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# Designing Map-Based Dashboards for Mobility Digital Twins

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**Abstract:**

Digital Twin is increasingly being explored to improve physical entities through virtual representations. They are composed of three components, a physical entity, a virtual representation, and bi-directional data connections (Grieves, 2014). Thanks to internet technologies and data science, Digital Twins are extended from their original purpose of manufacturing management to complex scenarios such as urban management (VanDerHorn and Mahadevan, 2021). Mobility management faces high traffic flow data and multiple restraints such as cost, efficiency, and emissions. Digital Twins can improve intelligent traffic control by capturing real-time data, such as images and LiDAR, and implementing of autonomous traffic regulating algorithms (Duran et al., 2024, Wang et al., 2024).

Maps translate the high volume of multiple data in Digital Twins as human-readable visual representations. Map-based interfaces can improve the interpretation of data by integrating complex contexts in the visualization and further enable system manipulations. Maps are used to synthesize and represent the visible world and abstract entities intuitively. For instance, a 3D map scene is created to show the real-time recognized obstacles and lanes, the road topology, and the landuse and terrine information along highways (Jiang et al., 2022). The map readers gain a better understanding of the data models in different terrines in the Digital Twin. Furthermore, 3D city models, e.g., CityGML, are widely used in Digital Twins to bring city context, including detailed building information and a photorealistic virtual 3D scene (Lehner and Dorffner, 2020, Schrotter and Hürzeler, 2020).

Digital Twin can improve green mobility by integrating raw mobility data (such as travel survey, and loop counter data), data modeling methods, and traffic and transportation modeling (such as traffic prediction and simulation algorithms) to improve calculation accuracy and efficiency (Grübel et al., 2023). In addition, maps serve as a medium to represent the modeling and calculating results together with the green mobility context. Figure 1 shows the conceptual relations of maps that synthesize the mobility data, geographic information, and contextual information.

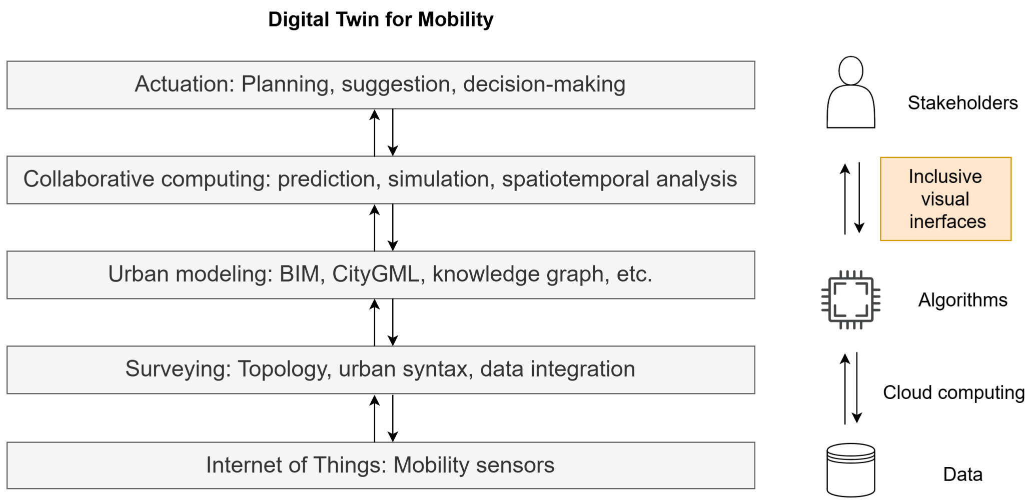


Figure 1. A conceptual relation of maps in Digital Twins to support green mobility.

Green mobility stakeholders are highly interdisciplinary, including transport planners, vehicle providers, policymakers, and citizens. They should not only have access to the mobility data, but also interpret transport patterns. Map-based visualizations could improve the data understandability of non-domain experts. To demonstrate the ability of dashboards to support visual analysis, two prototypes are developed as shown in Figure 2. The two dashboards represent transportation patterns with origin-destination (OD) data. The raw data contains 11,110 OD pairs in Corsica, France. By using the dashboards, users can recognize human mobility patterns, such as the popular places and time periods for departure and arrival, know which transportation modes are preferred, and even make assumptions about the activities people do at different locations. This information is important for the division-makers to make plans for the mobility system.

To evaluate how the dashboards help users understand mobility patterns, we designed user studies and invited 39 participants to join the study. The participants were asked to follow three stages: preparation, solving tasks, and post survey.

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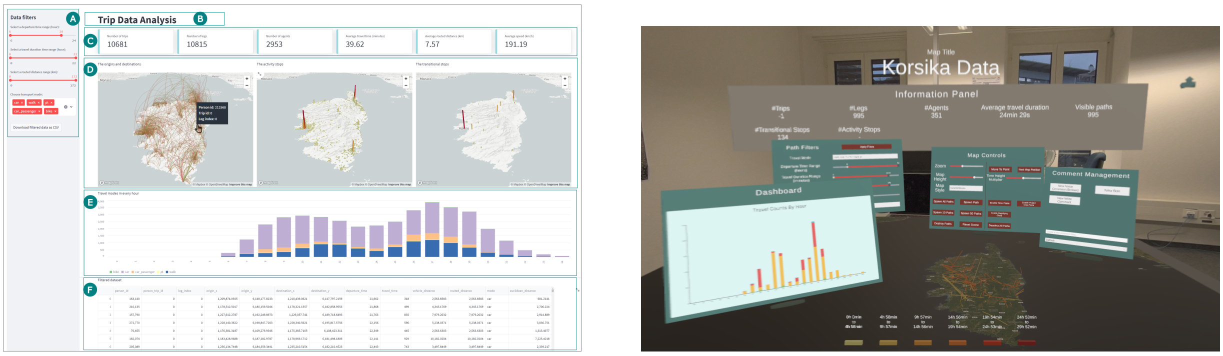


(a) a web-based dashboard

(b) an AR-based dashboards

Figure 2. Two dashboards for origin-destination data analysis

In the preparation stage, the participants were provided with information sheets and a consent form. The experiment continued only if the participant met the experiment recruitment criteria (normal vision or wearing contact lenses) and agreed to participate by signing the consent form. Then they were asked to do an exercise to think aloud while reading visualizations. Then they were guided to wear the augmented device, Apple Vision Pro, in this experiment. They then calibrated the eye fixation according to the device by looking at certain points. During the solving task stage, the participants were asked to complete three parts of the tasks: usability tasks, guided insight-finding tasks, and free exploration. During this stage, their eye gaze and screen were video recorded. While performing the tasks, they were asked to think aloud, which means they should talk aloud about what they see, what they do, and explain the reasons. In the third stage post survey, to fill in a short questionnaire for the NASA task load index. The whole experiment lasts about 45 minutes for each participant.

The results externalized what users were paying attention to, what data insights they have discovered, and whether they believed what they found or not. The preliminary results show that users can successfully acquire knowledge, such as identifying city areas, identifying peak hours, inferring transportation infrastructures, and inferring travel purposes. Usually, users first formulate an assumption and try to find answers from the dashboards to verify their assumptions. For dashboard designers, it means that more reading guidance should be provided to help users formulate assumptions so that they can acquire data insights efficiently.

The future work is twofold. First, we would like to further evaluate the user interfaces with predefined benchmark tasks, which would reflect the needs of the users of mobility digital twins. The results can be used to improve the usability of the user interfaces. Second, we would like to provide more guidance for the non-expert user group to acquire data insights, enabling them to make decisions together with the expert user group.

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