Connected & Automated Urban Mobility, Zombie Cars and Kitchen Knives

Will Autonomous Automobiles, Self-Driving Car-Sharing and Ride-Hailing, and Driverless Shuttles harm Cities?

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Topic: Technology, infrastructure and buildings
Synopsis: The paper presents a survey of surveyed experts’ assumptions of how three different emerging automated mobility technical-organizational solutions: Autonomous Automobiles, Self-Driving Car-Sharing and Ride-Hailing, and Driverless Shuttles relate to the metropolitan structures of both cities and suburban areas.
Keywords: Automated Mobility, Autonomous Vehicles, Driverless Vehicles, Self-Driving Cars, Connected and Automated Driving.

1 Introduction
The paper focuses on the particular relation between mobility automation and spatial structures. It is based on the notion that municipalities will ignore absorption strategies, therefore will not be well prepared for the revolutionary technological diffusion of fully-automated vehicles. This notion is based on historical evidence of personal mobility and current research related to each of the solutions in the metropolitan area, which are briefly reviewed below. Due to the current emergence of mobility automation, there is a deficiency of supportive evidence to verify the thesis that cities are prepared for mobility revolution which already began and will advance exponentially. Furthermore, present analyses mostly emphasize how emerging mobility solutions will alter transport efficiency or affect mass transit usage, rather than their impact on urban morphology, metropolitan society, or local communities. The mobility automation will have different results depending on the morphology of metropolises, their urban core, suburban sprawl or functional hinterland. Therefore, the author surveyed globally 36 highly skilled experts, conducting two-round Delphi studies based on scenarios from his previous research. The survey consisted of 35 research questions (statements/theses) which all but one concerned a probability of the medium-term 5-15-year future regarding mobility automation. The result presents the experts’ assumptions how three diverse emerging automated mobility technical-organizational solutions relate to the metropolitan structures (economic, physical, social), including both cities and suburban areas. These solutions, based on the author’s previous research are: the Autonomous Automobiles, the Self-Driving Car-Sharing and Ride-Hailing, and the Driverless Shuttles. The assumptions of benefits and disadvantages emerging from each spatial-technical relationship - the usability and ability to harm cities caused by ubiquitous automated mobility – are compared to the ubiquitous kitchen knives. The study results should be used to create or modify legislation and municipal policy to avoid future side effects and to endorse the optimal effects from implementing these new transportation technologies.

2 Literature Review
In general, the following study deals with the complex problem of technological diffusion. Technologies are being implemented to solve particular problems, although they are followed by unforeseen or ignored side effects which emerge throughout technological adoption
(Smolnicki, 2015). This research focuses on detection of possible negative consequences in regard to urban spatial structures and assumed scenarios. The technology itself cannot be discussed without understanding the context of inter alia social (Castells, 2012: 228) and economical (e.g.: Maas et al., 2009: 116) structures. Since time immemorial urban social-economical-spatial structures were under significant impact of technological development, while determining diffusion of technologies (Mumford, 1961; Benevolo, 1995; Mumford, 2010). In this regard, two major opposite theories exist: technological determinism and social construction of technology.

The presented research concerns relations between mobility automation and metropolitan spatial structures recently carried out by numerous researchers and writers in various contexts (Sullivan, 2015: 201; O'Toole, 2016; Wayner, 2015: 564; Bridges, 2015: 3155; Wadud, 2016: 2; Heinrichs and Cyganski, 2015; Klein, 2014; Morris, 2015; Harris, 2016; Mui and Carroll, 2013: 323; Greenblatt and Shaheen, 2015; Brunner, 2015). Connected and Automated Driving (CAD) is widely considered a revolutionary and disruptive change in mobility, as well as in human life and spatial development. The author previously diagrammed fully automated mobility against the background of existing urban modes of transport and derived a typology of four distinctive modes of fully automated travel (Smolnicki and Soltys, 2016b: 2186) which follows the use of three vehicle types: (1) Autonomous Automobiles, (2) Self-driving Shared (Car-sharing) and Hailed (Ride-hailing) Cars, and (3) Driverless Shuttles. The author also assumed various scenarios of the impact of each fully-automated mode of transport on metropolitan (urban and suburban) spatial structures (Smolnicki and Soltys, 2016b: 2188). Distinction between regular vehicles from “pod” like vehicles and between evolutionary and revolutionary approaches to vehicle automation were simultaneously proposed by Nordhoff, van Arem and Happee (2016: 64). Although, it is not possible to predict the exact future of new solutions universal laws can be still applied and extrapolated from historical trends or estimated using analogies to credible historical and contemporary examples. There is not enough space to explain all of them but this section of the paper presents a brief scrutiny of the knowledge on which the research part is based.

Yacov Zahavi formulated a model which described that “travelers attempt to maximize their utility of spatial and economic opportunities, represented by the total daily travel distance, subject to constraints of time and money budgets” (1979). He assumed that a household “must choose a certain combination of modes to maximize its total spatial and economic opportunities, as represented by the total travel distance” (Zahavi, 1979: ii–iii). A conclusion of this theory is that the faster people travel does not mean they save more time, but rather consume more space. Basing on Zahavi’s assumption that average everyday travel takes one hour, Cesare Marchetti conducted research on the historical evidence on a time span ranging through ages until automotive revolution. The results show that city scope depends on the mode of transport, including walking (1994: 77). Therefore, various consequences may occur according to this theory which could be applied to emerging mobility solutions. For example, fully-automated vehicles are not engaging riders, therefore people who prefer working or relaxing, instead of “wasting” time driving, can switch to autonomous automobiles (Wadud, 2016: 2; Wayner, 2015: 1095; Sullivan, 2015: 201). There are numerous examples of significant impacts which the conventional automobile had on spatial structures (Lefebvre, 2009: 237; Mumford, 1961: 430, 461, 503-510, 549-550; Wallis, 1987; Kunstler, 2013; Montgomery, 2013; Speck, 2013; Marohn Jr., 2014; Wolfe, 2013). A typical household can spend 11-15% of its money budget on travel (after Ausubel et al., 1998: 141). The question is how to anticipate the consequences when fully-automated self-driving “taxis” (ride-hailing), shared cars, and driverless public transit emerge. Perhaps longer distances traveled will result, rather than the household gathering savings, and only the time-budget will stay constant. Already, car-sharing fleets have expanded to suburban areas (Shaheen and Cohen, 2013: 6). In order to prevent negative consequences, the author proposed adaptive road pricing and gamification dependent on direction traveled (Smolnicki, 2017: 214–215).
Urban policy and especially spatial planning determine the implementation of a specific type of automobile as much as an automobile impacts the physical development. For example, flat owners who do not own a car pay construction costs of garage parking of their neighbors (Shoup, 2011a: 562), therefore they may be incentivized to buy a car in order to be treated equally to the motorized neighbors. The solution might be a new paradigm of Mobility Oriented Development which shifts investors from being only building companies (real estate developers) to being also mobility service companies (or MODs), thereby providing minimum parking required for a shared mobility service (Smolnicki, 2017: 215–217). This solution could work, for example for both Self-driving Car-sharing and Driverless Shuttles dropping people to the nearest transit network. Although vehicle full-automation combined with ride-hailing and car sharing could significantly reduce the need of parking (Fagnant and Kockelman, 2015: 174) the need of parking policy changes by municipalities would become even more urgent.

The transportation infrastructure generates high costs of construction and maintenance as well as indirect costs, such as diabetics, obesity, asthma, car-related injuries (Speck, 2013: 531), mobility costs, insurance (Schwartz, 2015: 1747) food and goods transport and storage (Frey and Yaneske, 2007: 86–87) and parking (Shoup, 2011b: 615). Moreover, the infrastructure is not used efficiently because capacity is designed for peak hours, and the same is true for roads and parking. The more infrastructure is built, the more it is used, therefore congestion reappears, especially on minor previously quiet roads. It reflects the theory of induced demand or Jevons' paradox of efficiency (Jevons, 1866: 124–125), also known as rebound effect - in transportation related theories were, e.g. Downs-Thomson paradox (after: Zhang et al., 2016: 104–105) and Lewis-Mogridge law (Polimeni et al., 2008: 86-91, 145, 176-177 apply; Mogridge, 1990). Mobility automation enables more efficient use of infrastructure, which may result in both positive and negative results though, from reduction of necessary infrastructure to filling up the infrastructure with traffic and therefore provoking to build more.

Future personal and group mobility will be more shared reflecting the 'Mobility as a Service' (MaaS) paradigm (Smolnicki, 2017) whose name is credited to the Finnish engineer Sampo Hietanen (2014). Determined by various local conditions, it is estimated that one shared car can replace between four to as much us twenty-three cars (Badger, 2013: 184; Shaheen and Cohen, 2013: 9; Neckermann, 2015: 1640; Ceille, 2015: 5). However, in the medium term future car sharing will not replace privately owned cars but complement them (Bundesverband CarSharing e. V., 2015). Car sharing has also potential to reduce vehicle kilometres travelled (Shaheen and Cohen, 2013: 9). Various impacts may occur due to implementing fully-automated car-sharing depending on private-public participation (Smolnicki and Soltys, 2016a: 817). It is worth to mentioning that public transit can be endangered due to self-driving car-sharing (O'Toole, 2016). And the last but not least, fully automated mobility is considered as much safer and smarter than human driving, besides bringing other meaningful benefits (Fagnant and Kockelman, 2015: 174) like increased mobility of youths, elders and disabled. It may also impact the streetscape, e.g. narrowing road lanes and widening sidewalks (Glotz-Richter, 2017). The purpose of the research is to find correlation between experts’ assumptions on what is presented above and other plausible examples.

3 Methodology
The objective of the study was to forecast the most probable future of mobility automation in the urban context. For this purpose the Delphi method4 was chosen which is similar to experts' panels techniques but anonymized (experts do not know each other's answers) and to in-depth interviews with a quantitative approach whereby experts’ opinions can be quantified and used in multiple rounds. “Delphi uses a panel of experts and [...] seeks to arrive at a consensus on complex problems” (Davidson, 2013: 54). The Delphi technique
was used for production automation already in 1960's (as mentioned in: Helmer-Hirschberg, 1967).

The study is based on a modified e-Delphi method/technique using an online survey. At present, the Delphi technique is widely used for various purposes, especially where there is incomplete knowledge about a problem or phenomenon, therefore it may be used to develop forecasts (after: Skulmoski et al., 2007), “predicting the occurrence of future events” (Hsu and Sandford, 2007). Other methods are also used for forecasting: Visioning is dedicated to community oriented planning to develop a strategy to reach a final vision; Modelling estimates the future based on historical trends (Lemp et al., 2008); or Prediction Markets based on market price preferences (Green et al., 2007). The Delphi technique is intended to experiment with models rather than in reality, therefore it can be called a “pseudo experiment” (Helmer-Hirschberg, 1967: 6). The model results depend on the output interpretation of individual experts (Helmer-Hirschberg, 1967).

The experts for the research were chosen from the author’s professional network due to their expertise. For the purpose of a higher rate of responses, experts were informed that the survey would be anonymized. A “self-evaluation” process was conducted, due to the specific condition of the Delphi research: the need of higher expertise rather number of experts. More than 100 experts were contacted with 36 responding.

During the study some disadvantages emerged. A double negation confused experts and one of the research questions was modified during round two. Another disadvantage of the method is that the second round of questions could be understood as both the probability of the event happening in the future which was intended, or the probability that the responses of round one were right if misinterpreted, therefore producing disturbing results. Since the number of experts is less important than the quality of their expertise there is no need of surveying many, and it did not matter that only half of the experts took part in the second round due to lack of time and impatience of the experts. Responses in a probability scope of 40%-60% were not taking into consideration in the final results as some experts marked middle probability commenting they had chosen neutral responses and asked not to be considered. Last but not least, the understanding of language was a problem as the author’s professional expressions were interpreted differently by other professions. For example, the word “transit” used in the meaning of mass (public) transport, could be understood as inter-local or inter-regional traffic.

4 Research

The survey was conducted in two rounds taken August 8th-14th and 20th-26th 2017. The first section of the first round survey form was a covering letter and the experts’ self-evaluation of expertise. Only questions in this part were obligatory to answer, including email addresses and experts’ names. Invited Respondents self-evaluated their expertise in four categories: (1) Urban planning; (2) Transportation planning; (3) Connected and Automated Vehicles; and (4) Digital Services & Mobility as a Service (MaaS). It was facultative to provide a self-evaluation of additional expertise in an open-ended field. The self-evaluation was divided into five options: (1) Not applicable; (2) I am interested in this topic; (3) I am somehow connected with this topic; (4) I focus on this topic; (5) I am a well-known expert on this topic. For experts whose main expertise was not mentioned an open-ended field was provided.

The research part of the first round survey form was divided into four sections: (1) General theses; (2) Automated or autonomous automobiles; (3) Self-driving car-sharing and ride-hailing; (4) Driverless shuttles. The first round survey form included an open-ended field for Additional comments. The research part of the form contained 35 questions with the possibility to respond quantitatively (one research question was based on Likert’s scale of agreement and the rest on a probability scale) and qualitatively (the “Commentary” open-ended fields). The first research question stated a general thesis and responses could be provided on the agreement Likert’s scale (1-5) with the possibility of additional Commentary.
The rest of the subsequent theses/statements were about the future in 5-15 years, with explanatory clarifications. The experts were responding on a probability scale ranging from 1 to 10, where a “1” meant “Not probable (0-10%)” and a “10” meant “Very probable (90-100%)”.

Due to more or less diversified responses, a verification of experts’ previous responses was conducted to reach consensus. Each statement in the second round was modified by adding the probability assumed by a majority of experts during the first round. The second round statements were also modified according to suggestions in the previous round comments. During round two the experts verified their responses in regard to the majority of the experts’ responses from round one. If the expert did not agree with the majority of the experts’ responses, he was asked to justify his or her response in an open-ended field. Experts were also asked to skip any answers they were unsure of. Before responding to the research questions the experts were provided with important information about the survey, i.a.:

- The "Majority" is defined as between 51%-66% of the experts; the "Vast Majority" is defined as more than 66% of the experts.
- All statements concern the range of 5-15 years in the future.
- Statements are modified (with major modifications in brackets "[...]") for clarification purposes due to suggestions in first round Comments.
- In the 1-5 Agreement Scale: (1) means "I strongly disagree", (2) means "I disagree", (3) means "I neither agree or disagree", (4) means "I agree", and (5) means "I strongly agree".
- In the 1-10 Probability Scale: (1) means a 0-10% probability, (2) means a 10-20% probability, ..., (10) means a 90-100% probability.

In the final results a Majority and a Vast majority were defined more restrictively, accordingly 50-75% and 75-100%.

The following sections were presented:

General Theses. The topics of this section were mobility in general, connected and automated driving (CAD), Mobility as a Service (MaaS), Urban Planning and Transportation Planning.

Automated or autonomous automobiles. The topic of this section was described as follows: Automated or autonomous automobiles are conventional cars with systems of high-level automation. These vehicles are an evolutionary version of conventional cars. Already all significant automakers produce cars with some kind of automation, i.a. with advanced driving assistance systems (ADAS). The new released Tesla model 3 is already equipped with a computer which is allowed to carry out all driving control if the system is wirelessly updated, when legislation allows autonomous driving of the automobiles.

Self-driving car-sharing and ride-hailing. The topic of this section was described as follows: Self-driving car-sharing is when you can individually pick up a car from the street without driving it yourself. Self-driving ride-hailing is when a person orders a car such as a taxi which has no need of taxi-driver, and they don't drive the car themselves.

Driverless shuttles. The topic of this section was described as follows: A driverless shuttle is a fully automated group transit vehicle with a capacity of around 10 passengers. It may ride on a fixed route or on flexible on-demand routes. It may be operated similarly to an elevator or via e-hailing communication device application.
5 Results

Expertise. During both rounds 33 and 17 experts with various expertise responded in the survey describing their backgrounds. Experts are anonymized, therefore for the purpose of this paper the following summary of their expertise is presented:

- Academia professionals: assistant professors, adjunct professors, PhDs, center director, head of the mobility department,
- Business professionals: founder, CEO, business owner, entrepreneur, vehicle mobility entrepreneur,
- Transportation professionals: transportation engineers and planners, mobility planning consultants, smart mobility solutions and products integrated with urban policies and street design measures, sustainable mobility, urban transport expert, Public transport consultant, connected and automated vehicles, transportation industries,
- Urban and regional professionals: urban designer, urban and regional planners, urban and regional strategy and consultants, urban researcher, urban underground infrastructure, urban systems, also urban planner in transport industry, smart cities,
- Digital mobility services and CAD's: new mobility services, mobility service program manager, system engineer, theoretical and practical aspects of Mobility as a Service (MaaS), chief digital officer, autonomous driving, IoT,
- Policy: municipal and national government leads, legislation, regulation and policy researchers, policy officer, reviewer of EU projects on autonomous transport,
- Management: MBA, management consultants, strategic advisor, managing relationship with automated vehicles manufacturers, project manager, senior project manager, director,
- Emerging technologies: electric mobility journalist, futurist, trend-watcher, keynote speaker,
- The experts live and work on all continents.

Table 1 presents the number of experts with different levels of familiarity in each topic of expertise. The purpose was to justify the experts' invitation by the author, as well as to compare experts' responses with different backgrounds. Comparison does not form part of the paper and further research is needed.

Expertise or High Expertise in the topic is considered when the respondent stated: I focus on this topic or I am a well-known expert in this topic (bolded in Table 1). According to the responses delivered 14 respondents (out of 33) have expertise or high expertise in Urban Planning (UP), 18 in Transportation Planning (TP), 19 in Connected and Automated Vehicles (CAVs), and 21 in Digital Services & Mobility as a Service (MaaS). As some considered themselves also as Somehow connected to topics, the following number of respondents are connected to each topic: 27 – UP, 28 – TP, 28 – CAVs, and 29 – MaaS. That means the vast majority of respondents consider themselves as being concerned with all topics. The self-evaluation was not repeated in round two due to limited experts' time, although some experts exchanged in round two.
In the open-ended field, experts added more professions and some self-evaluated themselves 1-5 in regard to Table 1: consulting (public administration, politics and companies in the four mentioned topics but not part of the decision making process), Non-motorized transportation (5), Public transport (5), Urban governance (3), Urban design (4), Parking management (4), Street design (5), Urban Underground Space Planning, Business, and Practitioner.

Table 2 presents a number of relations between each expertise and sector. This question was intended to compare responses between the following types of interests and professions.

<table>
<thead>
<tr>
<th>Not applicable</th>
<th>Interests (hobby)</th>
<th>Science &amp; Research (theory)</th>
<th>Design &amp; Manufacturing (applicative)</th>
<th>Public Administration (accords, opinions)</th>
<th>Political (self-governance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Planning (UP)</td>
<td>1</td>
<td>9</td>
<td>16</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Transport Planning (TP)</td>
<td>2</td>
<td>5</td>
<td>18</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Connected and Automated Vehicles (CAVs)</td>
<td>2</td>
<td>12</td>
<td>9</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>
Areas of agreement and disagreement. This section of the paper presents the final survey results. Due to some experts commenting about marking their neutral response in the middle, the probability scope 40-60% is not taken into account in the analysis as well as experts who skipped the response. A consensus is reached if a “Majority” (>50%) agrees that the future is “Very probable” (>80% probability) or “Very non-probable” (<20% probability), or if “Vast majority” of experts (>75%) agree the future is “Probable” (>60%) or “Non-probable” (<40%). If the “Majority” responded a probability scope of 60% “Rather probable” and “Rather non-probable” was added. The relation between the levels of agreement and the levels of probability are presented in Table 3. In specific cases of research questions the author decided to name the probability, due to a high level of agreement in other than proposed scopes of probability (no. 4, 8) or a low number of responses (no. 30, 32).

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of experts</th>
<th>Levels of probability</th>
<th>Probability name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Majority</td>
<td>50%-100%</td>
<td>80%-100%</td>
<td>Very probable</td>
</tr>
<tr>
<td></td>
<td>50%-75%</td>
<td>60%-100%</td>
<td>Rather probable</td>
</tr>
<tr>
<td>Vast Majority</td>
<td>75%-100%</td>
<td>other</td>
<td>Probable</td>
</tr>
<tr>
<td>other</td>
<td>other</td>
<td>other</td>
<td>Neither probable nor non-probable</td>
</tr>
<tr>
<td>Vast majority</td>
<td>75%-100%</td>
<td>0%-40%</td>
<td>Non-probable</td>
</tr>
<tr>
<td>Majority</td>
<td>50%-75%</td>
<td>0%-20%</td>
<td>Rather non-probable</td>
</tr>
<tr>
<td></td>
<td>50%-100%</td>
<td>Very non-probable</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Relation between levels of agreement and probability. Source: the author.

The first research statement was based on agreement scale 1-5, where 1 was defined as “Strongly disagree” and 5 was defined as “Strongly agree”. The vast majority of the experts agree that “mobility automation technology is like a kitchen knife - it is a useful utility but it may badly harm (cities) too.”

<table>
<thead>
<tr>
<th>Statement</th>
<th>Experts number</th>
<th>Level of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The mobility automation technology is like a kitchen knife - it is a useful utility but it may badly harm (cities) too.</td>
<td>15/17 (88.2%)</td>
<td>Agree</td>
</tr>
</tbody>
</table>

Table 4. Experts’ agreement with the research motto. Source: the author.

The rest of the research questions (statements/theses) are presented in Table 5. The consensus between the experts is mostly reached in a scope of 40% ranging from 60-100% probability. Although, the following research questions are the result of a consensus in the
narrower ranges: no. 4 with a 10% consensus scope; no. 8 with a 30% scope (with a 100% experts’ agreement); and no. 33 with a scope of 20%. Responses with a Vast Majority agreement are bolded, as well as Majority agreement in the narrower scopes of probability. The research question no. 6 is with neither consensus or tendency – half of the experts responded on both sides of the probability scale (0-40% and 60-100%). The experts disagree with the statement no. 13. The research questions no 30 and 32, due to the high number of experts responding in a range between 40-60%, were named as “Neither probable nor non-probable”.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Experts number</th>
<th>% span</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>General theses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2  Most cities will ignore connected and automated mobility in their spatial planning and strategies in the next 5-15 years.</td>
<td>12/17 (70.5%)</td>
<td>&gt;60%</td>
<td>Rather probable</td>
</tr>
<tr>
<td>3  The awareness of a novelty will be the biggest barrier for municipalities to implement the connected and automated mobility in their policy.</td>
<td>11/14 (78.6%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
<tr>
<td>4  The fully automated driving systems will be much safer than human drivers.</td>
<td>11/15 (73.3%)</td>
<td>&gt;90%</td>
<td>Very probable</td>
</tr>
<tr>
<td>5  The fully automated vehicles will move on separate lanes (not to mix with human drivers).</td>
<td>8/13 (61%)</td>
<td>&gt;60%</td>
<td>Rather probable</td>
</tr>
<tr>
<td>6  The big-scale infrastructure investments will be reduced due to higher efficiency of connected and automated mobility (no need of higher capacity infrastructure).</td>
<td>5/10 (50%)</td>
<td>-</td>
<td>Neither probable nor non-probable</td>
</tr>
<tr>
<td>7  The street lanes will be narrowed if automated driving systems will be safer than human drivers.</td>
<td>11/12 (91.7%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
<tr>
<td>8  The future everyday mobility, no matter the distance travelled, will be done mostly without ownership of any mode of transport with the use of communication devices and shared rides/vehicles (Mobility as a Service paradigm - MaaS).</td>
<td>13/13 (100%)</td>
<td>&gt;70%</td>
<td>Very probable</td>
</tr>
<tr>
<td>9  The private and public mobility companies will cooperate and collaborate to induce Mobility as a Service paradigm.</td>
<td>12/14 (85.7%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
<tr>
<td>10 The connected and automated mobility could increase traffic due to the higher efficiency of road use.</td>
<td>16/16 (100%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
<tr>
<td>11 The individual rides along transit lines will be regulated (i.a. limited, fined).</td>
<td>9/12 (75%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
<tr>
<td>12 The ubiquitous automated mobility will increase obesity even more than conventional cars did.</td>
<td>10/14 (71.4%)</td>
<td>&gt;60%</td>
<td>Probable</td>
</tr>
</tbody>
</table>
### Statement

<table>
<thead>
<tr>
<th>Experts number</th>
<th>% span</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>13  The ubiquitous automated mobility will jeopardize local retail shops and a streetscape even more than conventional cars did.</td>
<td>10/13 (76.9%)</td>
<td>&lt;40%</td>
</tr>
</tbody>
</table>

#### Automated or autonomous automobiles

<table>
<thead>
<tr>
<th>Experts number</th>
<th>% span</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>14  Traffic congestion will increase due to empty rides (zombie cars).</td>
<td>8/12 (66.7%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>15  The average number of passengers per car will decrease below 1.1 due to empty courses (zombie cars).</td>
<td>8/13 (61.5%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>16  The owners will prefer to leave an automated car cruising around, if not regulated, instead of paying for parking, if more expensive.</td>
<td>14/15 (93.3%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>17  The empty courses (zombie cars) will be regulated (i.a. limited, charged).</td>
<td>12/13 (92%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>18  The people will relocate and travel further distances due to more comfortable automated rides (i.e. no need of driving in traffic congestion), therefore cities will expand (urban sprawl, suburbs).</td>
<td>15/16 (93.8%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>19  In regard to the policy, the vehicle miles travelled will be charged, especially during peak hours on lanes with high demand.</td>
<td>10/12 (83.3%)</td>
<td>&gt;60%</td>
</tr>
</tbody>
</table>

#### Self-driving car-sharing and ride-hailing

<table>
<thead>
<tr>
<th>Experts number</th>
<th>% span</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>20  Unregulated traffic congestion will increase due to higher vehicle miles travelled, since shared and hailed cars will be on the move, rather than parking (although vehicles and parking will be used more efficiently).</td>
<td>11/14 (78.6%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>21  Pick up and drop off zones will be created from curb parking, therefore there will be less parking, although sharing vehicles will reduce the need for 8-hrs parking places.</td>
<td>14/14 (100%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>22  Traffic congestion will increase due to complementary use of shared cars and individually owned cars (owners will not give up their cars).</td>
<td>10/11 (90.9%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>23  If not regulated e.g. in spatial planning, people with limited income will relocate to edge towns because of lower living costs, rather than the city center, and due to the availability of car-sharing or ride-hailing to the transit network, their commute time will be longer but they could relax or work during a ride.</td>
<td>11/12 (91.7%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>Statement</td>
<td>Experts number</td>
<td>% span</td>
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<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>24 The city centers will be gentrified because people will relocate due to i.a. possibility of lifestyle change without owning a car in the city center (&quot;creative class&quot;, &quot;millennials&quot;), or lower living costs of families with limited incomes after relocating to suburbs and self-driving car-sharing/ride-hailing to the transit network.</td>
<td>8/12 (66.7%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>25 If parking standards and spatial regulations allow, self-driving car-sharing and ride-hailing will reduce housing development costs, due to no need of building underground garage parking, or it will increase profits if used for other purposes.</td>
<td>13/14 (92.9%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>26 Investors who build, own or operate large real estate developments will use their own car-sharing and ride-hailing fleets to reduce construction costs (such as garage parking) and increase profits due to bigger development area due to reduction of parking area.</td>
<td>10/14 (71.4%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>27 Cities will conduct private-public-participation to subsidize car sharing and ride hailing on the first/last mile gap to support public transit.</td>
<td>13/15 (86.7%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>28 Cities will invest in a low capacity shared automated mobility to reduce the negative effects of individually owned vehicles, although taking in consideration sustaining mass transit.</td>
<td>16/16 (100%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>29 If municipal/urban policies will ease and enable private car-sharing and ride-hailing companies they will cooperate and collaborate with public transit organizers.</td>
<td>14/16 (87.5%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td><strong>Driverless shuttles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 The shopping malls or online shopping will jeopardize local retail shops due to offering free and advertised rides to/from shopping, or free delivery, if local retail shops will not collaborate to do the same.</td>
<td>5/8 (62.5%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>31 For cities with a rare transit network, the housing density within a 1.5 mile proximity to the public transit stops will increase due to a better accessibility provided by the driverless shuttles.</td>
<td>11/12 (91.7%)</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>32 The first/last mile gap driverless shuttle services will be free of charge, if ticketing will be integrated to support transit, if used in multi-modal trip, e.g. driverless shuttle plus train or bus, or complementing Park-and-Ride hubs.</td>
<td>5/8 (62.5%)</td>
<td>&gt;60%</td>
</tr>
</tbody>
</table>
Statement | Experts number | % span | Probability
---|---|---|---
33 Driverless shuttles will increase mobility of disabled and seniors and all other people without driving license, e.g. youths. | 10/16 (62.5%) | >80% | Very probable
 | 15/16 (93.8%) | >60% |
34 Driverless shuttles will be allowed to ride in no-car zones, e.g. bus lanes or some segments of pedestrian and bicycle zones for shortcuts and for picking-up/dropping-off passengers. | 12/13 (92.3%) | >60% | Probable
35 It will be prohibited for pedestrians to disrupt the movement of a driverless shuttle, to avoid its safety stopping. | 9/10 (90%) | >60% | Probable

Table 5. Probability assumed by the experts. Neutral responses of a 40-60% probability are excluded. Source: the author.

6 Discussion

The vast majority of the experts agree with a very probable 5-15 years future with fully automated driving systems which will be much safer than human driving. Moreover, they agree on a very probable future of everyday mobility which will occur mostly without ownership of any mode of transport, with the use of digital communication devices and shared rides and vehicles. This reflects another very probable future, according to the majority of experts, that driverless shuttles will increase mobility of the disabled, seniors, youths and all other people without a driving license or a self-owned car. The research results summarized below are presented in regard to the following aspects of automated mobility: policy, traffic and development.

Policy. Cities could ignore emerging mobility i.a. due to the awareness of a novelty. Although, if autonomous automobiles become ubiquitous municipalities will regulate (i.a. limit or charge) empty rides, vehicle miles travelled (especially during peak hours) or rides along public transit lanes. However, driverless shuttles could be used to support the first/last mile public transit accessibility, in specific conditions also in pedestrian oriented zones. Dedicated lanes could be used for automated vehicles, for example thanks to narrowing street lanes due to the higher safety of connected and automated driving. Moreover, automated mobility services pick up and drop off zones will be created from curb parking, therefore reducing the possibility of self-owned cars 8-hours parking.

Traffic. It is possible that connected and automated driving will increase traffic due to, i.a.: the higher efficiency of road use (vehicles connected to vehicles or to infrastructure), higher vehicle miles travelled (shared cars), complementary use of shared and self-owned vehicles, or empty rides of automated vehicles. Zombie cars will emerge due to both ride-hailing mobility services and self-owned automobiles cruising when there is no parking or it is more expensive to park. Due to both zombie cars as well as switching public transit users to the automated mobility services, the average number of passengers per vehicles will decrease. Therefore, municipalities will conduct private-public participation to support public transit collaborating with private car-sharing and ride-hailing companies, for example by subsidizing the first/last mile gap. Although, cities will also invest in their own low-capacity automated and shared mobility to reduce the negative impacts of private vehicles, as well as to sustain mass public transit. It is very probable that the future everyday mobility will be done mostly without ownership, therefore private and public mobility companies will collaborate and cooperate.
Development. Cities will expand due to citizens’ relocation when connected and automated driving increases everyday travel, therefore gentrification could emerge in city centers. It is due to lower income citizens relocating to cheaper suburban areas and (in general well educated) “creative class” and “millennials” relocating to city centers i.a. due to ubiquitous easy access without car ownership (self-driving car-sharing and ride-hailing). Therefore, higher housing intensity could emerge in the 1.5 mile proximity to the public transit network when self-driving car and driverless shuttle “first/last mile” services are provided. Moreover, if parking standards and regulations allow, development costs will be reduced due to less need of surface, garage and underground parking construction. It will also free new development areas. These possibilities will depend on spatial regulations as well as the districts' accessibility to the automated mobility services, for example offering the firsl/last mile access to a public transit network.

Unknown. According to the experts’ opinions, it is unknown if big-scale infrastructure investments will be reduced due to higher efficiency of connected and automated mobility. Perhaps, a rebound effect of induced demand will emerge, although it is dependent on smart policy, including governmental subsidiaries, which determine investments even if they are not necessary. It is also unknown if free and advertised private vehicles used for shopping malls or internet shopping will jeopardize local retail shops. Some experts commented that although shopping malls are already “dead” local retail shops can do the same, as they are attractive to other kinds of clients than on-line shoppers.

7 Conclusions
A vast majority of the survey results confirms assumptions presented as the research questions (theses/statements). Assumed impacts on metropolitan spatial structures could be both positive and negative, depending on legal aspects and municipal policy environment. In general, mobility automation is an important tool, although it may be used tragically the way it is reflected in the study motto: “The mobility automation technology is like a kitchen knife - it is a useful utility but it may badly harm (cities) too”. The future mobility in 5-15 years will be much safer and more accessible for the people who cannot drive themselves or do not own a car, following the Mobility as a Service (MaaS) paradigm (no need of vehicle ownership). Under an upright policy the development costs will be reduced, mass public transit will be supported, therefore affordable urban housing will grow. However, if regulations will be depraved, the ubiquitous automated mobility will lead to numerous side effects, i.a. growth of traffic congestion, obesity, urban sprawl, or reduced mass public transit use. Good or bad impacts depends not on personal choices but on smart regulations and education. Responsibility should be taken by both the municipalities and the national and regional states.

Research usability. The study results should be used to create new or, to modify existing legislation and municipal policy to avoid future adverse side effects and to approach the optimal effects from implementing these new transportation technologies. In particular, the results should be used by municipalities (town and transportation planners) for better diffusion of automated mobility preparation through information technology.

Further research. Further research is needed. Comparison of responses between groups of experts with different backgrounds will show potential future misunderstandings which could determine possibilities. The second research proposal is to conduct an open survey to check general opinion and compare it with experts’ responses. Moreover, the ideas provided in the open-ended fields could be used to extend the scope of research questions. Furthermore, future case studies will be necessary to validate each of the assumed relations.

Acknowledgements. This study would not be the same without the help of few associates and colleagues. Professor Elżbieta Wojnicka-Sycz, an expert in foresight research technically supervised the survey. Matthew Henderson provided proofreading of the form and Mrs. Judith Ryser of subediting the paper. Krzysztof Stachura, Michał Jaśkiewicz and Łukasz Smolnicki, Piotr Marek
Bugalski were sharing their thoughts and helpful comments. Although these colleagues and peers helped to refine my argument, the ideas herein along with their deficiencies are my responsibility. Last but not least, I thank all experts for their precious time. Their input was a valuable addition to this study and to the general research.

**About the general research.** This study results from the author’s four-year research at the Gdansk University of Technology, the topic of which emerged as a result of the author’s early essay (2014) written for the PhD course subject of Professor Małgorzata Dymnicka. After that the essay was turned into a scholarly paper “The influence of modern technologies on spatial structures” (Smolnicki, 2015). As a result, the author focused on the gap between transportation and urban planning and devised a PhD Course about the “Relations Between Emerging Mobility Solutions and Metropolitan Spatial Structures”.

8 References

**Publications**


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Web pages


**Presentations**


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i “Kitchen knives” comparison was proposed by the author during the Civitas conference session after his presentation (Smolnicki, 2016).

ii Delphi method was developed in 1950’s at the RAND Corporation (Dalkey and Helmer-Hirschberg, 1962: 11).

iii Various labels appear in literature, such as method or technique as well as other modifications (after: Davidson, 2013: 54).

iv The Delphi method is used in the author’s PhD dissertation – as it was done by many others before that (after: Skulmoski et al., 2007).

v “The Delphi method is an iterative process to collect and distil the anonymous judgements of experts using a series of data collection and analysis techniques interspersed with feedback” (Skulmoski et al., 2007). The goal in the Delphi method is to reach a consensus among experts, which needs subsequent rounds of surveying (Hsu and Sandford, 2007) until achieving 70-80% rate of consensus (Hsu and Sandford, 2007). If there are diverse opinions a single combined position should be derived (Helmer-Hirschberg, 1967: 4–5). There are various numbers of experts proposed in literature but the majority of the studies have between 15 and 20 experts (Hsu and Sandford, 2007) but critical component of the research is the selection of the experts with knowledge and experience corresponding to the research topic, as well as their willingness and sufficient time to participate and, of course, communication skills (Skulmoski et al., 2007).

vi The anonymity of experts helps to avoid issues of modifying or changing opinions due to relating to other experts (Davidson, 2013: 55).