Autonomous Driving: From Means of Transportation to Mobile Architecture

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Introduction

During the 2nd industrial revolution, the development of transportation, especially automobiles, have fundamentally reshaped our cities. Automobiles have since evolved by adopting different technologies, from the Benz Patent-Motorwagen, Ford Model T, Toyota Corolla to Tesla Model Y. Each represents a breakthrough in automobile development, with the latest incorporating artificial intelligence (AI) technology. Given how much our urban experience revolves around automobile traffic, the purpose of the article is to explore how the current trend of regenerative AI and autonomous driving would result in spatial transformations to the automobile, within the cultural context of Hong Kong, to become a crucial architectural component of the city.

Review of Literature

Autonomous Transportation

Autonomous vehicles are commonly known as self-driving cars or driverless cars, which are vehicles capable of sensing their environment with cameras, LIDAR, radar, and GPS, to perceive their surroundings and make decisions accordingly without human input. The U.S. Department of Transportation National Highway Traffic Safety Administration defines autonomous vehicles as "any vehicle equipped with technology that can perform all driving functions, under all conditions, without human intervention" (National Highway Traffic Safety Administration, 2013). Autonomous vehicles are classified into several levels of automation, ranging from Level 0, where the driver has full control, to Level 5, where vehicles can operate without any human intervention. Most autonomous vehicles currently in development or on the market fall into Levels 2 or 3, where the vehicle can perform some driving functions, but the driver must still be ready to take control if necessary (Sivak & Schoettle, 2015).

Autonomous technology is not limited to land-based vehicles. Autonomous ships, also known as unmanned surface vessels (USVs), are already in development and used in some industries, such as oceanographic research, offshore oil and gas exploration, and maritime security (Zou et al., 2021). Similarly, autonomous aircraft, or unmanned aerial vehicles (UAVs), are already in use for military and commercial purposes, such as surveillance, package delivery, aerial surveys, and search and rescue operations (Laghari, 2023). USVs and UAVs greatly increase

efficiency, reduce operation costs, optimize fuel consumption as well as improve safety by eliminating human error (Zou et al., 2021).

Despite its overriding potential to revolutionize the transport and logistics industry, autonomous transportation raises concerns on the increased urban sprawl and car-dependency, as people are more willing to tolerate longer commute times in the comfort of their vehicles (Sengupta & Chattopadhyay, 2018). Additionally, autonomous transportation could exacerbate existing inequities in access to transportation, as low-income and marginalized populations may not have access to the technology or infrastructure needed to use autonomous transportation (Litman, 2023). The over-reliance on technology and IoT in delivering transport services imposes risks for cyber-attacks on autonomous systems (Zou et al., 2021). Similarly, there are concerns about the safety and regulation of autonomous aircraft, as well as the potential for UAVs to invade privacy (Laghari, 2023).

Autonomous Transportation and City Planning

The development of autonomous transportation has been shaped by and has the potential to shape city planning. As autonomous vehicles become more prevalent, they could become an architecture in the city, governing the way urban dwellers interact with and move through urban spaces, shaping the design of buildings, streetscapes, and public spaces. By reducing the need for parking and road infrastructure, land resources are liberated to provide for other land use to satisfy public interests, such as public open space, parks, promenade etc., to reknit community fabric (Camps-Arago et al., 2017; Litman, 2023). The dedicated autonomous transportation infrastructure interweaves with the design of new buildings and urban landscape, thus creating a seamless integration of autonomous transportation into the urban environment (Bagloee, 2016). Autonomous transportation itself removes geographical barriers by optimizing commuting and transportation. In turn, it also removes social barriers by unleashing public spaces which are originally roads, so as to make way for more community encounters.

Methods

Spatial Auditing of Transportation Typologies

Transportation vessels had always carried the potential to become a mobile architecture. However, they had been designed predominately to carry out their primary logistic function, putting the manual operation of the vehicle as their first design priority, and then with engineering efficiency and passengers traveling comfort as their next design considerations. With emerging technology on autonomous transportation and increase in the level of automation, design considerations and constraints imposed by the practical reason of manual driving could be eliminated. Hence, a new design revolution of transportation vessels could begin, leading to a new form of mobile architecture and bringing experiential design considerations back to the playing field, with how passengers or inhabitants use the vessels could be totally reimagined. The history and development of major types of past transportation vessels form the basis of the research. Spatial auditing of vessels according to their nature shall be categorized as ‘for operational use’ (e.g. cockpit, engine rooms), ‘serving as a carrier’ (e.g. seating area, cargo hold), and ‘for programmed use’ (e.g. dwelling, catering). Owing to the

drastic reduction of operational space and demand for carriers due to autonomous driving, there is potential for vehicles to be redesigned and transformed into ‘Mobile Architecture’.

Interview with the Hong Kong Tramways with Trams as Venues

Image 1: Tram as a Cultural Venue (Detour, 2013)

The transformation of transport vessels into mobile architecture will first be explored through local precedents to showcase the cultural possibilities for collaborative clusters. In the past few years, the Hong Kong Tramways had gone into an unprecedented transformation from becoming a purely transportation network into a cultural phenomenon. In collaboration with design exhibition “Detour”, four trams were transformed into dining, art or social venues. The short term project was eager to explore the relationship between the tram system and the city to test design possibilities of the tram space as an urban interface moving through Hong Kong Island, providing passengers and the community with new cultural and communal experiences.

Image 2: Marketing Campaign with Tram transforming Causeway Bay into "Keung To Bay" (Yahoo News, 2023)

With the revival of local Cantopop music and the emergency of boy group "Mirror" in 2020, fans club had been renting trams and sponsoring a free tram ride day as a marketing campaign to gain publicity for the Cantopop boy group. It resulted in social phenomenons during the birthdays of boy group members, especially at moment when the decorated tram passess though a particular junction at Causeway Bay also filled with large outdoor advertisements of a member of the boy group "Keung To", giving a new name of the area as "Keung To Bay". The Partnership & Business Development Department of Hong Kong Tramways will be interviewed to gain insight into how a mass transportation system became a cultural landmark, fueling the revival of local culture, and knitting a community transport network.

The Case of Jumbo Floating Restaurant and the Aberdeen Boat Houses

Image 3: The towing away of Jumbo Kingdom at Aberdeen Typhoon Shelter leaving behind its Kitchen Block and the smaller Tai Pak floating restaurant (CNN, 2022)

The Jumbo Floating Restaurant demonstrated how vessels could be programmed for use in catering, hospitality and tourism. The history of Hong Kong's floating restaurants can be traced back to the 1920s serving boat-dwelling people and visitors. The Jumbo Kingdom was built as a floating restaurant instead of intended for transportation or logistic use and consisted of multiple vessels with the restaurant block and kitchen block. Throughout the years, it had attracted celebrities and venues for film shooting. It was closed down due to COVID and the owner attempted to tow it out of Hong Kong in 2022 because of the expiring license. On 18 June 2022, the floating restaurant experienced bad weather and was capsized in the South China Sea. Together with the houseboats in the Aberdeen Typhoon Shelter, it formed a floating village with a population of about 6,000 that peaked in 1963 with about 150,000 boat dwellers. Passages were designated within the typhoon shelter like streets within a city. Navigation buoys and lights were installed with coordinates demarcating them. In the recent revival of tourism after the pandemic, some boat houses had been revamped into luxury hospitality boat houses.

The Case of HKTVmall's Automated Warehouse Progression

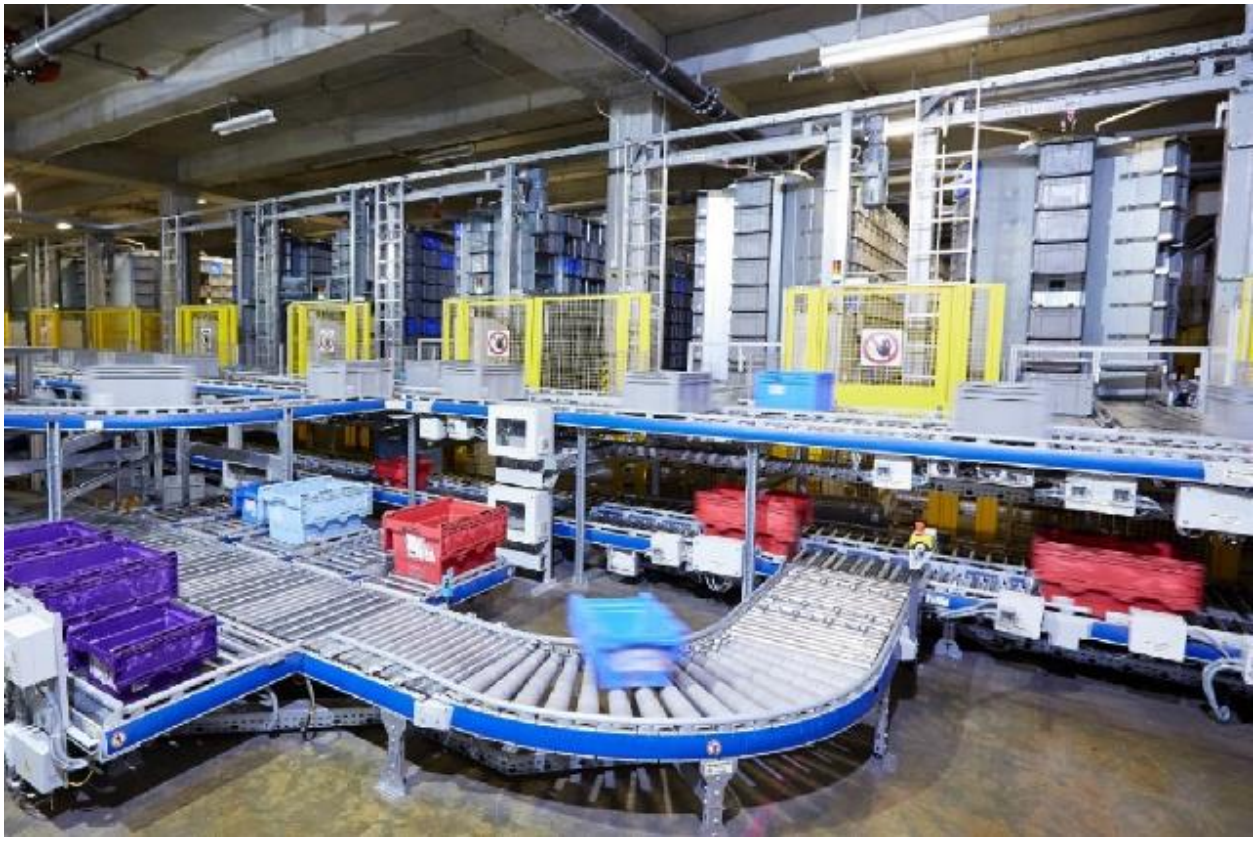

Image 4: The fast and responsive automated warehouse (HKTVmall, 2023)

In the logistics business, AI is already employed to perform a fast response type of clustering that can overcome the staticness of its architectural shell, empowering it with mobility for efficiency and resilience. The local online shopping platform HKTVmall, who outperformed multinational competitors by focusing on highly perishable grocery-based shopping, adopted automated and robotic systems at their warehouse. Orders could be fulfilled automatically and with real-time order tracking. Improvements in efficiency and product types that benefit the most from automation are also highlighted. All receiving and distribution of goods had been carried out under one roof within a warehouse with an automated robotic pick & pack system, cross-belt sorter system and automated guided vehicle system. The sorted goods will eventually land on conventional trucks delivering them to designated households in the city via the road network.

Results

Proximity to the City and the Community

In the case of Hong Kong Tramways and the Aberdeen Typhoon Shelter hosting floating restaurants and boat houses, it was identified that the vessels' with closer proximity to the city has a higher potential in transforming into an architecture hosting programme. The Hong Kong Tramways identified that the tram's proximity to the community enhanced personal touch by growing together with the city. The existence of the tram also matched with the vibe of the city, building up a relationship with the urban environment and adapting to the expanding city. The already half transformed mobile architecture can be seen as an overspill of architectural programmes from buildings to the transportation network. In the district they pass through, the vessels bring in the character and vibe of one area to another. In one case, luxury brands are willing to do a marketing campaign because the vessels pass through the central business district. However, the same vessel still travels to other residential districts along the line. There is a potential that a particular architecture that was developed in a specific context could be moved around as a node, informing and catalyzing transformation in another urban area. However for practical reasons, the vessels are also required to stay near to their supporting utility infrastructure such as fuel, electricity, water supply and the sewage system.

Allowance for Vigorous and Economic Customization

The materiality, construction method and design flexibility dictates the potential of customization of transport vessels. The higher the adaptability of the vessels with cheap and vigorous customization allowed, the larger potential for different architectural programmes to emerge. The Hong Kong Tramways is a narrow-gauge tram system consisting of tram cars either made of teak frame or aluminum alloy. Engineers from the train depot considered that trams made of teak frame are more readily available for customization when compared to aluminum alloy. The alloy tram cars are prefabricated at an offsite factory and the components are large in size so as to minimize assembly efforts. This construction method is not beneficial to customization as it will easily cause damage and be difficult to modify locally, while the tram depot has a wood workshop that could easily customize components or make changes to the teak frame. The connection details and surfacing material of the teak frame tram cars are also more beneficial to customization due to the material thickness and the easy re-appliance of protective surface layer (e.g. paint for teak but anodization for alloy).

Release from Design Constraints required by Manual Operation and Navigation

Governmental departments often impose strict regulations on vessels to ensure safety. For example, the sightline of tram drivers had to be ensured from the driver seat to the rear. The front seat offering the best view and experience is occupied by the driver for manual operation and navigation. An autonomous vehicle may relieve the design from above requirements, granting more freedom to design for the intended programme and the experience of the inhabitant during both the static and on the move. The vessel will no longer be designed for prioritizing logistics reasons. From a city scale, wider lanes and carriageways are required for manual operation of vessels and for manual navigation (e.g. choosing lanes for different destinations) and provide tolerance to prevent accidents. Implementing autonomous vehicles at the highest level implies narrower lanes due to more certainty and reliability on its movement. The built-in navigation system would eliminate the decision time required for wayfinding, resulting in smoother traffic and less carriageway width especially at road junctions.

Expand of Automation Network from Building Scale to City Scale

The development of self-driving technology is advancing at a high speed but not yet to the topmost level due to the complex road conditions. The technology is now applied at more controlled environments involving point to point destinations, such as at the HKTVmall warehouse, the restricted zone of the Hong Kong International Airport and the West Kowloon Art Park. If the technology is further developed, the network of autonomous movement could be further expanded from a building scale to a city scale, completing the last missing link from the logistic warehouse to households in the city. The increase in logistics efficiency shall benefit urban planners as satellite towns will be closer to the hubs in the infrastructural sense. There are often criticisms on infrastructure-led urban planning that focus more on engineering efficiency but less on humanistic community building and aesthetic spatial designs. The technology would hence allow new typology of towns with less space designated for road and transportation infrastructure.

Discussion

Liberation of Urban Planning occupied and driven by Transport Infrastructure

Pedestrian and transportation space are instrumental elements that form our cityscape. Ancient and medieval cities were built around roads, streets, public spaces and arcades, while the advent of the automobile evolved roads into driveways and highways. For example in the US, around 18-30% of urban areas are dedicated to driveways. (Duxfield, I. 2021) With the modern state, traffic is mostly institutionalized with its own inherent logic, rules and corresponding governmental body. But with the coming of autonomous driving, the bureaucratic split between pedestrian and traffic order would start to blur. Advancements in autopilot, motion sensing and related safety protocols could transform driveways to not only accommodate cars and public transport, but also assimilate different speeds of traffic, including pedestrian traffic, to occupy the same road to form a 'mobile' public space. Could the road become obsolete with the coming of autonomous driving? How will redundant streetscapes be reutilised once driveways have been freed up?

Increased safety and efficiency of autonomous vehicles could potentially reduce the size and number of roads. Wide lanes, traffic lights, and other infrastructure designed to accommodate human drivers would also slowly become obsolete. Autonomous cars could travel freely on any open space without traffic signs or routes, much like how ships and airplanes roam in water and in air, which could be a framework for the emerging jurisdiction of autonomous driving. This could allow for more compact, freeform and walkable city designs. What kind of public spaces will emerge when automobiles no longer dominate the streetscape in cities?

Reintroduction of Plug-in Architecture integrating Autonomous Vessels

Autonomous driving technology could fundamentally change our preconceptions of the automobile, and other types of land vehicles. Without modern traffic systems, is the vehicle and its associated spaces still bound by conventional traffic guidelines? What type of public transport would emerge with the advent of autonomous driving? What would be the optimum width of a road, street, or size of a carpark when vehicle design is no longer constrained? Vehicles could possibly come in different sizes and shapes, while the absence of a driver and driver's seat could mean that spaces could be freed up and possibly house tiny workshops, mobile libraries, mobile kiosks etc. When the vehicle is liberated from its conventional form, miniature programs could be integrated into the newly freed-up space of a driverless shell, the boundary between vehicle and architecture starts to blur.

Conventionally, roads often form the plot boundary of city blocks for land sale and real estate. With the freeing up of the streets as a docking zone for autonomous vehicles similar to ships, existing building blocks could become dockyards for autonomous vehicles to dock, not just for the loading and unloading of passengers and goods, but also connecting and extending existing building space into the street. On one hand at an urban scale, parking lots and garages could be drastically reduced or eliminated altogether, freeing up space for other uses such as public parks, bike lanes, and pedestrian walkways, on the other hand at a building scale, automobiles could evolve into 'Plug-In' architectures that enhance the existing infrastructure. Plug-in

architecture could become temporary extensions of private homes, or temporary functions in public institutions, which could respond to changing needs in the future, and might be a cost-efficient response to a sustainable and resilient community.

Ensemble of Autonomous Vessels becoming Mobile Architecture

Beyond its possible interaction with existing architecture, Plug-in architecture might also interact with each other, transforming and organizing itself into large-scale temporary ensembles. The current practice of Modular integrated Construction (MiC) as a construction method in Hong Kong is the prefabrication of structural and spatial units, fitted into large transportation vehicles, which is then transported and assembled into buildings at the construction site. Plug-in architecture could be a next step to MiC, merging modular units with its delivery vehicle. With the emergence of Generative AI used in textual and visual mediums, the same technology could be applied to these modular vehicles of different types and sizes to form clusters for temporary programs such as festivals, expos or even emergency shelters at large open spaces. The autonomous ensembles of Plug-in architectures would become a truly 'Mobile Architecture', that would redefine how temporary space and programs are organized.

The above case studies and possible implications shed light on the potential of vehicles evolving beyond the realm of transportation to become 'Mobile Architecture'. Within the specific context of Hong Kong, the possibility of a 'Mobile Architecture' could open up a new field of study that could possibly generate unique solutions to mobility, community and even sustainability in a fast-changing world.

Keywords: AI, Automobile, Autonomous, Mobility, Transportation, Urban Planning

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