THE INFRASTRUCTURE PROJECT OF THE FUTURE

Leapfrogging into a not-so-distant future, this article explores how technological advancements will significantly impact project delivery.

Future infrastructure projects will probably start similarly to those today, based on a prediction of the future needs of the population, but with much of the current guesswork eliminated by significant improvements in modelling; incorporating the use of all the available 'big data' and including sophisticated predictions[1] on the behaviour, lifestyles and locations of the future populace. Insights in this area, including predictions[2] of need and risk, may come from the development of large-scale cross-domain models, incorporating sub-models of employment, housing, schooling, transport and similar, and from crowd-sourcing techniques such as prediction markets.

Once a project is identified it will be specified in a formal manner[3], setting out exactly what benefits it should achieve. This formal specification will be in the form of a model, detailing what the project outcomes should be and the constraints within which these must be delivered. Concerns such as planning consents and sustainability will be entirely contained within the specification[4], and therefore automatically contracted and verified as part of the overall process.

Through reference to a library of all similar projects completed around the globe, an accurate initial estimate of the timescales and costs involved in delivering a solution — adjusted for past and predicted changes in technology, labour and economics — will be automatically be generated. This automatic costing process will enable fine-tuning of the specification to optimize the cost-to-value ratio for the area in question.

With a project described and agreed in a formal specification, a contract will be automatically generated to put it out to tender. This specification and contract will be 'computational', allowing them to be mathematically verified as being complete and consistent[5]. Initial work by prospective contractors will respond to the tender through the development of high-level designs[6], describing and costing the 'architecture' of their solution. As these will also be specified in a computational manner, compatible with the contract, the proposed solution can then be automatically

[1]The emphasis here is potentially moving from a 'Predict and Provide' approach to a 'Vision and Validate' ethos.

[2]Prediction markets are for betting on the outcome of events. They are increasingly being used to provide accurate forecasts of the future.

[3]Formal specifications are commonplace in software engineering.

[4]Text-based requirements are currently used to specify project objectives, however Model-Based Systems Engineering specification techniques are being investigated to support procurement.

[5]Projects such as Legalese are making progress in building a 'Domain Specific Language' for law.

[6]A combination of Systems Engineering and Building Information Modelling methods provide all the components necessary to fully specify a tender response in a database format.

verified as meeting the client's objectives. The selection between tenderers then becomes more straightforward and visible.

When a preferred supplier is determined, smart contracts[7] will be agreed using blockchain technology. These will execute the terms of the contract automatically, releasing payments of cryptocurrency to the supplier once the various stages of delivery are verified.

The client-developed outcome specification, along with the solution architecture proposed at tender, will form the basis for design development. The design will develop as part of a suite of interoperable tools that manage risk, cost, schedule and assumptions. Changes to any one aspect will be immediately reflected in all other areas of the project. This holistic approach will subsume all project details into a single model, representing the sum-total of all project knowledge. With all parties working with a single source of truth[8], misunderstandings, miscommunication, duplication of effort, and gaps in design are expected to reduce to virtually zero.

Templates, designs and delivery structures produced on similar projects will be imported early in the project lifecycle, driving rapid and efficient development. Bespoke three-dimensional physical design can then progress, in parallel with planning the time sequence of construction, cost of construction, and details of the operation and maintenance of the assets, all within the same design model. Any external input into these models can be scraped directly from input documents or existing models that may not be compatible for import. Open data sources will also be interrogated and used to populate key aspects of the project model.

Relatively early in design the model is likely to become 'executable' in several ways[9]. This will allow designers and other stakeholders to explore it as it develops. Automated operations may be simulated and revised as the operational concept develops, and virtual and augmented reality testing and training will provide early 'human-in-the-loop' assurance of a successful outcome. Further testing will be supported by person and crowd behavioural simulations. Through simulation, robustness will be built into design from the early stages; ensuring a reliable, safe and environmentally sustainable product is developed. Public access to simulations may also be used to increase stakeholder engagement and buy-in.

Artificial intelligence and machine learning techniques will be pervasive across all areas of the design and development process, working in tandem with human designers to prompt initial ideas, perform calculations, and carry out the mundane and trivial tasks.

[7] Ethereum already exists as a cryptocurrency supporting smart contracts.

[8] The aspirations of the Building Information Modelling approach go some way towards achieving this.

[9] Related ideas around computable documentation are currently gaining momentum, with tools such as observable being developed to facilitate this.

Project controls related disciplines such as project management, systems engineering, and digital engineering – rather than being represented by specific project roles – will become behaviours and processes embedded within the course of standard project delivery[10], supported by the toolset, and practiced by every engineer on the team.

Throughout development the design model will be automatically validated against the client's formal specification, to track and report on compliance. Non-compliant aspects will be automatically flagged for either re-design or specification change. Due to the early client-side modelling, the need for variation to the specification will be rare[11]; but where necessary this should be a clear and straightforward process. As the impact of changes will be automatically traceable to their effect on the highest-level outcomes, the decision for the client will be a straightforward optimisation exercise[12].

Where multiple projects are being delivered in the same area, or on the same network, the models produced by each team will be regularly federated together to resolve interdependencies or clashes[13] in any of the multiple project dimensions. Client organizations will likely be responsible for this federation, incorporating their own business models within the output, to maintain a full view of the city infrastructure as it develops into the future.

With all parties having access to a model containing the full source of truth, production of documents on the project will become a rarity[14]. Where they are still required they will be automatically generated from the model.

Construction of the design will be largely automated and driven directly from the model. Computer-controlled techniques will print, cast, or otherwise fabricate components, sometimes off-site, but frequently in-situ. Digital scanning and automated testing[15] will enable almost completely hands-off verification of the built environment against the design, completing test-plans that were generated in the early stages.

Due to the construction process having been planned from the outset, based on a complete understanding of the surrounding projects, infrastructure and operational environment, the build will be staged to create minimal intrusion; the result being large infrastructure projects that seem to appear almost overnight.

Transition into service will occur seamlessly, with automated testing, commissioning and operational monitoring being used to validate the achievement of high-level project objectives and terminate smart contracts. Where aspects of operation and maintenance are still manual, the operators and maintainer will have been involved throughout the design and simulated testing process, requiring virtually no training on the built assets.

[10]In the same way that typists have been completely replaced by everyone having their own computer keyboard, and drafters are in the process of being replaced by engineers designing in 3D.

[11]There will be no need for deviations or waivers, as the cost of complete specification changes will be low.

[12]Alternatively, dramatically reduced construction costs may enable an Agile delivery approach – the specification changing regularly and developing in parallel with a constructed solution that is rebuilt within 'Sprint' iterations.

[13]Clashes will include not only physical issues, but also schedule, risk, assumption, operational or maintenance concerns.

[14]Replacing documents will be a set of pre-defined 'views' of the model, providing live information in the format most suitable to the user.

[15]Test plans may be made concurrently with authoring of the formal specification, enabling Test-driven development practices to be used.

Handover will be supported by final updates to the project model, effectively providing a 'digital twin' to the built asset, already linked and interoperable with client models, that will support further operational simulation, training, asset tracking and repair management, future infrastructure upgrade and extension, and eventual disposal[16].

The above represents one possible vision of how infrastructure projects – regardless of location or industry – could potentially be delivered in the future. Although it is unlikely that everything discussed will come to fruition, many possible alternative and complementary ideas are not included, and the time-to-market may vary widely between technologies[17]. WSP has a view towards this future, both in terms of preparing for it and in taking steps to make it happen.

[16] Asset management could also potentially be handled on the blockchain.

[17] Although timescales are difficult to predict, all the above seems feasible within the working lifetime of current engineering graduates.

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