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How Will Automation in Transport Flows Impact Future Urban Form?

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INTRODUCTION

Today transportation sector is facing many disruptive transformations. Sperling et al define these disruptions broadly under 'three revolutions' – vehicle automation, electrification, and sharing/pooling[1]. The rise of electric vehicles integrated with smart grids and wireless communication and the much hyped automated vehicles[2], are poised to transform urban mobility . At the same time, personal mobility is giving way to mobility as a service. Technologies like 'Internet of Things' (IoT) that generates vast amounts of data and can enhance operations, enable better mobility management systems for ridesharing platforms and mobility-on-demand services [3].
Some advocates predict that by 2030, automated vehicles (AV) will be sufficiently convenient and affordable to displace most human-operated vehicles. However, critics warn against overt optimism for AVs, citing hurdles to implementation such as lack of clarity around the behaviour or vehicle and occupant in a hazardous situation, concerns about high infrastructure cost and the potential economic and social impacts of displacing jobs[4]. Even though the AV 'revolution' faces many hurdles, many commentators, academics and policymakers assume that they will eventually become a norm[5]. As AV technology matures, and converges with the other disruptive transformations in transport, it would lead to a paradigm shift in transportation flows, similar in scale to the impact of the advent of the private automobile.[6] This paper discusses the new challenges that emerge in urban design and planning disciplines as a result of this shifting technological context, and how the urban design discipline can address them.
The first section of the paper describes the two-way relationship between urban form and transport flows, as a consequence of which the technological shift in transportation signalled by AVs present new challenges for urban design. The second section gives a brief overview of the technological shift in transport flows and its the potential benefits and dangers, revealing their inherent contradictions. The next section demonstrate how existing methods in urban design are inadequate to address these contradictions and the technological shift, through a review of selected recent urban visions for automated vehicles. The final section presents some key properties for new methods to conduct urban design with transport flows in this shifting technological context, using a Singapore case study as an example.

URBAN FORM AND TRANSPORT FLOWS

Physical form of the city, referred to as 'urban form' in this paper is described by Aldo Rossi as the 'architecture of the city', summarized by its urban artefacts. These urban artefacts are intuitively considered fixed, durable and physical, but Rossi identifies that there are in fact forces acting upon that transform them [7]. These forces encompass various physical and non-physical flows that animate a city– water, energy, information, people and goods. The latter two are collectively defined as transportation flows in this paper.

Transportation flows play a crucial role in shaping urban form, as claimed by urban designer and theorist Kevin Lynch in his seminal book 'Theory of Good City Form':

"Settlement form, usually referred to by the term 'physical environment,' is normally taken to be the spatial pattern of the large, inert, permanent physical objects in a city: buildings, streets, utilities, hills, rivers, … I will take the view that settlement form is the spatial arrangement of persons doing things, the resulting spatial flows of persons, goods, and information, and the physical features which modify space in some way significant to those actions including enclosures, surfaces, channels, ambiences and objects."[8]

Lynch places emphasis on the importance of including activities performed in a city and the resulting transport and information flows in the definition of urban form, by arguing that these flows modify urban space. Literature in transport planning also points towards a converse relationship, wherein design and quality of urban form can influence travel behaviour.[9] For example, Cervero and Kockelman summarised the properties of built environment that influence travel demand as 3Ds – density, diversity and design. [10] The relationship between design of the urban form and transport flows can thus be conceptualised as a strong two-way relationship, wherein nature of transport flows impacts how the city is shaped, and planning and design of urban form influences travel behavior. [11]

If urban form has a strong, two-way relationship to transport flows, as this tradition of scholarship in urban design and transport planning suggests, then the question arises whether this technological shift will influence urban form, and if so how.

AUTOMATION AND THE TECHNOLOGICAL SHIFT IN TRANSPORT FLOWS

In recent years, automated vehicles have received enormous attention, with some scholars likening the impact of the arrival to AVs to that of the private automobile, signalling an 'AV revolution'. [12] Vehicle Automation is a significant, but not the sole driver of the technological shift in transportation flows. Imaginations of a driverless car have been around for a long time (see a 1957 advertisement in Figure 1). Due to limitations of technologies available at the time, these imaginations were mostly limited to fictional narratives. This is changing now as several technologies mature in parallel and converge.

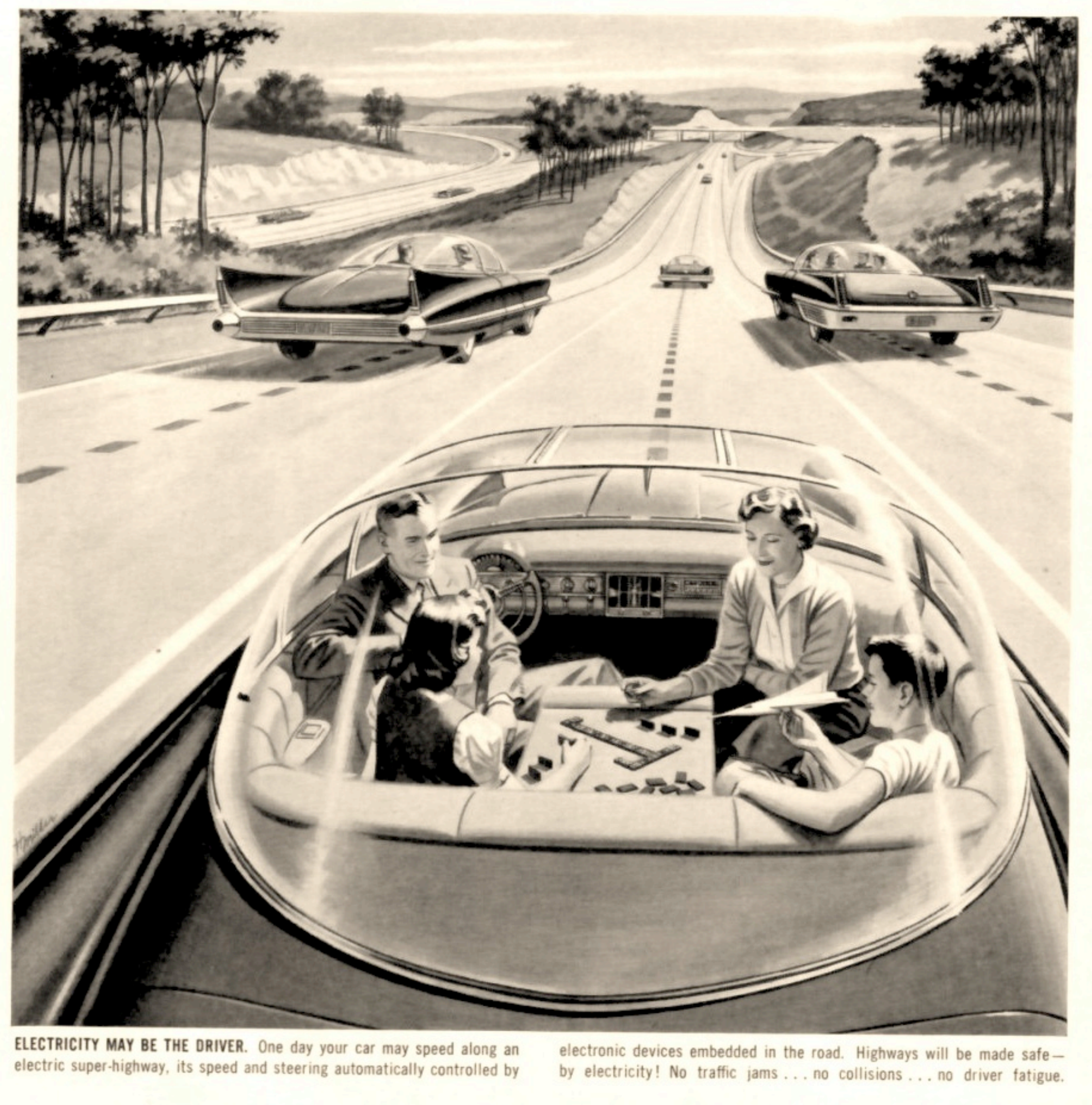

Figure 1: Driverless car in an ad from 1957 Source: Matt Novak, Paleofuture.com

- High level of **vehicle automation** promises an ease of personal mobility and driving efficiency like never seen before.
- The steep **rise in car and ride sharing industry** will mark a shift towards reduction in private car ownership. Since most private cars are used less than 10% of the time[13], AVs make car sharing even more viable. New operational paradigms and fleet management strategies will start emerging with the rise of car-sharing.
- **Electric vehicle (EV) technologies are maturing** and becoming more affordable. Currently one of the biggest problems of EVs is their limited range. If large AV fleets can employ different kinds of vehicles for different trip distances, they can sidestep this problem.[14]
- The rise of **transportation related applications of IoT** will enable a truly connected and 'smart' mobility environment that can be used to optimise public transit routes, improve safety and reduce vehicle congestion. In fact, connected transportation is crucial to realize the full potential of AVs.[15]
- Automobile **'unglued' transport flows from infrastructure**, from rail bound trains to cars that go as far as the road does, AVs will further this 'ungluing' process. Small electric AVs

may not even need to be restricted to the 'road' any more. Additionally, unlike traditional buses, shared vehicles do not need to be 'glued' to pre-determined routes, rather could be dynamically routed based on demand.

It may be fair to conclude that as these technologies mature and converge, transportation flows will undergo a paradigm shift. Fully automated and connected vehicle technology with a nearly 100% market penetration will create new needs and conditions for design of urban form. It is as yet unclear how this will impact urban form and travel patterns, but there have been several speculations on the positive and negative impacts of automated vehicles.

Speculations on Benefits and Dangers of Automation in Transportation

The benefits (or dangers) of AVs are only speculative at present. For the impacts of the AV revolution to be significant, almost full market penetration of fully automated vehicles is needed and speculations for such a long time horizon are inevitably uncertain.

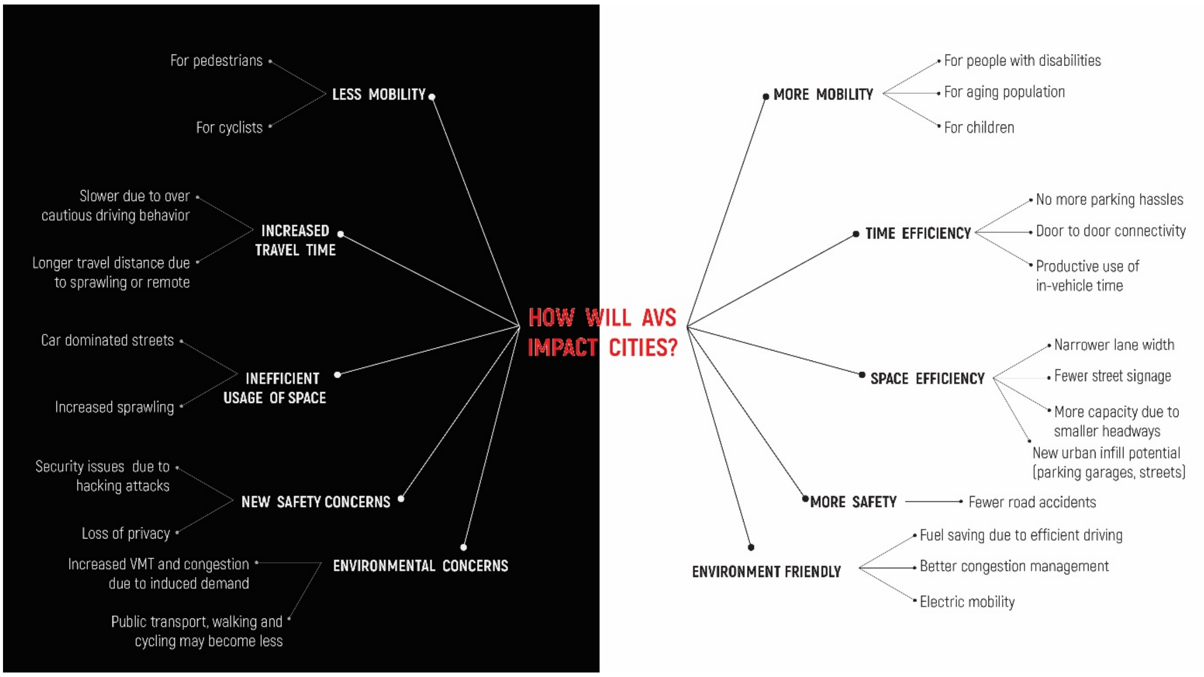

Figure 2: Benefits and dangers of AVs

Time: More efficient use of time vs more travel time

Travelers may gain time through more efficiently managed and connected transport system, self-parking, and more productive in-vehicle time.[16] At the same time, induced demand due to better managed travel might ironically add to congestion. New demand from those previously unable to drive, coupled with trips drawn away from healthier modes like walking and cycling, could all add to congestion.[17]

Space: More space efficiency vs. more sprawl

Current street design standards could probably be shrunk or revised since AVs are expected to require less physical space, and drive with greater precision. For example, a four-lane highway may be converted into a five-lane highway with minimal investment.[18] However some studies point to an increase in attractiveness of suburban residential districts, that are greener or cheaper, when AVs become available.[19]

Mobility: Enabling mobility for some vs restricting mobility for others

AVs offer new mobility options for previously unserved population including people with disabilities, elderly and children. But this may be paralleled with even greater restrictions placed on pedestrians and cyclists, like grade separated sidewalks or fences, in effect restricting their mobility, in order to maximise efficiency of AVs.[20]

Emissions: Fewer emissions or more
AVs are expected to use existing lanes and intersections more efficiently through shorter headways, coordinated platoons, and more efficient route choices leading to fuel savings.[21] On the flipside, we can also expect increased total travel distance due to sprawling, new travel demand from non-drivers and induced demand due to travel time savings, less congestion, and ironically, fuel savings.[22]

Safety: More safety of more safety concerns
AVs have the potential to dramatically reduce road accidents, since most of them are a result of driver error.[23] But there are still several unresolved questions around liability in case of an accident, vulnerability to hacking attacks and loss of privacy due to perpetual location tracking.

As is evident, the benefits of automation can just as easily translate to dangers, under different base assumptions. Planning and design decisions can enhance benefits in one area, while endangering another. Many urban design visions have been put forward that address both ends of the spectrum.

URBAN VISIONS FOR AVS: PREVAILING ISSUES
Leading architecture and engineering firms as well as governments have speculated on a future vision for automated flows, usually in the form of imagery in the design fiction genre. Speculative design and design fiction does not try to predict the future but uses design to speculate, criticise and open up possibilities[24]. Upon critical examination of a selected set of imagery, five prevailing issues were identified.

AV ≠ (Car – Driver)
As discussed in a previous section, automated vehicles are not the only drivers of the technological shift in transport, but in popular imagination AV revolution is seen as merely a car without a driver. Urban visions for AVs often bear a resemblance to modernist urban visions produced in response to automobiles in middle of the last century. The separation of flows on multiple levels in Colin Buchanan’s seminal report ‘Traffic in Towns’ (Figure 3) bears a similarity to Singapore’s AV vision by the Ministry of Transport (Figure 4). This emphasis on the driverless vehicle takes away from benefits that can be derived from the technological shift as a whole.

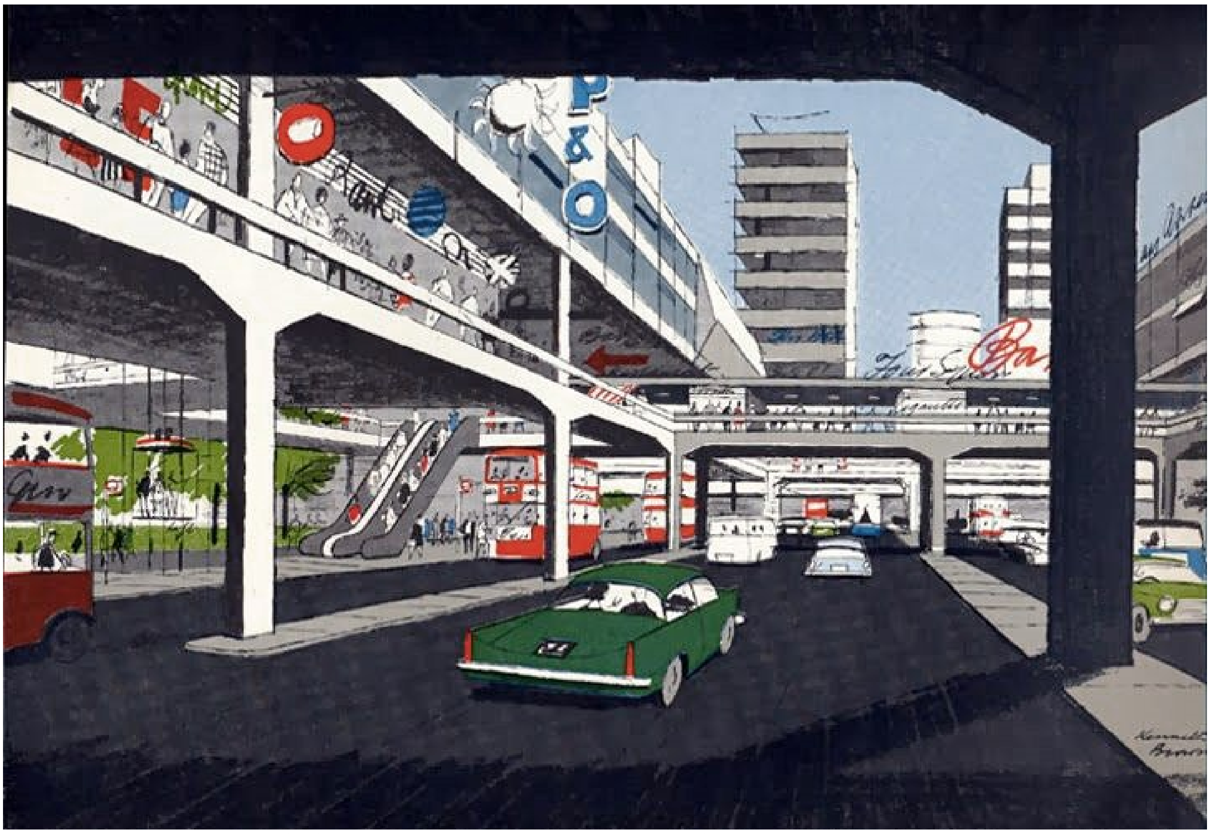

Figure 3: Plans for Oxford Street, London, in the 1963 Colin Buchanan report 'Traffic in Towns'

Figure 4: Concept of a future town centre in Singapore with autonomous Vehicles. (Source: Ministry of Transport)

No Two-way Interaction of Urban Form and Transport Flows

As discussed in a previous section, there exists a strong two-way relationship between urban form and transport flows. This relationship is not sufficiently addressed in future visions for AVs. There is a marked difference between purely visual urban visions[25] that lack transport flows, and more quantitative transport studies[26] that don't regard qualities of urban form. This could be an

epistemological (value-based normative theories vs functional descriptive theories) or methodological (lack of tools that can transition across qualitative and quantitative methods) limitation.
In urban design representations, the visual and experiential quality of the space is apparent, but the physical and environmental impact of transport flow remains hidden (In Figure 7 it is unlikely that efficiency of AV in shared environment was taken into account). In transport planning, modelling and simulation are commonly used as methods to predict transport flows and their impacts. Although these models take into account some aspects of urban form (usually aggregated land use information and networks), they are based on the assumption that current behaviour and patterns can be extrapolated.[27] This assumption means that the results do not capture emergent behaviour, for example if and how urban design strategies may influence transport flows.

Place based vs People based Design

Urban design is largely a place based disciplined. Despite Lynch's strong argument for including activities and flows in urban design, urban form continues to be represented through static media, frozen in one moment in time. Urban design imagery is an appropriate medium to communicate the experiential quality of the vision but does not make apparent the physical or environment aspects of flow - speed, friction or volume and travel time or vehicle kilometers travelled. For example, does a vision like that in Figure 5 lead to more or less emissions?

Missing Context

Despite the arguments against place based analysis, an understanding the context is essential when developing a vision for an AV enabled future. As discussed in the previous section, the benefits of automation are ambiguous and depend heavily on the initial context and future policy. In the absence of the geographic, social, planning and policy context, AVs might be misread as a technological panacea in some imagery. Low density Midwestern American cities requires a different transportation strategy (as illustrated in Figure 5) than high density Asian cities (Figure 4). This differentiation is often not made apparent.

Figure 5: Perkins + Will's vision for AVs by Gerry Tierney

3. Heaven or Hell Narrative

The imagery for AV futures tend to follow either a heaven or a hell narrative[28]. For example, contrast the optimistic shared AV zone proposed in Figure 7 with the dystopian sprawl proposed in Figure 6. The uncertainty of the speculative impacts of AVs discussed in a previous section, make it clear that extremes in either direction (heaven or hell) are highly improbable. It might be more appropriate to use imagery to make trade-offs explicit instead. For example in Figure 7, the lively shared mobility environment is a trade-off for more smooth flowing traffic.

Figure 6: Matthew Spremulli's visualization of a low density AV suburb Source: MIT

Figure 7: An AV zone imagined by WSP Parsons Brinckerhoff and Farrells in 2016

HOW TO CONDUCT URBAN DESIGN IN A SHIFTING TECHNOLOGICAL CONTEXT

Based on the review of current imaginations urban form for automated vehicles, it is clear that we need new methods to conduct urban design in this shifting technological context. One such methodological framework is demonstrated here, which is currently being applied in a Singapore based research project. The research employs an iterative design experiment and scenario building methodology, to address the issues listed above.

Understanding Emergent Behaviour

The discussion on limitations of place based analysis in transportation planning reveals how it is insufficient to deal with the complex interactions of technological disruptions and travel behaviour. New methods are emerging for analysing human activities in space and time[29], moving from a place based understanding of urban form-flow interactions to a people-based one. One such method is Agent Based Simulations (ABM).

ABM is based on a cumulative product of multiple decisions of people or ‘agents’, who have characteristics, goals, and rules of behaviour. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. The characteristics of the environment change in response to agent activities.[30] This approach is comprehensive, justifying the fact that travel and transport are rarely autonomous activities, but are the result of people wanting and needing to participate in activities that are spatially apart, giving a more complete picture of an individuals’ travel behaviour.[31]

Understanding two-way relationship of transport flows and urban form

In transport planning, one approach to thinking about future of cities is the ‘predict and provide’ model[32], which identifies current needs and extrapolates them into the future. This approach neglects the two-way relationship of urban form and transport flows, and how design can influence travel behaviour.

For the research in Singapore, multiple design scenarios are constructed and assessed using an activity based simulation framework called MATSim. Activity based simulations are able to capture emergent, often unpredictable behavior. However, such simulations can be extremely complex and time consuming. Recent advances in MATSim (Multi-Agent Transportation Simulations) enable a quick iterative design-evaluation cycle, in a customised version of the software, ‘Sketch MATSim’, which is used in this research project.

Understanding Goals and Trade-offs

Benefits and dangers of AV exhibit a close inter-relationship and occasional circularity. An understanding of this interrelationship is key to making intelligent design decisions for an uncertain future. While the quantifiable benefits and costs of technology are relatively easier to estimate, the assumptions they are based on have a high level of uncertainty. At the same time societal and qualitative impacts are harder to estimate and compare and therefore are often ignored.[33] This is why it is important to establish a baseline ‘good urban form’.

In this research the goals and values ‘good urban form’ in the context of Singapore are collectively decided through interactive workshops with local planning agencies. Several scenarios can then be developed, analysed with agent based simulations, to assess trade-offs against established goals, and iteratively improved.

Refining projections for the future, should not remain the ultimate goal of this scenario building exercise. Forecasts are rarely accurate[34] and unpredictability of the future coupled with fast pace of technological development leaves designers and planners ill-equipped to plan for an indeterminate urban condition. The context-specific goals and values that inform long term planning should set the tone for the quantitative analysis that follows.

CONCLUDING REMARKS

Automated vehicles are a significant technological leap in transport flows, and require a visionary response from urban planning and design disciplines. In the early automobile era the question driving the vision was, how do we maximize the opportunities presented to us by this new technology. The focus moved from optimism about technology to accommodating it, as automobile consumption grew beyond all predictions. The need to accommodate growing transport flows led to superhighways that splintered urban communities. As a reaction, the urban design discipline questioned how we can conduct urban design to influence transport flows? As we move into the future era of automation, lessons from this experience indicate that urban design and planning discipline needs to reduce its reliance on uncertain predictions and debate multiple visions for future urban form in response to this shifting technological context. In order to do this, we need to adapt and revise existing urban design and planning methods and tools as well.

This paper attempted to present some of the issues with current trends in automated futures visioning in order to build and argument for this. Subsequently a new methodological framework that tackles some of these issues was presented. With updated tools and methods, if we can obtain a better understanding of future transport flows and integrate it in the process of designing urban form, we can nudge it towards a more sustainable and liveable city.

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