International Association of Societies
of Design Research Congress 2023
LIFE-CHANGING DESIGN

Politecnico di Milano
9-13 October 2023

The future archives: a speculative approach for visualising the impacts of 6g-enabled infrastructure in Japan

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doi.org/10.21606/iasdr.2023.613

6G-enabled technologies are set to become an integral part of infrastructure within the next decade. This paper provides a speculative design-based approach to shape future technology development. Specifically, we focus on how 6G networks could transform mobility in Japan. We begin with an overview of the country's societal macro trends, the current state of technologies, and the expected novel capabilities of 6G. We then introduce four scenarios, used as the basis for developing two types of outcomes. These include (1) physical prototypes where we leverage current technologies to simulate novel interactions enabled by 6G and (2) an archive of fictional objects, or props, from this future world. Through these outcomes, we aim to foster a more society-centred approach to technology development and spark a comprehensive conversation about the impact and opportunities that come from the adoption of such technologies.

Keywords: 6G; speculative design; mobility; interaction design

1 Introduction

This project aimed to explore possible applications of 6G-enabled mobility in Japan. The objectives of this research included creating physical and digital outcomes that promote and inspire conversation about the societal implications of a 6G-enabled tomorrow. To do this, we employed techniques of speculative design (Dunne & Raby, 2013). After an initial phase of fundamental research, co-design through workshops and ideation sessions, our team consolidated four directions with the following titles: Ubiquitous Navigation, The Remote Driver, Rural 6G, and The Responsive Network. This work has been recorded in our previous publication (Trucchia et al., 2023). These fictional worlds were developed and conceptualised through the following two techniques: (1) prototyping to simulate future technologies and (2) prop creation for 'archiving' the future. Our research process is documented in Figure 1.

1.1 Prototyping methods

To better understand these scenarios, we are building prototypes which are either explanatory, technical, or experiential. Explanatory prototypes serve to communicate a system-level view of our idea to wider audiences. The technical prototypes simulate specific elements of 6G and demonstrate how the ideas would function. Finally, experiential prototypes allow parts of the user experience to be tested. Each scenario is a different take on the role that 6G could have on mobility, opening a conversation on topics such as privacy, autonomy, and labour economics.

1.2 Prop-making methods

Props serve as a media to help designers imagine new technologies and experiences. In her 1965 essay entitled "The Imagination of Disaster," Susan Sontag writes of the necessity of props in science fiction: "Things, objects, machinery play a major role in these films. A greater range of ethical values is embodied in the décor of these films than in the people. Things, rather than the helpless humans, are the locus of values because we experience them, rather than people, as the sources of power. According to science fiction films, man is naked without his artefacts" (Susan Sontag, 1965). While speculative futures are not interchangeable with science fiction narratives, both rely heavily on objects to convey worlds which have yet to exist. Props were built to support the storylines of four videos that are currently in production to articulate certain aspects of 6G which do not yet exist. Building these objects led to the questioning and revisiting of each fictional future. We named this collection the 'Archives of the Future,' as they help us think about what everyday items may exist in a speculative 6G-enabled Japan. But before creating props and prototypes, it was imperative to understand the technological and societal landscapes that we were working in. As such, this section is followed by some of the highlights from our literature reviews.

2 Background information

2.1 Population trends

Japan is home to the world's largest city (approximately 13.96 million people reside in Tokyo), but it also has the fastest shrinking population out of all 'net mortality societies' (Government, 2016; Hori et al., 2021; Nicolas Eberstadt, 2012). The world average proportion of ageing population (65+ years old) vs the total adult population is 10%. In Japan, this proportion is 30% and is expected to increase to 40% by 2050 (Otsu & Shibayama, 2016). Due to urban development of new towns at the end of

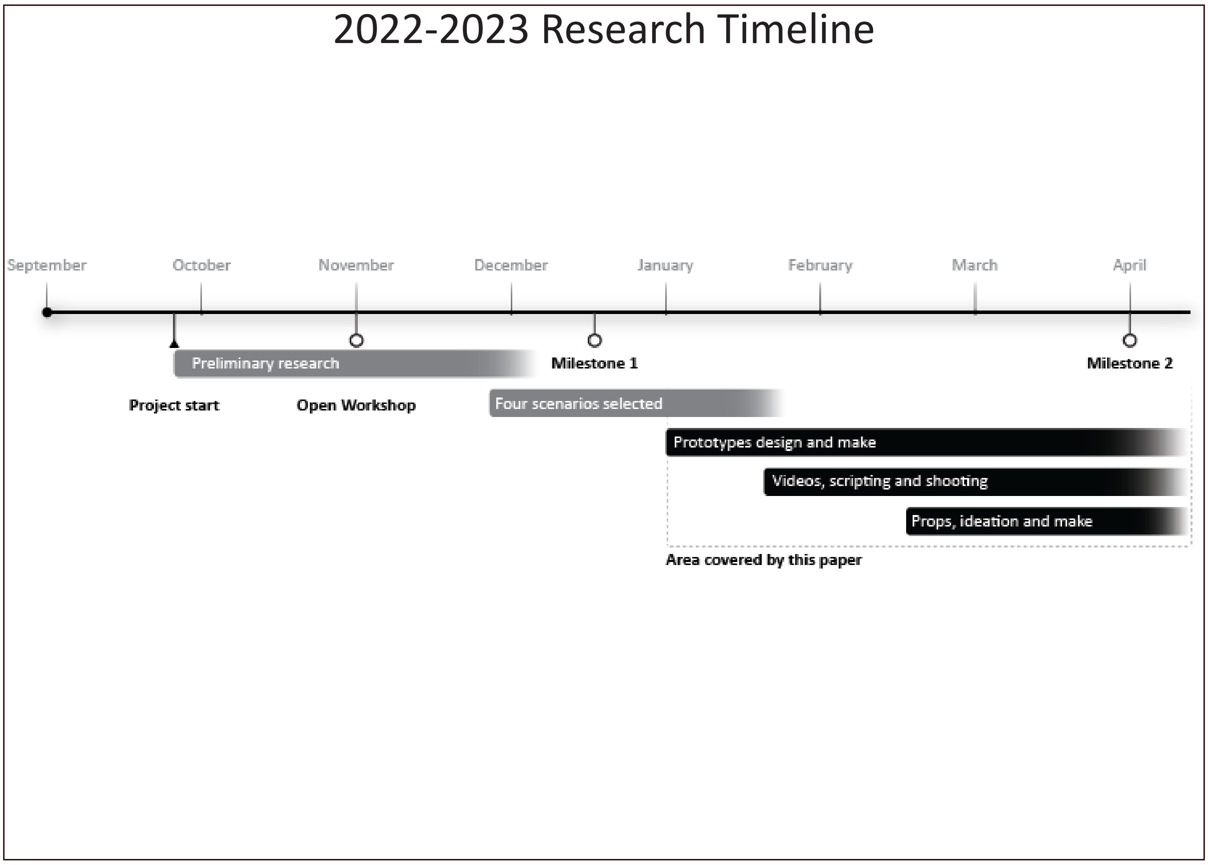

Figure 1. Framework showing the timeline of the project, and the scope covered in this paper.

the 20th century, citizens on the outskirts of Tokyo are accustomed to car-dependent environments, and live further away from traditional means of public transport (Yang et al., 2022). Alongside these suburban populations, there are those living in rural areas whose connections to cities are mainly based on public transport. Yet these connections are difficult to sustain due to running costs, giving potential prospective residents little incentive to move to rural areas, and current residents no means of travelling to surrounding areas. If the current depopulation trend continues, more than 860 of Japan's 1,718 municipalities are expected to disappear by 2040 (Morioka et al., 2018; Richarz, 2019).

2.2 Environmental trends

Japan is vulnerable to typhoons, earthquakes, and subsequent tsunamis. Within the next two decades, urban landscapes are predicted to become much more susceptible to damage from natural disasters. For example, due to the frequency and reach of floods, 40% of urban land will be located in high-frequency flood zones by 2030 (Güneralp et al., 2015). To address the growing economic threat that depopulation and natural disasters pose to Japan's society, in 2016 the Japanese government published a plan to enact the concept of "Society 5.0" (Harayama, 2017; Mavrodieva & Shaw, 2020). This term was coined to explain the use of data collection and processing techniques to create a data-based, reactive society.

2.3 Technological trends

6G is in a phase of active development, with the intention of being introduced throughout Japan in the next decade (5G Evolution and 6G, 2022). The term 6G defines the next telecommunication standard that features a range of 'classical capabilities' and 'new dimensions', as described by Ericsson (Wikström et al., 2022). Classical capabilities advance upon 5G features such as increased data transmission speed, virtually instant communication, the ability to support more devices on a network and physical positioning of devices to within a centimetre. The new dimensions are unique to 6G and include network sensing, where radio waves can be used to sense the surrounding physical environment, and wireless information and energy transfer (WIET), which allows devices to be wirelessly powered by 6G waves.

The preliminary research phase informed the following four scenarios. The scenarios highlight a time in which 6G will enable a variety of approaches to mobility and infrastructure on a large scale. We will also explain how our proposed futures reflect technology and are informed by relevant social trends in Japan.

3 Future 1: Ubiquitous Navigation

Ubiquitous Navigation imagines a responsive form of navigation that allows for the precise positioning of people, places, and things (see Figure 2). Through a combination of digital workflow and physical active landmarks, we imagine traditional navigation applications to become obsolete. This concept is enabled by the ability of 6G to locate connected devices with centimeter-level precision.

3.1 Ubiquitous Navigation prototypes

To demonstrate a method for finding the shortest route between the user and a desired person, object or place, we built a scaled-down model of an interior space (see Figure 3). When the starting point and end point are inputted, a Floyd Warshall-based algorithm calculates the shortest route and indicates the path through LEDs. Each point has a weighting which describes the relative ease of travelling through it. Traffic or obstacles can be simulated by increasing the relative weighting, and the routing algorithm would then avoid it. We plan to scale up the algorithm and incorporate this into a 1:1 prototype to test the intuitiveness of different types of sensory cues (haptic, visual, sound) in navigation experiences.

3.2 Ubiquitous Navigation props

In this scenario, we are exploring navigation interfaces that are inherent in the environment and the granularity of data collection. To contextualise this future, we have designed a user interface that shows a navigation flow from a recipe on a phone to an item in a grocery store that the user is lacking in their kitchen (see Figure 5). The system automatically augments ingredients with pointers that help locate them in the grocery store. Another prop within this future is 6G-enabled curry blocks (see Figure 4). A popular base for many curries in Japan, this ingredient is easily recognizable and synonymous with Japanese cuisine. The curry box is labelled as '6G enabled' and 'Phone friendly', implying that it can be located with granular precision from anywhere.

4 Future 2: The Remote Driver

'The Remote Driver' takes place in a world in which remote driving services are a common business. A driver will be able to drive one connected car or supervise multiple semi-automated vehicles from anywhere in the world (see Figure 6). With 6G providing extremely low latency and high bandwidth, remote driving established itself as a serious alternative to level 5 autonomous vehicles (Yuan et al., 2018). In this scenario, questions arise about how labour economics will be affected by off-site driving of private and commercial vehicles. Within this future, we imagine a new labour economy emerging from the possibility of remote driving. Due to its low labour cost and ease of operation, remote driving can be compared to a traditional call centre.

4.1 The Remote Driver prototypes

To better understand the sequence of interactions between a passenger and the remote driver, we used our simulator room, which features 360 degrees of uninterrupted projection as well as a car. In our prototype, a remote taxi experience is enacted. A passenger can sit inside the car, connect to a driver via app on the vehicle touchscreen, and be virtually driven to a destination. The driver is stationed outside of the room on a separate bench with a computer monitor or a VR headset, with a USB steering wheel and pedal set (see Figure 8).

Figure 2. 6G-enabled navigation to a specific object in a grocery store.

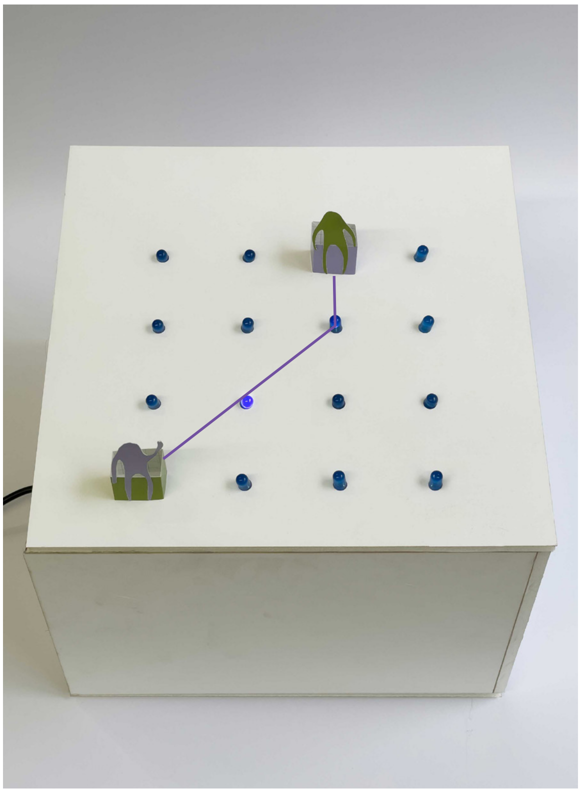

Figure 3. Navigation prototype box, overlayed with lit-up path, running Python code on Processing.

Figure 4. 6G Curry Box Prop, with navigation features enabled by 6G precise positioning.

Figure 5. 6G-enabled navigation for finding the precise location of objects.

4.2 The Remote Driver props

For the props, we imagined the user interface used to control multiple semi automated long-haul trucks remotely (Figure 7). Drivers can oversee these vehicles from their terminal and take control when required, the user interface allows for the monitoring (yet not actual driving) of several 18-wheel trucks located in different parts of the world. The remote driver desk is also populated with props that communicate the nature of the job: a small trophy titled 'Driver of the Month' (see Figure 9) which is awarded to the driver who completes the most driven hours in the time span of a month, and a 'remote driving operation manual': a troubleshooting book to guide the driver in case of need.

5 Future 3: Rural 6G

6G is used to deploy a fleet of cheap driverless shuttles that operate via a high-resolution digital twin of a territory. 'Rural 6G' emphasises the opportunity to challenge a car-centric lifestyle, especially present in rural territories. This service encompasses a new model for public transport: one that has no predefined routes, is available anywhere on demand, and whose fleet size is dynamically adjusted to balance demand (see Figure 10). Here, we explore opportunities to drive social cohesion in ageing and isolated communities.

5.1 Rural 6G prototypes

This scenario depends on the existence of extremely simple and inexpensive autonomous shuttles. To simulate the ability of 6G to operate such a system, we used Ultra-Wideband Bluetooth (UWB) modules acting as 6G antennas. The remote controlled car notes its relative position to a specific area and navigates itself along programmed routes. It does not make use of conventional and often expensive AV sensors (cameras, ultrasonic sensors, LIDAR etc.) or intensive processing capabilities (see Figure 11).

Figure 6. A remote driver working at an autonomous taxi driving centre.

Figure 7. Example of UI and desk of a remote long-haul truck driver operating multiple vehicles at once.

Figure 8. Driver operating simulation vehicle from a remote location.

Figure 9. Prop for the remote driving set: "Employee of the Month" trophy.

5.2 Rural 6G props

In an effort to revive public transportation in these sparsely populated communities, the government introduces autonomous shuttles that are available on demand and determine their route in real-time. Within this future, we imagine a 6G network whose reliability reaches even the most rural towns and municipalities. One key artefact in this world is the next-generation transport card (see Figure 11). Currently, these iconic transportation cards are used as a simple payment method for public transport in Japan. In this future, we envision a 6G-enabled smart card that becomes a key form of identification for a citizen. This card will allow the user to directly summon a shuttle and will respond to smart interfaces within a shuttle. This card will also have WIET capabilities to retrieve energy from the network whenever an interaction is initiated.

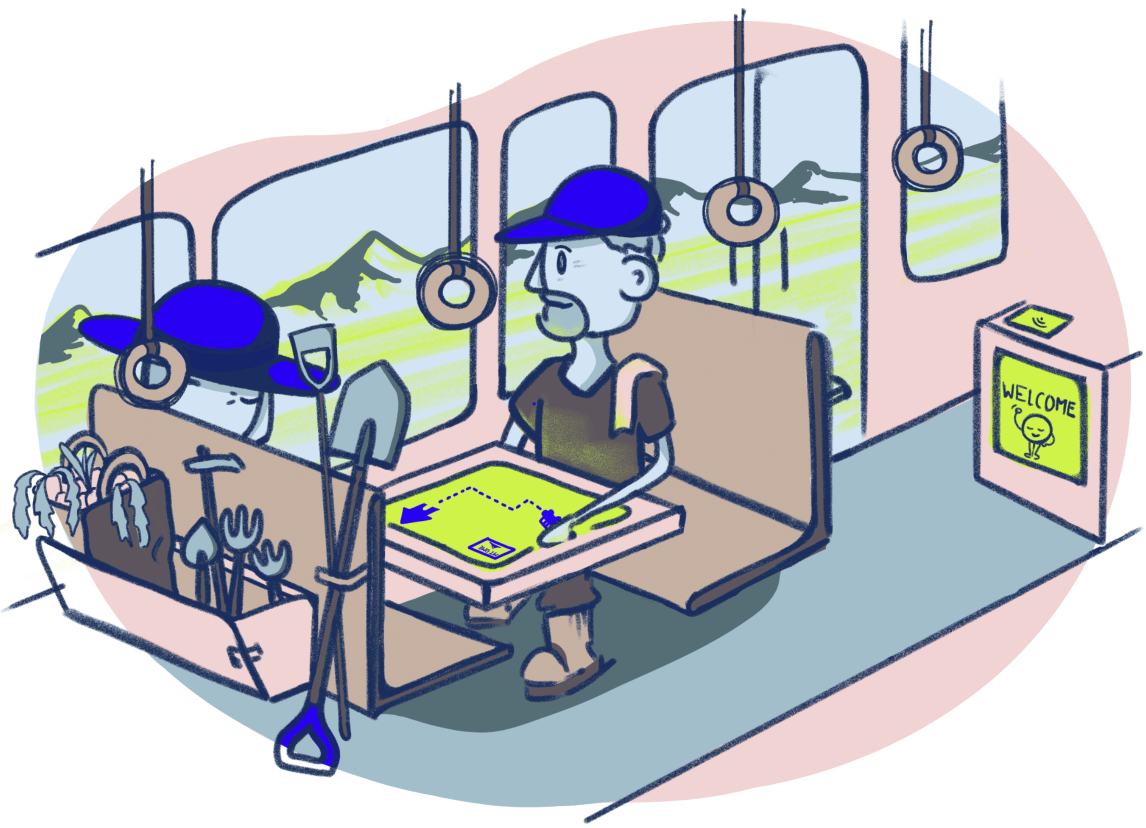

Figure 10. 6G-enabled transportation in rural areas

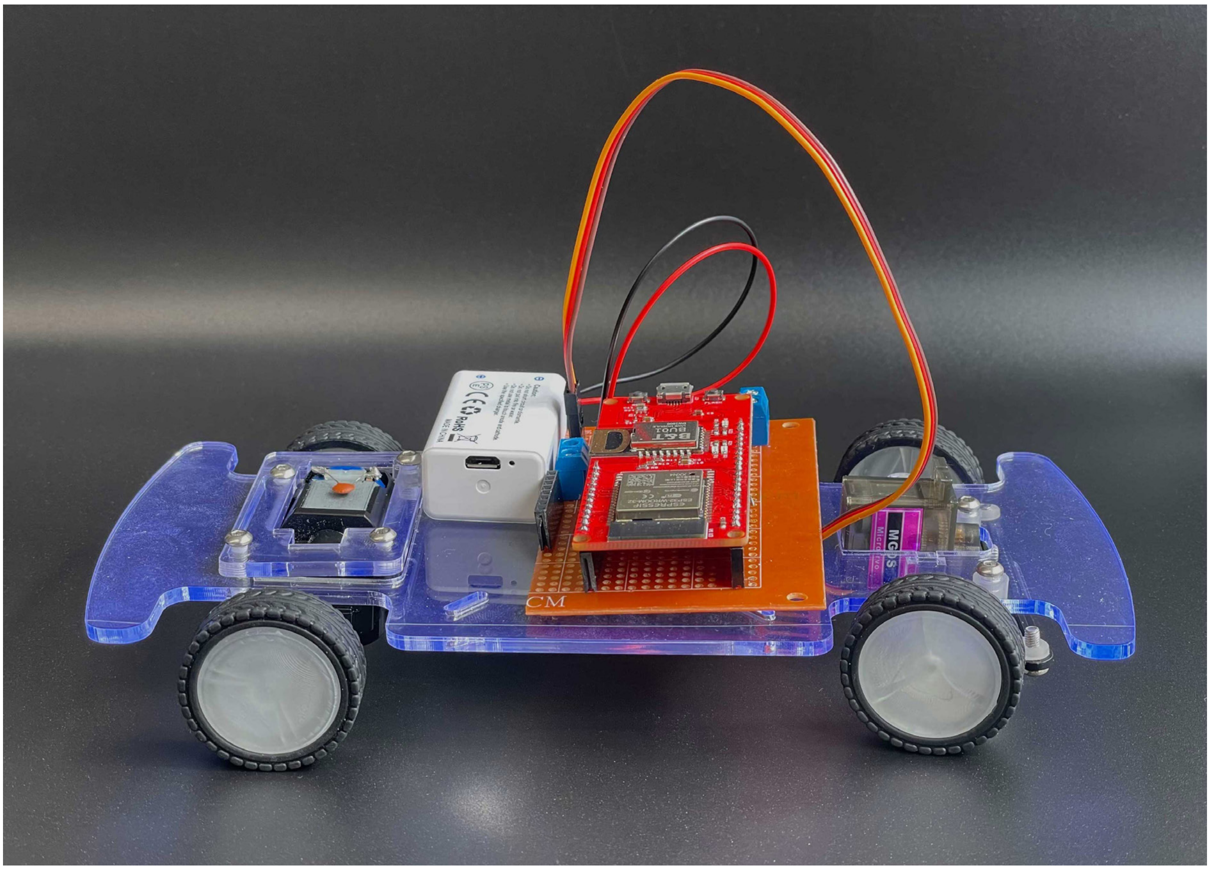

Figure 11. Remote controlled car modified to navigate via UWB bluetooth.

Figure 12. "YumeiiGO" transport card allows for travel via autonomous shuttles.

6 Future 4: The Responsive Network

The Responsive Network describes the use of 6G antennas as a distributed sensor used to sense the environment and react to disruptions in the territory. This future addresses adaptations to increasing extreme weather conditions and how 6G networks could help divert traffic flows from dangerous areas and into safe zones in real-time (see Figure 13). Predictive, risk-based algorithms coupled with the sensing capabilities of the network can reduce vital decision-making time and optimise the way emergency situations are handled.

6.1 The Responsive Network prototypes

To communicate how a system measures risk and organises subsequent evacuations, we created a diorama featuring rural, urban and suburban areas. Using Unreal Engine, we developed an animation depicting a flood event occurring in the coastal area. The model serves as a representation of the system mapping, showing how the digital twin of the territory is used to quickly assess and reconfigure the flow of people and vehicles throughout an area dependent on various situations (see Figure 14).

6.2 Responsive Network props

Within this future, the 6G-connected public infrastructure and personal devices will be able to measure essential parameters such as social vulnerability, disaster probability, and traffic levels. These will be used to respond to traffic congestion, damaged roads, fires, or accidents. With the integration of large data sources and improved accuracy in the 6G world, each individual in a risk area will be given a "Disaster Priority Index" (DPI) at the time of the disaster. Based on risk score, citizens will receive a personalised alert and course of action, thereby optimising the movement of people during a disaster. One artefact from this future is the digital DPI heatmap, which is determined in real-time and guides network response in the city (see Figure 15).

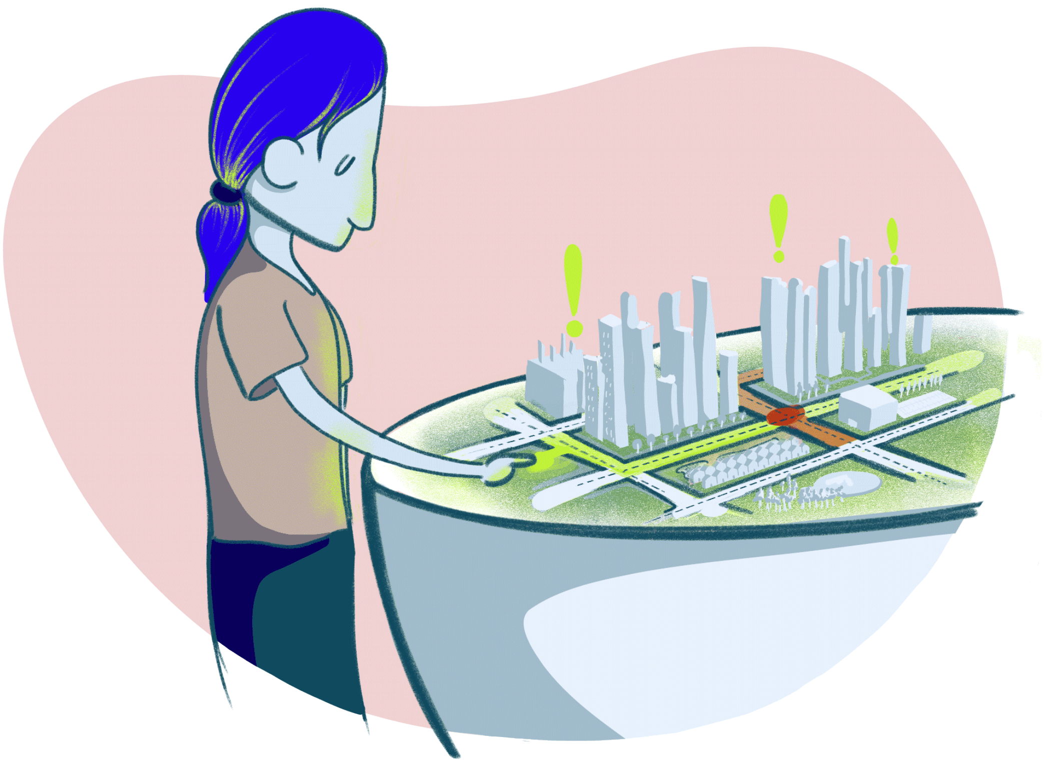

Figure 13. Map of the digital twin of a city, displaying real-time rerouting of traffic.

Figure 14. Projection mapping onto a diorama of the digital twin of an area.

Figure 15. Representation of the Disaster Priority Index, overlayed onto Tokyo Bay.

7 Discussion

Using speculative design tools and methodologies, our team was able to address a technological inquiry from an unorthodox angle. Working on generating technology-enabled solutions should not start from technical capabilities, but rather from societal needs and user centricity as a means to find opportunities where technology could create value. As 6G is expected to be widely available in about a decade from now, scenarios should take into consideration all the possible and probable futures. Our 6 G-enabled scenarios were addressed with interventions, made credible through validation of prototypes, videos and descriptive props. Proposed solutions can also create value when they highlight potential unintended challenges or threats. Building narratives to give credibility to future scenarios helped us understand how we could iterate from the initial ideas towards a more robust solution, effectively helping us test the initial assumptions.

8 Conclusion

This paper describes how we utilise speculative design tools to envision how future technologies will shape society. This exploration resulted in simulation prototypes, props, and videos. By using these techniques, we step out of a solution-based approach and instead think about the context in which the solution lives. Instead of proposing prescriptive visions of the future as solutions, we aim to start conversations about the ideas themselves. In the first phase of our work (September to December 2022), one method used to help these ideas surface was to employ key value indicators, matching 6G capabilities with societal values in Japan (Wikström, Gustav et al., 2022). The next step of this process was to use the outcomes of this framework to build fictional worlds. The main limitation of this process is that 6G is still at an early stage of its development, so all of its technical assumptions are based on white papers published by major stakeholders in the field. Nevertheless, the outcomes show new ways to interact with technology and provide new visions of what technology can do. In this regard, we are now iterating the prototypes to create measurable experiences and test the validity of some novel approaches that surfaced from our work.

Both scenarios and proposed solutions are a means to create more collaboration opportunities with other laboratories at the University of Tokyo and engage with the broader community and bring research out of academia. Later this year, we will host a public exhibition in which our four speculative narratives, videos, props, and prototypes are displayed to a public audience. By publicly showing the results of our work in the near future we hope to create an opportunity to gather feedback and further understand what design can do to shape technological development. This feedback also serves to cross-check whether the technologies are explained in an understandable manner to a non-specialist audience. Through this work, we hope to further reinforce the necessity for design within the development of technologies, both as a means to communicate advancements and spark conversation about it.

Acknowledgments

We are deeply indebted to Prof. Miles Pennington, Prof. Kentaro Honma and Dr. Hyungjung Kim who supported, guided, and mentored us throughout the project. We also thank Hisae Tamura who supported our administration, and our interns Sanjeevani Marcha for her help in design and research and Olivia Raherinirina and Quentin Bernyer for their enthusiastic work on the prototypes. These research results were obtained from the commissioned research by the National Institute of Information And Communications Technology (NICT), JAPAN.

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