Towards Digital Twin of Living Environment – Use Case from the Zwolle City and the Dutch Kadaster

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Key words: digital twin, smart city, internet of things, innovation, citizens participation.

SUMMARY

In the real world, we have to deal with numerous social and environmental challenges, such as energy transition, climate change or subsidence. These tasks are complex and require integrated solutions engaging various stakeholders, technology and data. A concept of digital twin offers such a solution by integrating diverse data and sophisticated technology to create a digital representation of the reality used for visualization, analyses and modelling of different reality scenarios. In 2019 the Dutch Kadaster and the City of Zwolle started a pilot to build a prototype of digital twin of living environment. The focus of the pilot is to create a digital twin of a city district of Zwolle - Stadshagen to combine data relevant for visualising and communicating the impacts of climate change. The pilot focusses on assessing the needed resources to create a digital twin such as diverse type of data, experimenting with the involvement of the local communities and exploring the role of the Kadaster in creating and facilitating the digital twin.

From the pilot so far we have learned that to a certain extent it is possible to create a platform visualizing different types of data in 3D, needed for the purpose of the pilot. Most of the needed data are open and can be acquired from the National Geo information Infrastructure. For some datasets it was more challenging to acquire them due to large fragmentation and not uniform data formats. The data from sensors are also hard to find and use due to the lack of central register of sensor data sources. We also learn that the citizens engagement in the early stadium of the pilot helps to define the user requirements from the digital twin. The engagement of the local community in defining the pilot goals and even collecting data via crowdsourcing platform was high, partly due to the high societal relevance (local climate change impact) to the local community needs. Also the role of Kadaster as a central facilitator of the digital twin platform and the custodian of most of the data assuring their quality can be confirmed by the pilot.

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1. INTRODUCTION

In the real world, we have to deal with numerous social and environmental challenges, such as energy transition, climate change or subsidence. Those challenges require solutions that are usually complex and that require engagement of various stakeholders and integration of many technologies. Examples of such technologies might be sophisticated simulation models, algorithms and computer programs which can calculate scenarios to deal with various (environmental) challenges. Those technologies require huge amount of data coming from different sources. Those various and voluminous data together with a sophisticated modelling technology allows for creating replicas of living of non-living entities often called Digital Twins (Saddik, 2018). Digital Twins as a digital "copy" of e.g. living environment allow for performing various environmental simulations and scenarios of reality to solve many problems of today's world.

1.1. Digital twin of the living environment

Already in 2017 Digital Twin technologies were listed by Gartner as one of the top 10 technologies. In 2018 Digital Twin technology was placed on the Gartner Hype Cycle as being at the "peak of inflated expectations" which means that the technology is at the beginning of adoption. It can be expected that in the coming 5-10 years this technology will significantly impact the agendas of business, society and people and millions of things will have its own digital twin (Gartner, 2018). The concept of digital twin was coined at the beginning of twentieth century by Grieves (2019) in the domain of engineering.

For the purpose and the goal of this paper which focuses on the living environment domain, we will use the following definition of the digital twin: A digital twin of the living environment is a smart, dynamic, digital representation of the physical world with user-friendly visualization. It focuses on the digital representation of the combination of the objects placed on the surface (objects, buildings, etc.), the environment (green terrain) and the underground (cables, pipes, underground assets etc.). We consider digital twin smart because you can use it to calculate, predict, simulate and monitor different aspects of living environment. A digital twin of the living environment is not a goal for itself. A digital twin of the living environment may help to make the physical world smarter, healthier, safer and more sustainable.

The potential benefits of a complete, accurate and user-friendly digital twin of the living environment are numerous. Consider a living environment represented with standardized, connected and represented in 3D (open) data. Anyone with or without knowledge of geo-data,

and with or without specialistic software, could get access to an online environment and user-friendly platform where different scenarios can performed and visualized to different stakeholders.

The benefits and the extent of the impact of using the digital twin of the living environment can be different for the different user groups. A number of examples are listed below.

For the citizens of the living environment digital twin could mean:

- More insight: What's going on in the neighborhood? What are the constructions plans? Where are the cleanest and safest (cycle) routes? Where are free parking places, available electric charging posts? What is the impact if the tiles in the garden will be replaced by the greenery?
- Communication platform between residents and municipality: for citizen initiatives and ideas, an platform as support tool to apply for a permit (huis extension)

For the emergency services the digital twin of the living environment could mean:

- Access to the most current and accurate data (enriched by live stream data from the sensors),
- Assessing different emergency scenarios and choosing the best measures to address those emergencies

For the governmental organizations the digital twin of the living environment could mean:

- The foundation to implement a smart city concept
- Simulating impact of various decisions on the living environment
- Better policy making based on results of various scenarios simulated by the digital twin
- Acceleration of internal and external processes;
- Easier monitoring of traffic flows and other processes within the city;
- Increase of the work efficiency - towards smarter and more sustainable;

For the private sector the digital twin of the living environment could mean:

- A reliable and uniform basis on which companies can base their models, analyzes and customize products;
- Opportunities for new business

Digital twin put in the context of living environment is often seen as a foundation of building smart cities (Farsi, 2019). Smart cities are defined as urban areas using data from sensors and then using insights from data analytics and visualizations to manage its assets, resources and services (McLaren et al., 2015). The benefits of digital twin regarding (real-time) data analytics and visualization may improve confidence in decision making, reasoning, monitoring and warning within the urban environments which have to deal with complex societal and environmental issues. The goal of digital twin is seen to improve the overall efficiency of the urban system by improving its performance. These improvements may be seen in enhanced energy consumption, reducing emissions by e.g. dynamic calculation of the best route based on live traffic information, etc.

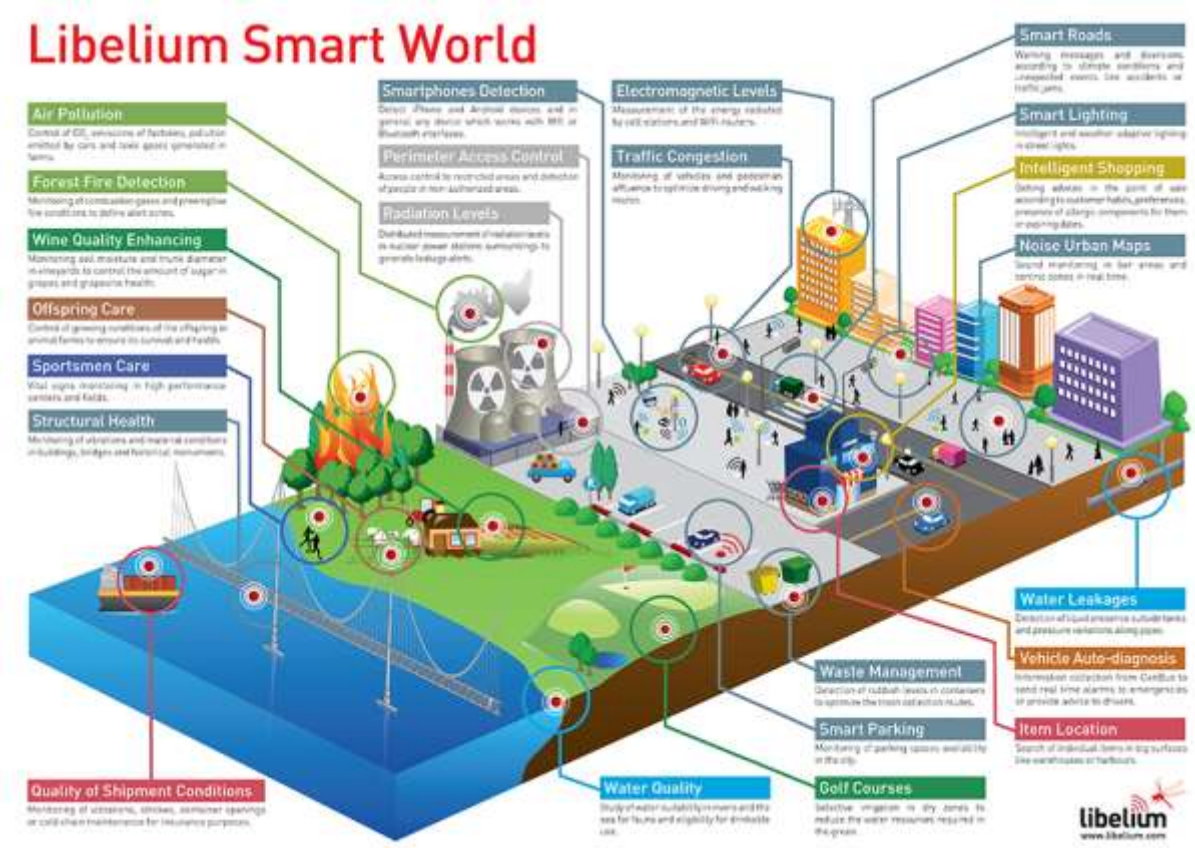

Figure 1. Internet of things as a foundation of digital twin and smart city (www.libelium.com)

As digital twin can be seen as a foundation of the concept of smart cities, the internet of things can be seen as a foundation of digital twin. To be able to analyze and visualize data in the context of living environment, we first need to have data of high temporal and spatial accuracy. The concept of Internet of things – as coined in 1999 by Ashton (2009) and describing a system where the internet is connected to the physical world via ubiquitous sensors address the issue of data availability. Digital twin can thus be seen as an enabler of smart cities built on a foundation of internet of things.

Figure 2. Relation between Digital twin concept and internet of things and smart environments.

1.2. Potential challenges that might be addressed by a digital twin

In 2018, the Netherlands had to deal with extreme weather conditions: prolonged drought, heat and heavy showers. In the summer of 2019, the national heat record of 1944 fell. Research showed that the sea level may raise even faster in the future. And the World Economic Forum (WEF) found that climate change is the biggest threat to the global economy. It is therefore important that the Netherlands continues to be well guided and prepared for the consequences of climate change (Deltaprogramma 2020).

In 2017 for example due to the extreme rain, parts of the city and bicycle tunnels in Zwolle were out of use. The flooding affected the traffic roads but also many houses and buildings.

Picture 1. Local flooding in Zwolle. Photo by Iljan Stegeman, source: *https://www.weblogzwolle.nl/nieuws/47162/wateroverlast-in-zwolle.html*

Those incidents trigger some municipalities in the Netherlands to explore the potential of new technologies and data to address problems related to climate change. They believe that the digital twin of a city can be an instrument that will help maintain and manage cities in a smarter way and minimalize the sides effects of climate change.
Next to the city of Zwolle, also the city of Amsterdam, Rotterdam, den Haag and many others are quite far exploring this concept, its value and the possibilities it creates.

1.3. The role of the Dutch National Mapping Agency (Kadaster) in building a digital twin

The Dutch Kadaster collects and registers administrative and spatial data of the properties and the rights involved. Also, Kadaster is responsible for national mapping and maintenance of the national coordinate systems. In the context of digital twin of living environment, we want to explore the role of the mapping agency. Kadaster maintains the most accurate and complete register of topographical objects of the whole Netherlands (BRT) which can be used as a basis for creating a digital twin. Kadaster also maintains the cadastral registration (BRK) and maps. Next to the role of data owner, Kadaster facilitates central access to many other datasets via National Geo Information Infrastructure. Those datasets originate from other subnational governmental agencies such as municipalities, provinces etc. Those datasets include information about buildings and addresses (BAG), large-scale topography (BGT), spatial plans, locations of underground infrastructure (KLIC).

A digital twin of living environment requires connecting all of those data sources within one platform in an uniform way. The digital twin should also allow connecting other relevant data sources such as data streams from the sensors measuring various characteristics of the living environment. Initiatives to build a registry of available sensor data have already been started.

As a starting point, we miss at this moment a platform that would provide building blocks for the digital twin. The platform would help to organize the availability and accessibility of static and dynamic (sensor) data. Furthermore, it is also unclear whether the current National Geo Information Infrastructure (NGII) is ready for the "connected era". Finally, the transparency of digital twin and the underlying data is not regulated. This makes it very difficult for residents and other stakeholders to use the fragmented information for initiatives aiming at improving the living environment. That is precisely what the smart cities concept want to encourage to no longer see the resident as only consumers, but rather as initiators. The first step is to actively show the residents what is available about data from their own living environment and to make them aware and provide insight in the possible solutions of their problems. The first step can be an information provision about relevant to them aspects of their environment such as the possibility of heat wave, the quality of air in the neighborhood, how much water flow can cross the threshold level.

In summary, we want to consider two important questions related to the concept of digital twin of living environment:

- What do we need to create a digital twin of the living environment?
- What is the role of Kadaster in making the digital twin successful.

To find answers to those two questions we started at the end of March 2019 a pilot with the municipality of Zwolle to build a prototype of a digital twin of a living environment.

2. THE DIGITAL TWIN POLOT WITH THE MUNICIPALITY ZWOLLE

The climate is changing and that affects many cities in the Netherlands. It also applies to Zwolle – a city in the Dutch province of Overijssel with almost 130 000 inhabitants and an area of 111 km^2. It is also the lowest under the sea level located city in the whole province of Overijssel.

At high water on the Ijssel river, there is a risk of flooding affecting Zwolle and other cities in the neighbourhood. The municipality of Zwolle is working intensively with many partners to make the city more climate-proof.

In March 2019 the municipality of Zwolle and Kadaster started a pilot with the aim to create a digital twin of the one of the districts in Zwolle - Stadshagen. The aim of creating the digital twin for this area was to mitigate flooding and heat stress. In long term the city of Zwolle may use digital twin as an instrument for different scenarios analyses. An instrument by means of which it would be possible e.g. to make a simulation of heavy rain (40 mm) and simulate its potential consequences. It that way the digital twin can be used to predict and avoid negative effects of changing climate.

The pilot aimed to find out what is needed to create an complete digital twin of the living environment and what is de role of the Dutch Kadaster to make it successful. An important part of the pilot was to involve citizens in data collection process and combine those data with relevant data from different stakeholders and sources, including IoT and 3D models.

In the first step the multidisciplinary team was formed. The experts from the municipality of Zwolle and Kadaster made a cooperation agreement and started working on a plan of action. The group was working based on “High 5 method”. The High 5 is an innovation method implemented by Kadaster used for product and process optimization or creating a new services and products. The main goal of this method is to translate an idea into a prototype in five weeks. The translation process had 5 stages: the kick off meeting where the goal was defined; data preparation period; focus week where the multidisciplinary team work the whole week together; presentation with the feedback; finishing touches and the final presentation given to the stakeholders.

2.1. The results from the pilot

During the data preparation and the focus week, the pilot group was working on a prototype of the digital twin of the living environment of the Stadshagen district. It was decided to use the 3D-model of the Netherlands from Kadaster as the basis and the visualization environment for the digital twin which will be enriched with other relevant and available (open) data. The 3D-model will be available to everyone from June 2020. This product is a digital topographic file based on: Key Registry for Large Topography (BGT) and Key Registry for Addresses and Buildings (BAG). The objects such as roads, water, terrain objects and buildings have all three dimensional geometry. The height of the objects is determined based on aerial photos. The reason behind the use of 3D model as a visualization platform of digital twin of the environment was that this model can digitally represent the closest the real features of the living environmental. Moreover, it was assumed that 3D representation of the reality is easily understandable to communicate with different stakeholders. Moreover, the 3D model from Kadaster contains real attributes of the visible 3D objects which allows for combination with other data and attributes which can be related to the same or nearby objects.

We started enriching the 3D model with data layers coming from the National Institute for Public Health and the Environment (RIVM) and Royal Netherlands Meteorological Institute (KNMI). We focused mainly on dynamic, real-time data inputs from sensors e.g. Nitrogen Dioxide measurements from RIVM (Fig. 3)

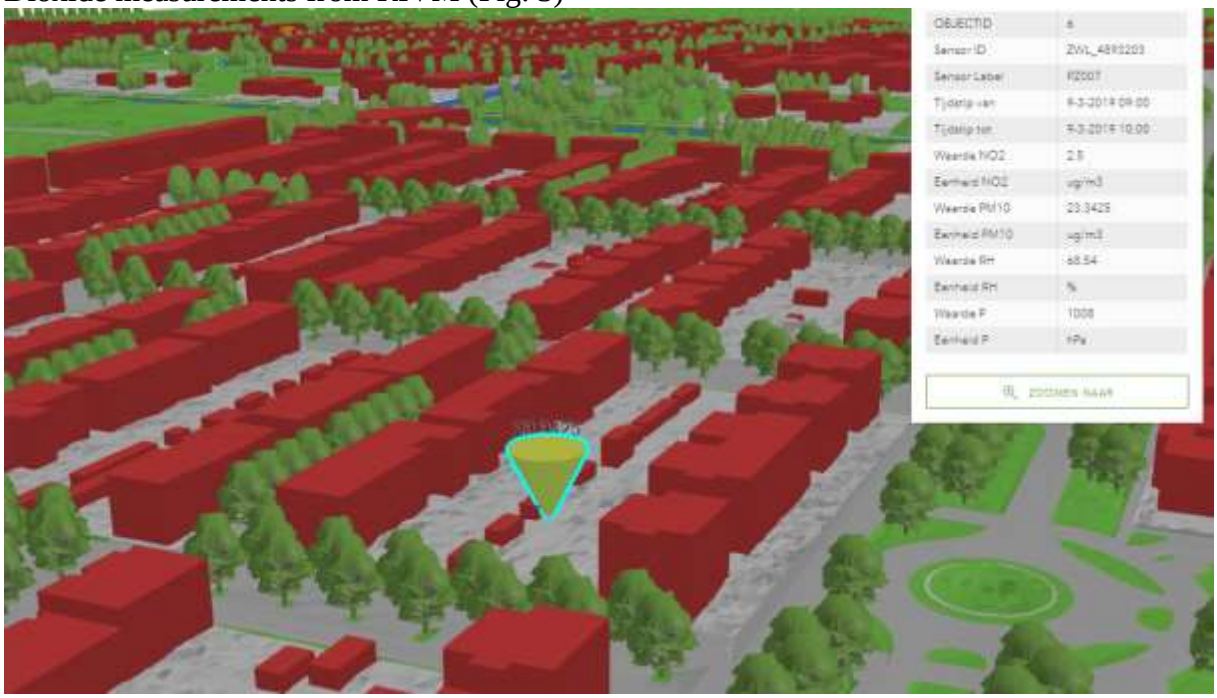

Figure 3. The data from the RIVM sensor, measuring the Nitrogen Dioxide (NO2)

RIVM is responsible for the sensors that measure air quality, and KNMI for sensors measuring the temperature and rainfall. In this particular pilot case the data sources for those particular sensors were found in the Smarthub of the city of Zwolle. The Smarthub is a platform that Zwolle has built together with Esri to experiment with the environmental measurements related to wind, heat, temperatures etc. measurements. The data is open and available to everyone. Via an Application Programming Interface (API) they can be accessed and visualized in real-time. It is worth mentioning that next to the "official" sensors from RIVM and KNMI the Zwolle experiments also with sensors built by children at school during lessons about climate awareness. Those sensors are less accurate and reliable than the official measurements, nevertheless they can easily be calibrated with the RIVM and KNMI sensors to determine the deviation.

In the next phase we started adding data from the crowdsourcing sources such as the "Nattevoetenkaart" (Wet feet map). In 2017 Zwolle developed the "Nattevoetenkaart" (the wet foot map) - an interactive (web)map where residents can report (information and photo's) incidents related to the flooding after heavy rain. The goal is to create together with the citizens an overview of locations where the flooding was the worst (Fig. 4)

Figure 4. Data from the citizens – Nattenvoetenkaart with photos in the attachment

We also used the social media data from Twitter and added them to the 3D model. The data contains tweets from the people who were staying in the Stadshagen and/or sent messages about Stadshagen. Because of a permission from the users to share information about their location, it was possible to download messages based on GeoTags. Geotags are also known as Geotagging, is the provision of a GPS coordinate to a media (photos, videos or text). In this way it was possible to find and filter the twitter messages from the Stadshagen district. Another dataset added to the digital twin prototype was the heat stress layer developed by the consultancy office Tauw. It contained information about hotspots in the city and the indication of the days when the heat had been accumulated.
Next to the datasets about objects located above ground (buildings, trees) the datasets with underground objects were collected. For the pilot needs the open data with sewage locations were used (Fig 5).

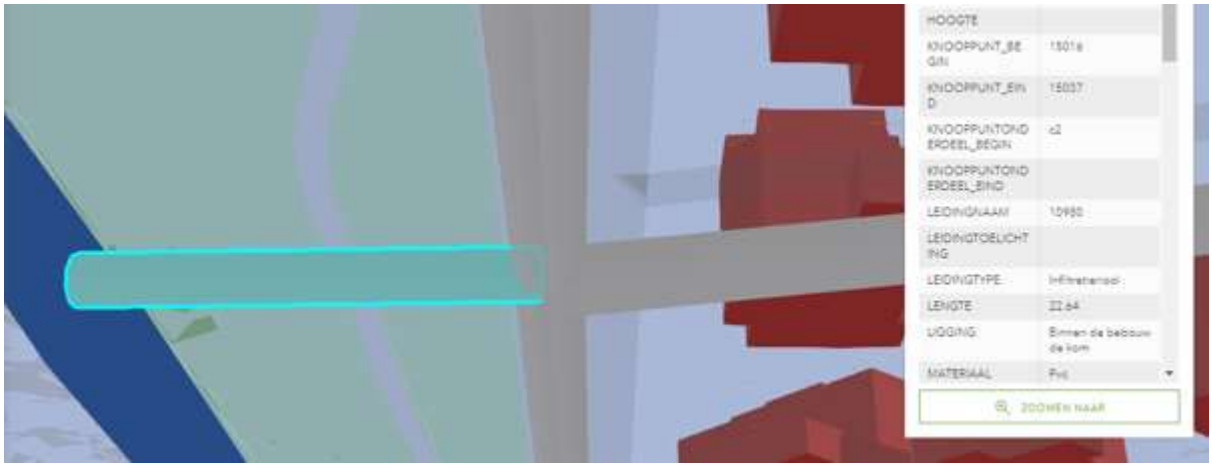

Figure 5. Open sewage locations data with additional attributes about the material, form, width etc.

For data processing, transformation, combination and visualization, ArcGIS platform from Esri was used, specifically the software components: ArcGis Pro and ArcGis Online.

At the moment of writing this article, the pilot is still unfinished. However, until now we have managed to build the first prototype of the digital twin and collected already some valuable insights and conclusions.

3. DISCUSSION AND CONCLUSIONS

In the first place, the active involvement of the users helped us to sharpen the overall goals of building a digital twin for the city of Zwolle. Based on discussion sessions with different user groups such as citizens, governmental organizations, business and workers from the city safety department we could collect overall needs that could be facilitated by a digital twin. In summary, those stakeholders express a strong need for access to relevant and reliable information in one place. It is also worth mentioning that the citizens involved in local citizen science project such as "Nattevoetenkaart" are eager to collect data on their own and share them with others. Moreover, the geodata and information should be uniformly linked. It also became clear the role of data and information visualisation plays an important role in the user – digital twin interaction.

The active involvement of the citizens and close cooperation and discussions with the workers of the municipality Zwolle, helped us define the concrete requirements and expectations from the digital twin prototype. We have learned that specifically in the context of heat stress and flood, the citizens of Stadshagen district expect from digital twin an answer to specific questions such as:

- Where are the problematic areas near my neighbourhood?;
- What (if any) is the impact of "non-soaking through" surface of my garden (e.g. stone tiles without grass) for the local environment and its water balance?;
- What would be the impact of a heavy rain storm (40mm); what if we replace a pavements into a greenery?
- What can I do as an inhabitant to improve the local environment?;
- What is the effect and consequences (also financial) if I take no action?

The data needed to create the digital twin prototype were mainly available as open data. Most of the have been made available via PDOK – a central portal of the Dutch National Geo Information Infrastructure (NGII) or come from the local data portal from Zwolle City – the Smarthub. Nevertheless we conclude that still a large number of datasets relevant for the context of this pilot are not easy to acquire and are highly fragmented. Those were the datasets about assets, underground objects and data from sensors. The fragmented data were often available in different formats and it was challenging to transform and combine them into one uniform data sets.

Acquiring data from the sensors was challenging. At this moment in the Netherlands there is no registration of the sensors and no central place to find the data generated by those sensors.

We found this disappointing because specifically those kind of datasets play a crucial role in the concept of digital twin. Sensor data enable the almost "live" copy of the reality which is key to the concept of digital twin and crucial instrument to help many stakeholders (e.g. emergency services). Because of a long time experience and task with registry, it sound reasonable for Kadaster to facilitate the (future) sensor registry. Sensor register can became a nationwide, uniform platform to register and provide data about the sensors, their locations, owners and link with access to the most actual stream-data.

It seems that digital twin of the living environment could be an answer to many problems of the cities and its citizens. It can be also seen as a citizens-government participation platform where cooperation between citizens and government help increase a commitment and solve problems in a faster way. DT can be built around several societal relevant topics like climate change; heat stress, flooding etc. but to make it successful it is important to build it on a stable and trustable fundaments.

Zwolle is a city which have a great potential to create a complete digital twin of the living environment. There is a lot of data available, there is space for innovation, collaboration and initiatives engaging citizens (also the youngest ones). Creating awareness and insights into the (environmental) challenges, Zwolle is helping society to became smarter and more involved - a crucial actor for a smart city.

The role of Kadaster in building the digital twin of the living environment could be to provide a solid data foundation platform as shown in this pilot with the provision of 3D data model and the key registry. Kadaster could also play a role of a facilitator of the digital twin datasets similarly to its current role in the national provision of the basic registrations. In that way the highest quality of data contained in the digital twin can be guaranteed.

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BIOGRAPHICAL NOTES

Magdalena Grus is an Advisor for Product and Process Innovation with Kadaster, Netherlands. She also acts as a board member of Geo- information Netherland. She specializes in spatial information systems, socio-spatial analyses and innovation. She was actively involved in the European Cooperation in science and Technology (Cost Action) "Mapping and Citizen Sensor". She is currently involved with project work on Smart Emission (2); Digital Twin and National Sensor Register.

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