Deliverable

D8.1 Project Vision

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1. Vision

1.1 Purpose

A vision statement is an anchor for any project. It provides a picture of a better future, showcasing what the world will look like if your initiative is successful. It is the basis for all the deliverables and outcomes delivered by a project and therefore provides a strong focal point for engagement and motivation of project partners and stakeholders towards the future state.

Having a strong vision is often the difference between a great project and one that is just 'good enough'. Whenever changes occur in a project the vision should always be reviewed to ensure delivery aligns to strategic objectives. This does not mean the vision is set in stone, it should be reassessed frequently during any project, with stakeholders to ensure it's still relevant and delivers the expected outcomes.

For DUET, the vision below will be updated based on project calls in the three months ahead, and then will be revisited annually with all project partners at a general meeting.

1.2 Vision Statement

To make DUET's vision statement easy to understand and coalesce around, it has (a) been broken down into three core project focus areas, and (b) been condensed into one simple to understand sentence for each of those areas.

Cities:	DUET makes it easy for any city, regardless of size, to benefit from opportunities that digital transformation provides, such as cloud infrastructure & Artificial Intelligence (AI), and realise the full potential of city data to drive an era of informed, smart and co-created policy making.
Technology:	DUET leverages cloud and high powered computing to connect physical and cyber systems resulting in a near real-time, digital footprint of a city for exploration and experimentation. The solution is extendable and reproducible, allowing new modules to be added easily to create a digital twin for a new city.
Standards:	Thanks to strong focus on interoperability and portability, DUET's Policy-Ready-Data-as-a-Service (PRDaaS) advances global standards for city data enabling a digital twin to be set-up in one-click for systemic policy impact exploration and experimentation.

2. Mission Statement

2.1 Purpose

A mission statement is an action-oriented vision statement, declaring the purpose of the project to its audience. This includes a general description of the project, its function, and its objectives to clarify the *“what,”* the *"who"* and the *"why"* of an initiative. Essentially, it's the roadmap for the consortium's vision statement.

2.2 Mission Statement

Cities across Europe are using DUET to create their own digital twins for systemic policy impact exploration and experimentation based on Policy Ready Data as a Service (PRDaaS) in a virtual environment. Initially, DUET will be developed and tested in Flanders, Pilsen and Athens. These pilots start from different positions on the digital twin journey. Antwerp has a working prototype. Pilsen has the tools but not an integrated solution. Athens is in the early stages of its Digital Transformation Roadmap and is starting from scratch. However, what unites the three is a conviction that digital twin technology is key to effective, future-proof policy making. By the end of the project, each pilot receives a solution commensurate with their city’s digital maturity, smart city strategy, political buy-in and budget.

As results from the original pilot network begin to spread, new cities with similar needs, challenges and data literacy will start to eye DUET as a potential solution. This is because DUET is not just about making trendy 3D maps. It is not about digital objects that cities can use as window dressing to impress the public, foreign investors or smart city researchers. DUET is not meant as a mere box-ticking exercise so that cities can raise their score in some international ranking. DUET is, above all, a purpose oriented initiative. Whether the goal is to empower citizens, improve foresight and scenarios simulation capability, strengthen coordination during emergency, optimise business performance, reduce traffic or carbon footprint, DUET provides a cost effective solution that cities can adapt to their context with minimal development effort.

DUET enables decision makers from multiple sectors to co-create innovative solutions to complex urban challenges by drilling down into data through a shared, easy-to-use interface. Although DUET’s solution is designed primarily for cities and public administrations, there is no reason why the application can’t be used by other industries. The underlying architecture is built with interoperability in mind. As such, DUET technology can support decision making at a sports event, on a factory floor, in a port’s control room. Users can upload any model so long as it complies with the framework requirements, after which they will be able to run simulations, analyse data, visualise insights, and much more.

Built to handle large datasets, both historic and real-time, the solution enables interrogation of anomalies and deviations before a disaster strikes. Thanks to the IoT connection, investigations can be done remotely from any place within a city and beyond; all that is needed is access to the DUET dashboard. Other benefits come from embedded ML and AI functions, which allow the system to make predictions concerning e.g. depreciation of road infrastructure or environmental footprint.

We start by testing DUET in the smart city environment, with local administrations as main users. However, a fully developed solution has no restrictions when it comes to potential adopters. City halls, companies (big and small), universities, emergency services all are using DUET because it is cheaper, more advanced and user-friendly than competitor solutions. **Thanks to DUET, organisations are more responsive, reacting rapidly to real-time events; policy decisions are faster and more effective, and relationships with citizens are improved.**

3. Background

The idea that physical objects can have a virtual representation is not new. The oil and gas industry has used digital technology to simulate fuel reservoirs since the 1980s.[1] Companies such as Rolls Royce, General Electric and Siemens have been designing their engines and turbines with the help of simulations decades before Michael Grieves coined the term digital twin in 2001.[2] Scientific literature of the pre-digital twin era abounded with concepts of similar nature e.g. digital models, digital avatars, digital shadows.[3,4]

After the idea hit the mainstream, digital twins attracted a slew of interpretations, ranging from simple to more complex (see Appendix A). One thing that is different across all these characterisations is focus. Some authors have applied the concept strictly to objects and products, others to processes. Many have chosen to focus on an entire system or some combination of the three i.e. object, process, system. Another differentiating factor concerns purpose. Depending on researcher's or organisation's background and interests, the aim of a digital twin can be return on investment (Deloitte), safety (NASA), real-time monitoring (Microsoft).

The fact that many definitions exist can be seen as a positive thing. Multidisciplinary interest which the concept has enjoyed over the years is a testament to the growing recognition of its benefits in policy circles, industry and academia. It wouldn't be an overstatement to say that digital twins offer something to everyone. Whether you are an economic development officer, a car engineer, a supply chain specialist, a doctor or an ITS researcher, with digital twin technology you can work more effectively by investigating problems before they happen. You can assess the impact of different interventions before making a final decision and react to events remotely without having to visit the actual place. The diversity of use cases means that digital twins do not depend on any particular sector for survival. This greatly reinforces digital twin's continuity as a concept. Even if the interest fades in one industry, in the grand scheme of things the concept will be doing just fine.

Having said that, with so many competing interpretations around, it is easy to get confused about what digital twin really means. For a multidisciplinary project like DUET, it is very important to get a common understanding of the concept before proceeding to the R&D phase. To that end, a special workshop was held at the kick-off meeting to stimulate partners' thinking about digital twins, what the concept is, what it is not, what kind of digital twins we should have in the end, and what should be their function, content, purpose.

1 Yergin, Daniel (1991) "The Prize: The Epic Quest for Oil, Money, and Power." New York: Simon & Schuster
2 Grieves, Michael, et al. "Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems.' in Kahlen, Franz-Josef, Flumerfelt, Shannon, Alves, Anabela (Eds.) (2017) "Transdisciplinary Perspectives on Complex Systems: New Findings and Approaches." Springer
3 McKenzie, J. (1999) "!nt3rh4ckt!v!ty." Style, 33(2), 283-298 www.jstor.org/stable/10.5325/style.33.2.283
4 Clarke, Roger (1993) "The digital persona and its application to data surveillance." The Information society. Vol. 10: 77-92

4. Approach

4.1 What is a Digital Twin?

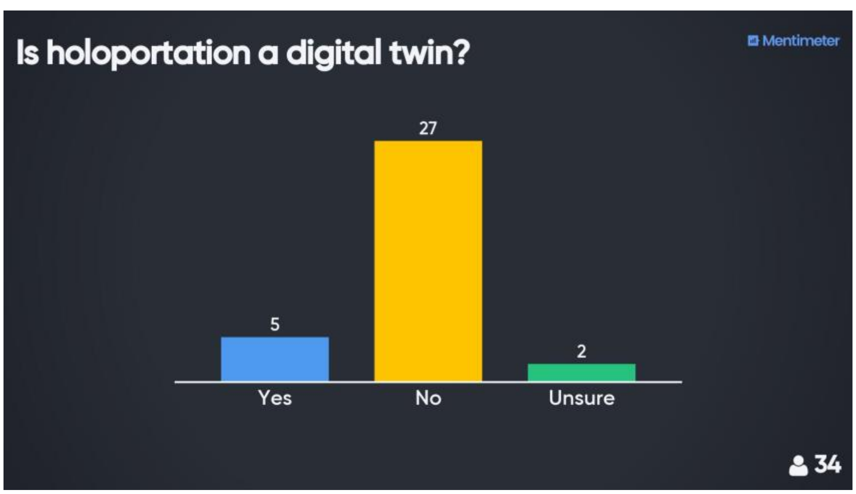
What actually is a *digital twin*? A basic common understanding is a prerequisite for the co-creation of a coherent vision, and was the guiding principle that underpinned our rationale for organising an interactive visioning workshop at the DUET kick-off meeting in Antwerp.

The workshop was not intended to coalesce partners around a fixed definition of a digital twin. Rather, given the multi-dimensional nature of the concept and the consortium's interdisciplinary background,[5] **the aim was simply to establish a framework for thinking about digital twins in general and DUET instances in particular.** This was achieved by testing partners' assumptions about the concept using various real-life examples. The examples were real in the sense that they all have been tested in a professional setting, and as such are not mere academic abstractions that are nice-to-have but practically impossible to implement. In total, we looked at five examples from different industries to answer a more important question: what kind of digital twins should we built in DUET?

The workshop was run using Mentimeter, an interactive presentation tool that enables people in the room to participate in real-time in discussions by voting/choosing answers to slide questions via their smart device. The results were as follows:

Example 1: Holoportation

Holoportation lets you appear in someone else's reality as a full-sized, three-dimensional hologram. For it to work, you need to set up a number of cameras around a room to track shapes and movement and ultimately create a 3D model of a person in real time. The necessary data is then compressed and transmitted to a headset which can show the motion-captured figure as if it's really present in a room.

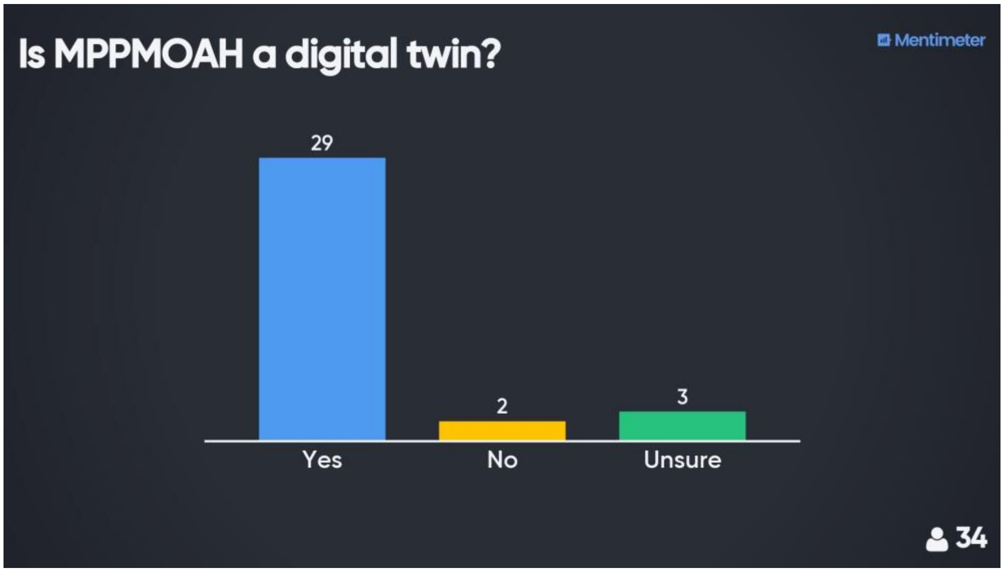


5 DUET partners come from a variety of backgrounds: data modeling, system integration, cloud computing, project management, local development, community building, legal, communications

After a brief explanation, the audience was asked to vote on whether holoportation is a digital twin.[6] Overwhelmingly, partners voted no, citing the lack of continuity as the main reason i.e. the digital twin exists only while the cameras and headset are on; when these are switched off, a digital twin ceases to exist. Those who voted yes explained that, visually, a hologram does appear as a person's digital representation. Two undecided participants said that, on the one hand, holoportation has all the hallmarks of a digital twin (real-time connection, physical-digital nexus etc.) but, on the other, a hologram does not have any inherent reasoning function; hence the dilemma.

Example 2: Multiscale, personalised, physiological model of a heart (MPPMOAH)

MPPMOAH represents a shift in healthcare towards personalised cardiology. The model is built using patient's medical history, as well as data from images, ultrasound and lab tests, among other sources. First, the heart's anatomy (physiology) is created. Then, all the electromechanics are computed to "make the heart beat." Thanks to the latest advances in science and technology, MPPMOAH can accurately model heart's dimensions, muscle contraction, ejection fraction, pressure dynamics. Doctors have full control of the model and are able to test different therapies, evaluate outcomes and select the best treatment for the patient based on simulation results.

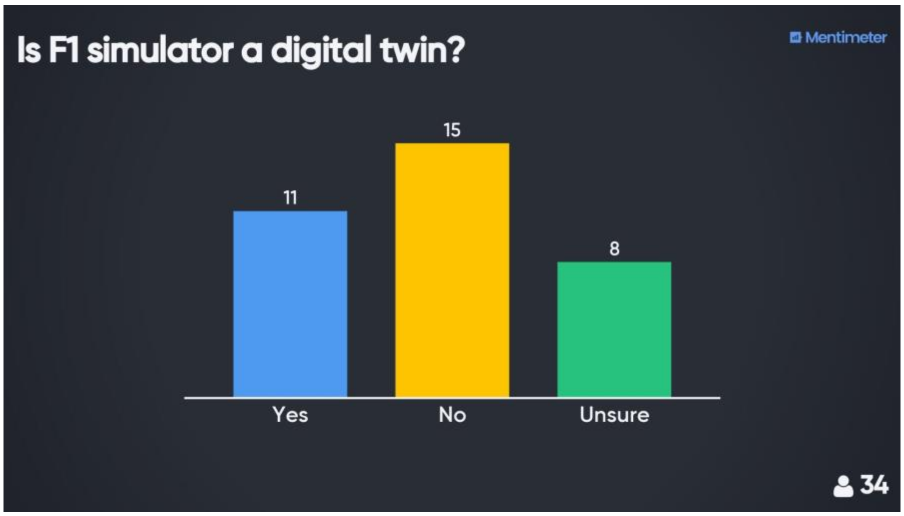


Workshop participants almost unanimously agreed that MPPMOAH is a digital twin. The fact that IoT connection (in this case, between a person and a model) is missing wasn't considered an issue. If doctors can make accurate conclusions about heart's response to different therapies, it means historic data is fit for purpose. Only two people thought that real-time link is important and for that reason voted no. Three people could not make up their mind as to whether historic data is enough for MPPMOAH to be called a digital twin.

6 Feedback was captured using https://www.mentimeter.com/

Example 3: Formula 1 simulator

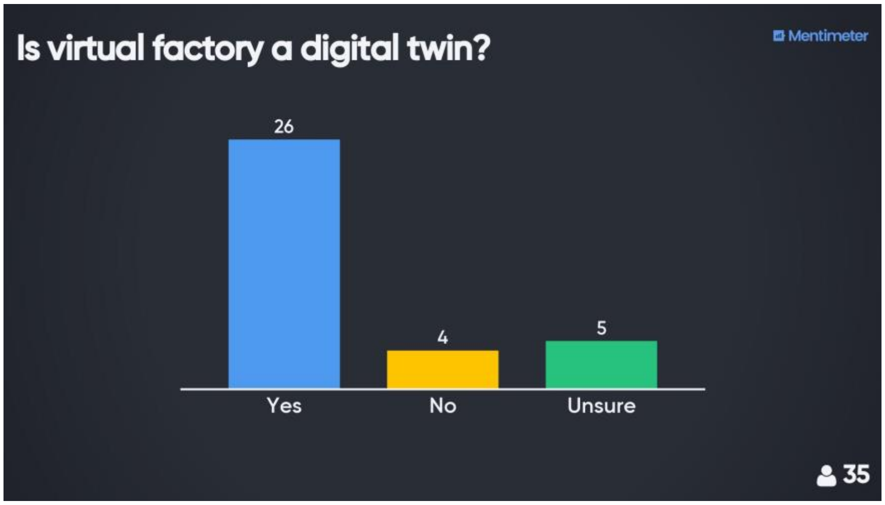
Racing simulators are increasingly used by F1 teams throughout the course of the season to test the best configurations and setup. For example, they can be used to engineer features, predict parameters and visualise results on streaming events. The software enables engineers to immediately sense, respond and adjust the focus to the important combinations of parameters while streamlining the process, providing a centralised location for racing intelligence, rapid visualisation and interrogation of all current and accumulated data.



Although most people (44.1%) thought F1 simulator isn't a digital twin, the gap between them and those who voted yes (32.3%) is smaller than in previous examples. The main reason why people voted no is because all data (aerodynamics, engine etc.) is generated by the simulator i.e. there is no real-time connection with the driver and that the simulator is only a digitally made environment, not a digital representation of real-time reality. For people on the opposite side, the IoT link isn't crucial. If the racing team can achieve its objective (e.g. improvement in car's performance) with a pure simulation, the question of data provenance becomes less of an issue. The undecided minority (23.5%) said they needed more information to make up their mind.

Example 4: Virtual factory

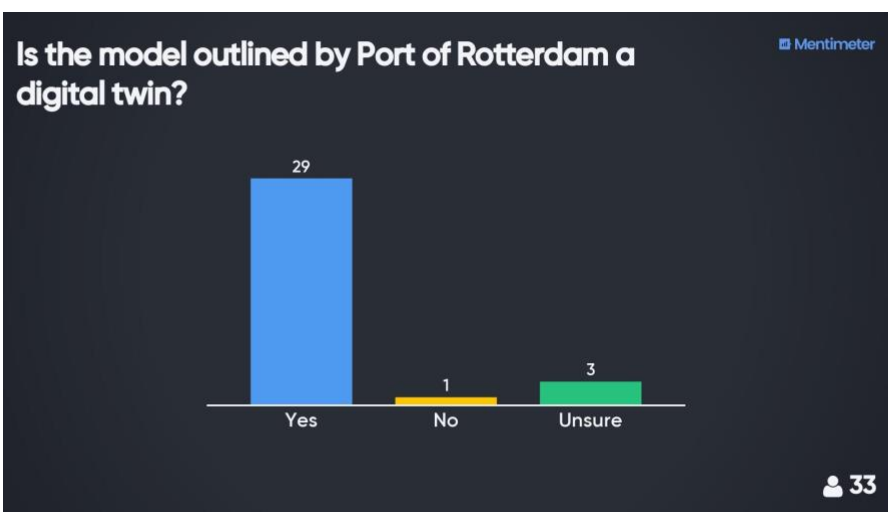
Virtual factory solutions have gained traction as industry 4.0 has taken hold in the manufacturing industry. In the factory context, digital twins make it possible to assess and review an asset virtually before production without physically visiting the space. These solutions have a unified repository that links virtual and physical products together. Instead of simulating what should be happening in the factory, a virtual factory is replicating what has actually been happening at each step in the physical factory on each product. Furthermore, users can see in near real-time or even real time what is actually occurring on the factory floor and view the actual product characteristics as they go through production cells.



For the vast majority of workshop participants, virtual factory is a digital twin. It has a direct connection to products and processes on the production line. Information from the system can be used to optimise business performance. There is a strong physical-digital nexus. Doubters, however, pointed out that operational decisions were still being made by humans as opposed to the system itself. For that reason, virtual factory cannot be called a digital twin, they argued. People who were unsure considered both possibilities. For them, a digital twin is a digital twin regardless of who has the ultimate decision making powers: humans or computers.

Example 5: Port of Rotterdam

The Port of Rotterdam is undergoing a major transformation. Recently it made a commitment to become the first digital port by 2030, anticipating the first autonomous ship to moor there within the next decade. Among the more unique and innovative aspects of the transformation is a sensor-packed experimental physical container (Container 42). Communicating with a digital twin of the port, ships will be able to calculate exactly how much cargo can be unloaded there. This allows the vessel to sail sooner and with more cargo to its final destination.



The model outlined by the Port of Rotterdam in their 2030 vision was accepted by the vast majority of participants as being a digital twin. Why? Because all the defining features are there: IoT, AI, ML, Big Data, physical-digital nexus, a clear results-oriented mission. Once implemented, the changes will allow the port to do many things more effectively e.g. estimate future capacity, manage port traffic, offer cognitive services to vessels, run macro-scale scenarios, integrate multiple digital twins (Container 42, Maasvlakte 2 etc.) into a sophisticated, unified network. A person who voted no said the port already has terminals that work autonomously - and therefore act as digital twins - so future plans don't add anything new. The undecided voters said they deem the 2030 vision too ambitious, and questioned the port's ability to make good on its promise.

The five examples considered above provide an initial framework for thinking about digital twins. First, digital twins should link physical object/process/system with a virtual counterpart. Second, this relationship should be underpinned by data, ideally from IoT devices but historic datasets can also be fit for purpose depending on user requirements. Third, digital twin should offer more than a visual representation of the physical asset. It should comprehensively represent all the elements and dynamics within it. Fourth, digital twin should be results-oriented, helping its users achieve a concrete business outcome. Fifth, given the advances in AI and ML, digital twins should be able to learn, reason and predict while operating in a vast network of systems in which many twins are horizontally and vertically integrated.

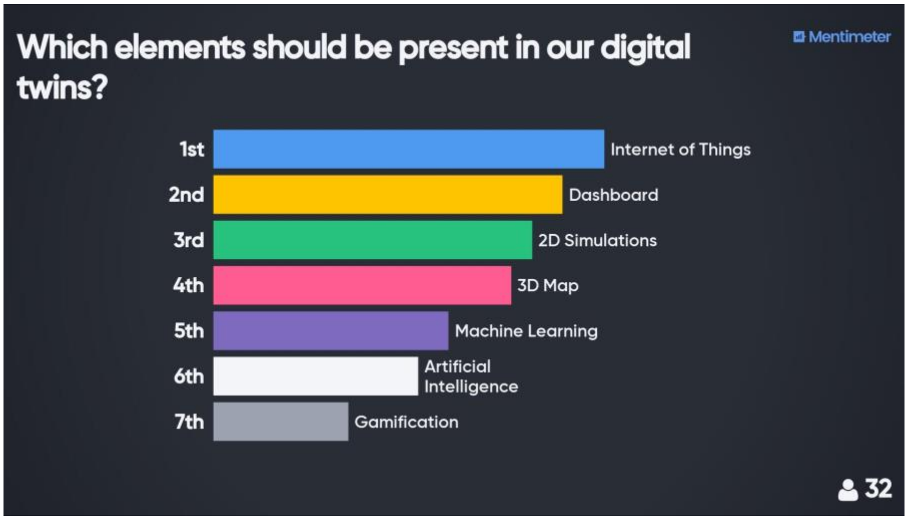
4.2 What kind of Digital Twin is DUET?

At the workshop, participants had a chance to vote on elements that should be present in DUET solution. Although some partners had previously questioned the importance of real-time data connection, the IoT component nevertheless came out on top. The message is clear: policy makers are increasingly challenged to respond to life situations sooner than later. Being able to take the right decision quickly is a new standard for agile policy making. Policy makers should also react proactively using advance knowledge that something is about to happen. This will make it easier to minimise the impact of a crisis or avoid one altogether. Our digital twins should help users make informed decisions based on evidence using IoT data and tools.

The next most desirable thing to have was dashboard. As someone in the room explained, dashboards have been around for a while but they can greatly help collect and share data in an accessible format. It can also be used to draw attention to a need for change, assess progress, promote learning and accountability, and communicate information to the public.

In third and fourth places we have strictly visual outputs: 2D simulations and 3D maps, respectively. This finding suggests that for digital twins to be useful they don't necessarily have to be beautiful i.e. produce spectacular graphics, although having this functionality is certainly beneficial.

Somewhat surprisingly, ML and AI components turned out to be among the least popular elements. Only gamification was worse. Whether this means DUET instances should be wholly or mostly controlled by humans remains to be seen. Partners added, however, that there should be some predictive function to enable users carry out foresight.

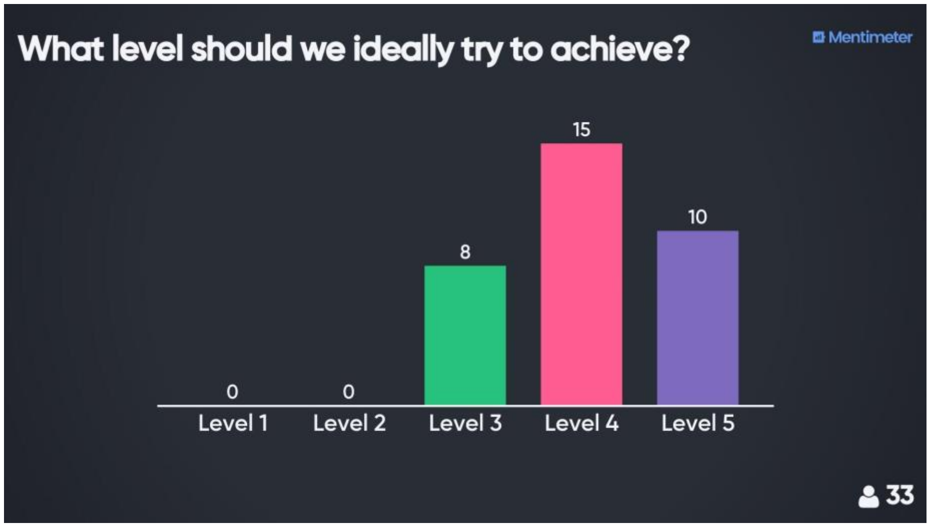


The finding about ML and AI is also interesting because an autonomous digital twin with significant decision making powers is regarded as the most advanced type according to subject matter experts.[7] An evaluation framework designed by ARUP and international digital twin researchers moves through five levels, beginning with a simple digital model. As the model evolves, feedback and prediction increase in importance. At higher levels, ML capacity comes into play along with the ability to reason and act autonomously, and to operate at a network scale (incorporating lower-level twins, for example). The five levels can be described as follows:

- Level 1: basic 3D map
- Level 2: digital model with a feedback loop to the operator e.g. virtual factory
- Level 3: digital model with predictive function e.g. response to medical treatment e.g. MPPMOAH
- Level 4: digital model capable of learning from data and able to make limited decisions e.g. connected cars environment
- Level 5: extends Level 4 by making decisions on behalf of humans e.g. Port of Rotterdam

When we asked partners about what level we should try to achieve, most people voted Level 4 (n=18). 10 partners were very ambitious and selected Level 5. Level 3 received eight votes. However, partners noted that interoperability (of data, models etc.) is missing in the five-level framework, and that we should ensure it is reflected in our approach.

7 ARUP (2019) “Digital twin: towards a meaningful framework.”
https://www.arup.com/perspectives/publications/research/section/digital-twin-towards-a-meaningful-framework



We concluded the exercise with ideas for potential target audience. Below is a word cloud generated from submitted responses. Policy makers and citizens are by far the most prominent categories.

5. Conclusion

Like e-government, open data and smart city, the digital twin concept has been a hot topic in many consecutive waves of digital transformation that have shaped the international ICT agenda. But to realise its full potential, digital twin must become more than a buzzword in yet another digital hype cycle. For one, it has to evolve into a meaningful tool with distinguishable features and benefits. Those looking to embrace the technology must first understand the difference between a digital model, a simulation and a digital twin. Figuring out what a digital twin *isn't* is a good starting point. As discussed in the DUET's workshop, it is *not* a digital model whose sole purpose is to provide information on a physical object. A digital twin is also not a simulation operating in isolation from physical reality. One of the concept's defining features is a digital-physical nexus underpinned by data exchange.

To be useful, digital twins must be open to interrogation for current and past histories, in DUET's case for example allowing the measurement of changes in traffic count, CO2 emissions, energy efficiency. For those looking to predict the behaviour of system components that vary between high and low tolerance levels, the ability to run what-if analysis is important. Adding ML and AI to the toolbox can extend digital twins further by enabling them to make ever-improving predictions about the physical world they were programmed to mirror. This function goes beyond mere monitoring as digital twins should also control and optimise physical assets, be they traffic lights or an assembly line. In this scenario, digital twins do not simply improve decision making, they start making better decisions themselves thanks to the inherent ability to understand, learn and reason using data from the surrounding environment.

The drive toward AI controlled digital twins is already evident in some industries. The Port of Rotterdam is a case in point. Maasvlakte 2 is one of the port's container terminals that is practically fully automated. Ships are loaded and unloaded by automatic cranes. Unmanned self-driving vehicles take the cargo to the storage area. Not only do they know where to drive, they also know when the battery runs out. They replace it at the battery swap station serviced by a robot. Humans do play a role in Maasvlakte 2, but their involvement is limited to remote supervision.

Whilst DUET participants didn't rank AI or machine learning as the highest need for the twins, the majority of the group voted to create a digital twin at Level 4 - **a digital model capable of learning from data and able to make limited decisions**, which certainly requires both those technologies to make it a reality.

This decision also raises the debate about whether humans or AI should control digital twins which is unlikely to be settled anytime soon. In logistics, (semi) autonomous systems could become the norm but in industries such as healthcare there might still be a strong preference for decision making powers to rest with human operators (doctors). This is beyond the scope of DUET but helps to raise interesting ethics questions around the general acceptance of AI generated digital twin intelligence.

Besides ethical issues, any discussion about DUET's digital twins should include security considerations. Imagine a situation where the Consortium have sensors deployed in a bridge to predict maintenance requirements. Say a hacker wanted to intercept and falsify sensor data for malicious purposes e.g. to precipitate bridge failure. How do you prevent this from happening? These are the sort of questions we'll be asking ourselves in DUET from the very outset to ensure watertight security, integrity, confidentiality and availability of our digital twins.

Last but not least, in DUET we certainly value accuracy, however our aim is not to make digital twins that are 100% realistic representations of a city. Instead, we strive for digital abstractions that are relevant for a specific purpose. It may be desirable but not necessary for city models to mirror every single brick in a building or a kerbstone along the road. The level of granularity should be determined based on the needs of a policy team and the challenge they are trying to solve. Put simply, digital twins should be fit for purpose.

There are still many decisions for the DUET team to make in the months ahead around the scope, purpose and functionality of its Twins but now we can start with a strong clear vision statement to gather our thought processes around.

Appendix A: Selected definitions of a digital twin

"A digital twin is a realistic digital representation of physical things."

Cambridge Centre for Digital Built Britain

"Digital twin [is] a virtual representation of a physical environment that brings in data from a variety of sources."

Microsoft

"A digital twin is a virtual representation of a physical product or process, used to understand and predict the physical counterpart's performance characteristics. Digital twins are used throughout the product lifecycle to simulate, predict, and optimize the product and production system before investing in physical prototypes and assets."

Siemens

"A Digital Twin is an integrated multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin. The Digital Twin is ultra-realistic and may consider one or more important and interdependent vehicle systems, including airframe, propulsion and energy storage, life support, avionics, thermal protection, etc."

NASA

"A digital twin is a dynamic virtual representation of a physical object or system, usually across multiple stages of its lifecycle. It uses real-world data, simulation or machine learning models, combined with data analysis, to enable understanding, learning, and reasoning. Digital twins can be used to answer what-if questions and should be able to present the insights in an intuitive way."

IBM

"Digital twins are software representations of assets and processes that are used to understand, predict, and optimize performance in order to achieve improved business outcomes. Digital twins consist of three components: a data model, a set of analytics or algorithms, and knowledge."

General Electric

"A digital twin is an evolving digital profile of the historical and current behavior of a physical object or process that helps optimize business performance."

Deloitte