them over the course of their lives. **Digital innovation can help with this by upcycling waste.** The EU set an ambitious target of recovering 70% of all construction materials by 2020, which it nominally met by establishing markets for the recovered materials. But it found that most of these recovered materials were not suitable for reuse or closed-loop recycling because they were substantially impure. Most of the 70% figure had been achieved through backfilling or low-grade recovery that leaves little scope for future reuse.[34] Upcycling waste products can restore their wider utility to create a true circular economy.

More and more funding is coming available for digital measures to address the problem of demolition waste: Digital Deconstruction, a project run under the auspices of Interreg North West Europe, has a total budget of 7.61 million Euros to research this topic.[35] Some innovative startups have already developed their own upcycling methods.B C-Materials (Belgium), for example, converts soil excavated from building sites into new building materials. –

31 https://www.newpower.info/2021/03/hospitals-schools-and-other-public-sector-buildings-win-nearly-1b-funding-to-decarbonise-second-competition-promised/
32 https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges
33 https://www.ehs.ufl.edu/programs/chemrad_waste/demowaste/
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35 https://www.nweurope.eu/projects/project-search/digital-deconstruction/