Transit Hubs & Mobility Experience

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Four scenarios for the Dutch mobility system in 2050

TU Delft

Transit Hubs & Mobility Experience

Bio

Manuela Triggianese is an Assistant Professor in the Department of Architecture at Delft University of Technology, where she coordinates research in the Section Building Knowledge and MSc education in the Complex Projects Group. She contributes to the Future (proof) Urban Infrastructure program led by DIMI, and she is a member of the Transport and Mobility Institute. An architect by training, she holds her PhD from IUAV in Venice, focusing on high-speed railway station design and development. Her research centres on co-creation in architecture for an integrated building project, using the architecture of mobility spaces – stations - as a testbed. She explores how design fosters dialogue by integrating multidisciplinary expertise, diverse data, and stakeholder perspectives. The scope is to align architectural design with transitions in sustainability, digital transformation, and social innovation. Formerly at the Dutch firm KAAN Architecten, Manuela has held research positions at Beijing Technical University as Marie Curie fellow and at the Amsterdam Institute for Advanced Metropolitan Solutions, where she led the Stations of the Future project and AMS-Mid City. She leads the NWO-funded project Walk-In and the open access book series City of Innovations (TU Delft). Read more about her work in stories of science.

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Four Scenarios

Top Left: Innovation Fast Track
Society embraces new technologies, and market competition drives change

"The Demand-Adaptive Hub"

Society is increasingly tech-driven, with AI, automation, IoT, and MaaS reshaping daily life. Mobility hubs like transit stations prioritise efficiency and cost-effectiveness, using digital platforms for personalised travel. Competition among private providers fosters innovation, reducing costs and overshadowing public transit. Digital twins predict and manage congestion, ensuring smooth operations and controlled maintenance. Hubs now feature flexible, modular designs that reconfigure in real-time, optimising operations and enabling a decentralised, sprawled urban fabric. Major hubs such as airports and central stations, including hyperloops for long-distance travel, accommodate automated vehicles,

offering on-demand services that cut wait times and improve efficiency. The shift from predetermined shuttle routes to more dynamic systems aligns with car-free streets and residential zones. Small hubs, strategically placed in these areas, become essential for providing convenient and efficient access to mobility services, ensuring that people and goods can move seamlessly within these pedestrian-friendly environments without relying on private cars or fixed transit schedules. Goods distribution relies on micromobility, drones, and automated systems. Urban air mobility solutions serve as premium services in congested centres, transforming hubs into high-tech innovation centres but raising concerns about affordability and inclusivity. While these advancements maximise space and efficiency, they risk prioritising data providers' interests over public welfare. The real-time reconfigurations demand significant energy, and the increased modularity risks rendering existing stations obsolete, necessitating retrofitting to avoid abandonment.

Top Right: Hyperconnected Systems
Society embraces new technologies and government intervention drives change

"The Seamless Hub"

Stations are multimodal hubs facilitating seamless travel between trains, buses, micromobility, and automated vehicles. Rooted in governmental urban mobility plans and strategic spatial development, these hubs form a polycentric network shaping urban areas. Dense, mixed-use neighbourhoods emerge around stations, enhanced by electrified and automated micromobility, enabling mid-low-rise developments instead of high-rises, with expanded green and open spaces. Governments prioritise sustainability, investing in infrastructure tied to environmental and social goals, such as high-efficiency trains and zero-emission buses. This ensures stations drive urban regeneration, avoiding gentrification and displacement. Transit hubs are designed as carbon-neutral (BSbm, 2024), regenerative spaces to reduce urban carbon footprints. Suburbs shrink into ecological green belts exclusive to non-motorised mobility, with Park and Ride hubs facilitating smooth urban-rural connections. These hubs, acting as "urban batteries," harness renewable energy from solar and wind sources to power stations, electric vehicles, and local systems. The resilient dimension plays a crucial role in this scenario. Highly complex, connected transport systems are more fragile to disruptions, such as climate events. While centralised coordination and connectivity bring benefits, they also risk inefficiencies like bottlenecks, higher costs, or underutilisation of resources. Inner cities evolve into car-free zones, emphasising active transport, light electric vehicles, and shared mobility. Automated taxis integrate into transit networks with designated drop-off points, while varied hub sizes ensure accessible options in car-reduced zones. Shared mobility facilities, including bike parking and on-demand services, are conveniently located within a 5-10 minute walk or bike ride of main stations. Urban Air Mobility is deprioritised due to its high energy demand and reliance on non-preferable data practices. These interconnected hubs foster sustainable, energy-efficient urban mobility, prioritising people and environmental goals while transforming cities into greener and more accessible spaces.

Bottom Right: Sustainable Slowdown
Society is cautious towards new technologies and government intervention drives change

"The Eco-Conscious Hub"

In a technology-cautious society, the government drives change by investing in mobility hubs that prioritise safety, inclusivity, and social cohesion. These hubs, designed with community input, blend traditional transit services with facilities like day-care centers, libraries, and co-working spaces. Accessibility is central, catering to all, from families with strollers to older adults requiring assistance. Sustainable construction features renewable energy sources and low-rise, human-scale architecture that integrates into the urban landscape. Hubs address growing vulnerabilities, such as heat-related challenges, while supporting the shift to public transport through investments in urban, suburban, and rural mobility nodes. Suburban stations, with park-and-ride (P&R) facilities, connect highways to public transit, enhancing accessibility and encouraging car-free city centres. Governments also promote circular approaches, low-tech solutions, and renewable energy, balancing efficiency with societal concerns like data privacy. Private car use faces heavy taxation, reduced parking, and restrictions in city centres, with allowances for logistics. Environmental and car-low zones, combined with nature-based climate adaptation measures for stations (BSbm, 2023), further promote sustainable mobility. Challenges include housing deficits and integrating new dwellings near stations while maintaining a polycentric urban fabric. Despite

fewer mobility options, improved quality and comfort in public transport are prioritised. This strategy ensures equitable access and supports sustainable, low-carbon urban development, embedding hubs seamlessly into urban environments to foster resilience and cohesion.

Bottom Left: Mobility Patchwork
Society is cautious towards new technologies and market competition drives change

"The Competitive Hub"

In a technology-sceptical society where market competition drives change, transit hubs adopt technology cautiously, with gradual improvements spurred by competition among mobility providers. Stations blend traditional and modern mobility solutions, with hubs of varying sizes present in urban, peri-urban, and rural areas. However, mobility choices are scattered, transfers are unregulated, and modal splits are disorganised. In cities, competing services increase congestion due to a lack of network integration. Duplicate routes from private operators exacerbate traffic jams and inefficient road use. Minimal collaboration between private and public transport networks results in fragmented, non-seamless travel options. Urban densification around stations, combined with limited space, leads to districts that appear overcrowded and unsafe. A strong focus on densification and real estate development limits space for mobility growth in the future and puts pressure on the quality of the living environment (CRa and BSbm, 2023). Market-driven development around stations prioritises economic competition, impacting hub attractiveness. This approach risks gentrification and inequality while failing to ensure cohesive planning. Smaller hubs for shared mobility options, such as electric vehicles, are located near car-free streets and residential areas, but the fragmented mobility space lacks quality public infrastructure. While market-driven efficiency improves cost and speed, it does so at the expense of liveability, sustainability, and the seamless user experience. Public spaces remain disjointed, with limited positive developments in mobility space quality or urban cohesion. Overall, this scenario underscores the challenges of balancing economic competition with inclusive and sustainable transport systems.

Questions for Future Research

- How to design and adapt transit hubs responding to new challenges, e.g. climate change, scarcity of materials, and carbon footprint, while enhancing users' experience and comfort?
- How does the design of transit hubs influence the mobility experience of commuters and what design strategies can enhance accessibility and users' satisfaction?
- How can design and technology embody and express cultural and shared values - e.g. local heritage - of transit hubs, meeting people's needs and sense of belonging?
- How can design and technology facilitate conversations among different stakeholders to look for solutions together for an attractive, sustainable and inclusive mobility hub? Which tools and methods?
- How can design and technology balance hubs as transit nodes in the network with the creation of liveable spaces, well integrated into their urban surroundings, promoting wellness, connectivity, and community?
- How can design and technology align slow development of the built environment with rapid tech advances to maintain mobility hubs still vibrant and efficient?