25TH HOUR FLOW

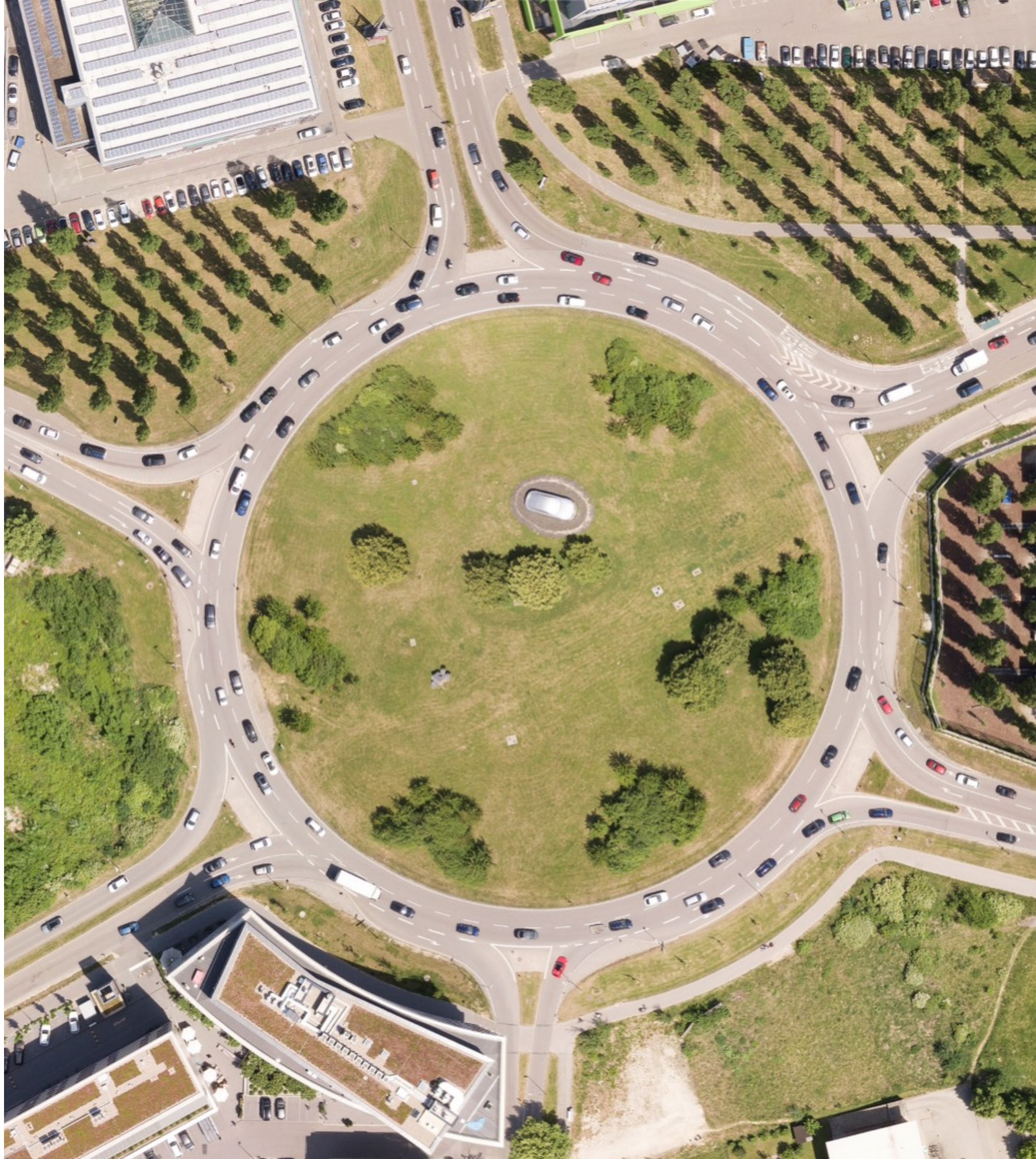
SUMMARY

How much time will we save in a city with autonomous cars, ride sharing and smart traffic management? Answers are given by the Audi study "25th Hour – Flow". Partnering with the traffic experts at the Karlsruhe Institute for Technology (KIT) and the Munich consultancy MobilityPartners, the research simulated the future of mobility in Ingolstadt/Germany. According to the study, a lasting reduction in travel times can be achieved on a typical commute: in fully automated traffic by one third, even though over ten percent more people are on the road. The prerequisite is that the trend towards sharing takes hold.

Fleets of self-driving cars will help to solve traffic problems in cities in the long term. These benefits become even more apparent when coupled with smarter traffic management and a higher occupancy rate, i.e. increasing the average number of persons per car. If this figure rises in a balanced scenario moderately from 1.1 to 1.3 persons, because more people share a car, there is no more congestion during rush hour. In a fully automated, networked traffic system, more people (+12%) can be transported much more quickly (-33%) in commuter traffic (see animation).

Connected, automated and shared vehicles also provide cities with new opportunities to use and reallocate space to improve urban quality of life. For example, the study found that the incorporation of fully autonomous vehicles could repurpose one traffic lane in a four-lane network and dedicate this new space to pedestrians or bicycles instead of vehicles. The study takes into account that, with an increasing number of autonomous cars, more senior citizens and children without a driver's license have access to mobility, and convenient robo-taxis will compete with local public transportation.

"The results suggest that autonomous cars, mobility services, and networked infrastructure can significantly reduce congestion and road space. At the same time, more young and old people can travel safely and conveniently. In this way, the quality of life in cities will be improved dramatically. These findings encourage us to continue working for the future: with self-driving cars such as the Audi Aicon, services like Audi on demand, or networked technology such as Audi traffic-light information," says Melanie Goldmann, head of Trend Communication at Audi.



MOTIVATION

"Automobile concepts and services are being developed today – but will have to blend smartly and efficiently with developing mobility systems in the future."

Strategic Relevance

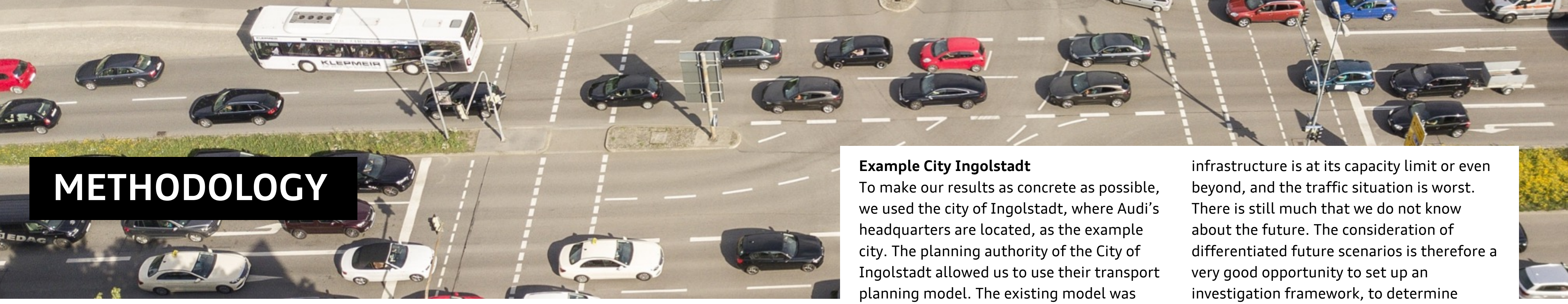
"Autonomous vehicles (AVs) are changing our traffic systems and cities. This is an age of disruptive changes, artificial intelligence, great quantities of data and sensors, when smart infrastructure and high-performance computers outline new perspectives for efficient future urban mobility solutions. And AVs are appearing at the right time to take traffic management to a new level. But what does that mean for Audi?
How do we manage traffic in the changing mobility ecosystems of the future? And, to be more concrete, how many AVs are needed to make the traffic flow noticeably better? What role is played here by the networking of cars with traffic infrastructure, for example with traffic lights? Apart from a quantum leap in terms of road safety, is it really true that we will get more bike paths, parks or playgrounds when self-driving cars navigate with high efficiency – and thus see a truly sustainable ecosystem? And how do people have to use these cars to make the dream come true of a city that puts the focus on people, not on the car? In a nutshell: What's in it for all of us?
For Audi's strategists and designers, the answers to such questions are highly relevant. Because automobile concepts and services are being developed today – but will have to blend smartly and efficiently with developing mobility systems in the future."

Melanie Goldmann, head of Trend Communication at Audi

Scientific Relevance

"We might all agree that automated and driverless cars will change mobility. There will be technical impacts such as higher road capacities, but most probably our mobility behavior will be affected as well. Using cars will be more comfortable and convenient, thus shifting decisions between transport modes towards cars. People will use cars who are currently not able to drive themselves, especially the younger and the elderly. Looking into the future, some more trends and developments which are not caused by automation can be realized, for example the increasing willingness of travelers to share vehicles or trips. The effects of all these developments will contribute to the shape of tomorrows mobility.
The effects of connected and automated vehicles and of other technical and societal developments are continuously studied in the transportation research community. In most cases, the studies focus on single aspects of these developments in order to better identify the isolated effect of exactly that aspect alone.
Our objective was different: We wanted to draw a picture of what mobility will look like when all these effects come together."

Peter Vortisch, professor at the Karlsruhe Institute for Technology (KIT), head of the Institute for Transport Studies



METHODOLOGY

The method we adopted consisted of three steps. First, we collected as many studies on single effects as were available. For some effects, the studies showed a pretty consistent picture; for others diverging results had been found. In that case we had to decide what to take as the most probable outcome.
The second step was to build scenarios. Each scenario is defined by a consistent set of assumptions on how the different developments in technology and society will evolve. Within all scenarios we varied the proportion of driverless cars from 20 to 100 percent, because we especially wanted to see the impact of driverless cars in these different future scenarios.
The objective of the final step was to quantitatively assess the effects on our daily mobility experience. Will congestion increase or decrease? Will commuting time go up or down? And will these effects help to free valuable urban space which today is devoted to major arterials. The tool for answering such questions is a transport planning model.
In these models the travel demand, i.e. all the wishes of the population to move from one place in the city to another, meets the transport supply, i.e. all the transport infrastructure such as public transport and the road network with their limited capacities.
The single effects identified in the collected studies can be modelled into such a transport planning model by e.g. modifying road capacities or increasing or decreasing travel demand. Road capacity, for example, could be increased by smaller distances between AVs or smarter and more efficient junction control. Demand, on the other hand, would be affected by willingness to share a ride or the question of whether people will still drive to the supermarket when efficient delivery services prevail.
The outcome of the transport planning model is the traffic situation on the road network of a city, including traffic volumes and speeds on every individual road link. From that we can compute travel times and especially delays for all origin-destination pairs.

Example City Ingolstadt
To make our results as concrete as possible, we used the city of Ingolstadt, where Audi's headquarters are located, as the example city. The planning authority of the City of Ingolstadt allowed us to use their transport planning model. The existing model was implemented using the modelling software system PTV VISUM and replicated the average daily traffic of a normal workday. While looking at the average daily traffic can be sufficient for long-term infrastructure planning, it does not reflect a traffic situation that actually exists at any time of the day. Therefore, we recalibrated the model to reflect the traffic situation in the morning peak hour. To do this, we first adapted road capacities from daily capacities to hourly values. On the demand side, we used the temporal patterns of residents' activities to extract only travel demand in the peak hour. Finally, we applied a tool (TFlowFuzzy in PTV VISUM) to calibrate the traffic volumes computed by the model to the real traffic volumes measured in the peak hour provided by the city's planning department. The goodness of fit we reached for the peak-hour model was comparable to the quality of the daily traffic model used in transport planning by the city.
The study was conducted for a time of day when the most people are on the streets, the infrastructure is at its capacity limit or even beyond, and the traffic situation is worst. There is still much that we do not know about the future. The consideration of differentiated future scenarios is therefore a very good opportunity to set up an investigation framework, to determine which boundary conditions can lead to which effects in the future.
These scenarios differ in their assumptions about the mobility behavior of the population. How attractive is ride-sharing, what is the usage of new delivery concepts? Additionally, it can be assumed that we can achieve mobility for new user groups (elderly, kids etc.).
All the scenarios were tested for different proportions of AVs (20 to 100%) and different assumptions about technological developments in infrastructure and traffic management.
At the beginning of increased automation in traffic we assume that the impact of automated vehicles will slightly reduce the road capacity. Human drivers are somehow efficient, because they don't follow all the rules. In contrast, AVs must follow all the rules. This leads to an increase in traffic safety but also to a decreased road capacity in the initially mixed traffic. For example, AVs keep the legally prescribed minimum distances.

PARAMETERS

For the simulation model several assumptions for the input parameters had to be made. Here we explain the different input parameters and their possible values.

PERSONS PER VEHICLE

This parameter shows the average occupancy rate in persons per vehicle. The typical occupancy rate in German cities during the peak hour amounts to **1.1** persons per vehicle. Within the different scenarios in this study, the average occupancy rate is varied between **0.9** ("Delivery") and **1.7** ("Shared Value") persons per vehicle.[3, 11, 12, 13]

INNOVATIONS IN TRAFFIC MANAGEMENT

This parameter represents the realized potential for innovation in traffic management and control and its effects on the capacity of the road network. The maximum potential of a **27 percent** increase in supply ("Revolutionary") can be achieved in a completely automated transport system (100% AV-share). It incorporates effects like omitting intergreen times at urban traffic signals, dynamic lane allocation in peak hours, advanced freeway control systems, and reduced amount of traffic due to search for parking spaces, but also infrastructural effects like the replacement of parking spots by drop-off zones. The medium potential amounts to **10 percent** ("Ambitious"). Today, the overall time loss of all vehicles in the network during peak hour amounts for 2.500 hours.[2, 4, 5, 6, 8]

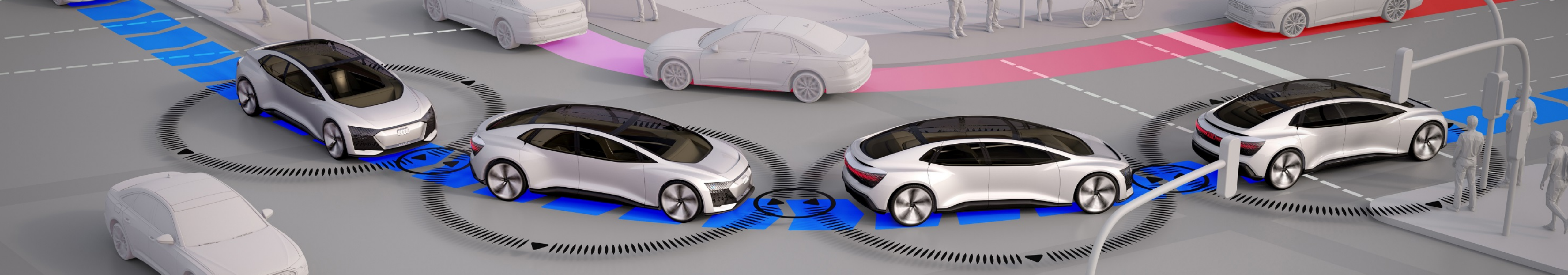
DISTANCE TRAVELLED PER PERSON

This parameter symbolizes the possible changes in demand in the various future scenarios. These changes could result in either an increase or a decrease depending on the different scenario definitions. Several studies state a possible increase in future demand in the upcoming years by between **10** and **20 percent** due to various demographic and societal effects.

On the other hand, current trends like increasing grocery delivery or teleworking have the potential to decrease demand by around **15 percent**. Therefore the possible spectrum for this parameter was defined to range from a possible decrease in demand of **15 percent** ("Less") or no changes to the current situation ("Equal") to a potential average increase of **15 percent** in demand ("More"). The effect of an increase of the commuting distance and therefore the mean travelled distance due to a more comfortable ride in AVs does not have an impact on the peak-hour traffic in the inner city of Ingolstadt.[3, 5, 7, 10, 11, 12, 13]

AV-SHARE

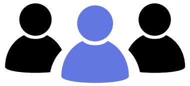
In the future, with an increasing proportion of AVs on our roads, traffic will benefit overall from a more harmonized manner of driving. According to various studies this effect together with the realization of shorter headways between AVs, can lead to a higher capacity of roads and intersections of up to **40 percent**. However, with only a few AVs on the road, some studies found that the initial mixed traffic with human drivers results in a slight reduction in the performance of the overall system. Even though human drivers do not always adhere all the rules, according to previous simulations they are able to increase the efficiency of a dense traffic network (partly at the expense of road safety). AVs, on the other hand, adhere to all traffic regulations, such as the minimum distances prescribed by law. Another factor has been considered by the study: AVs are very convenient, because the passengers can spend time in the car usefully: working, enjoying time with family and friends or simply relaxing. This could increase demand. A further aspect is that, with an increasing number of autonomous cars, more senior citizens and children without a driver's license will be on the move. However, most of the people, who cannot drive today but will be enabled with AVs would not necessarily travel in the peak hour. For that reason, the maximum additional demand realized by this group was set to **10 percent**.[1, 4, 5, 6, 7, 8, 9, 10]



PERFORMANCE INDICATORS

Amongst others, the following performance parameters were used to describe the system-wide traffic efficiency for each scenario.

TRAVELERS IN THE SYSTEM

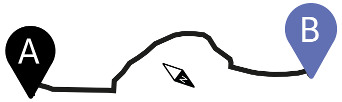


Relative changes in the total number of persons travelling simultaneously in the whole simulated traffic network.
Unit: [persons]

TIME LOSS

The quantitative value of time loss is defined as the amount of time lost due to congestion, dense traffic conditions, additional waiting times at traffic lights etc. Here the time loss represents the percentage of lost time as a share of the total time spent in the network during peak hour.
Unit: [%]

TRAVEL TIME



Relative change in the average travel time compared to the current situation on the example route between the main train station in Ingolstadt and the Audi headquarters. The values relate to the morning peak hour.
Unit: [%]

INGOLSTADT *("the lab")*

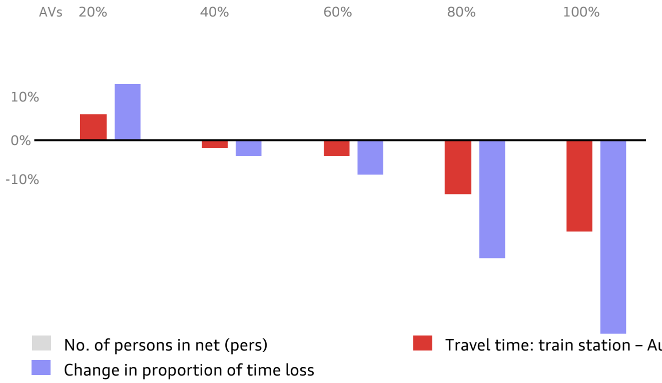
With its approximately 140,000 residents, Ingolstadt, Audi's base, is well suited as a "laboratory" for traffic flow on the roads, as traffic here has four wheels: for historical reasons there are many automobiles and buses here, but no subway or trams. These conditions are a framework that applies to many medium-sized cities in different countries. In the official simulation model for transport planning in Ingolstadt, the researchers computed several scenarios of possible outcomes for future mobility.

SCENARIO 0

STATUS QUO

The “Status Quo” scenario with zero percent AVs reflects the morning rush-hour travel times in Ingolstadt today.
On the one hand, this setup was used to compare all results from the other scenarios. On the other hand, this was the perfect setup for investigating one parameter in isolation, without taking account of changes in user behavior or increased demand: how many self-driving cars would be needed today to make the traffic flow noticeably better? At least **40 percent**! Computers do not tailgate other vehicles, drive too fast, or make dangerous lane changes. Previous research shows that this style of driving in compliance with the rules is more a disadvantage than a benefit in today’s mixed traffic. Journey times are noticeably cut only with an increasing number of autonomous cars. If the roads in Ingolstadt today were used only by robot taxis, travel times would fall by one quarter, while the factor “time lost” in traffic is cut into half **(-51%)**.

KEY FINDING



After a small drop AVs improve the traffic flow

Although at the beginning the effects on traffic efficiency are slightly negative, AVs continue to in-crease the network performance and reduce the time losses significantly by more than **50%**.

PARAMETERS

PERSONS PER VEHICLE

1.1

DISTANCE TRAVELLED PER PERSON

EQUAL

INNOVATIONS IN TRAFFIC MANAGEMENT

NONE

RESULTS

AV SHARE, in %	now	20	40	60	80	100
TRAVEL TIME	24 min	+7%	-2%	-4%	-14%	-24%
TIME LOSS, all vehicles in network	2,500 h	+15%	-4%	-9%	-31%	-51%
TRAVELERS IN THE SYSTEM	59,500	0%	0%	0%	0%	0%

SCENARIO 1

BALANCE

A model in which everyone benefits is a balanced system. In this “Balance” scenario, cities should digitalize their infrastructure – but do not suddenly have to replace traffic lights by virtual signal devices. They can integrate AVs into the traffic mix cautiously – radical approaches are not necessary. People can decide for themselves whether they prefer to book a people mover with 6 seats and more or a premium-mobile like, for example, the autonomous Audi Aicon. Whether they would rather live with a long journey to work in an AV, or take a bicycle or bus. When the number of passengers per car rises moderately from **1.1 to 1.3** people, in a networked traffic system nobody is stuck in a traffic jam. On the contrary: with a proportion of only **20 percent** AVs, travel times will be reduced by **12 percent** even though **4 percent** more people are on the roads. In the age of self-driving cars, if **100 percent** of the cars on our roads are AVs, **12 percent** more people can be transported **33 percent** more quickly in commuter traffic. Alternatively, cities could decide to fix congestion, and also convert the excess capacity rather to space for the people: almost **one car lane in four** would then disappear.

PARAMETERS

PERSONS PER VEHICLE

1.3

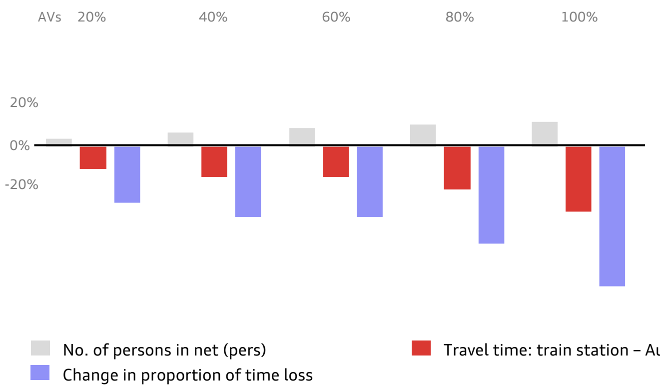
DISTANCE TRAVELLED PER PERSON

EQUAL

INNOVATIONS IN TRAFFIC MANAGEMENT

AMBITIOUS

KEY FINDING



Even with more mobile people, less time is lost

Despite an increase in the number of travelers (up to **12 %** for 100 % AVs) the traffic network still shows a reduction in time losses of up to **69%**.

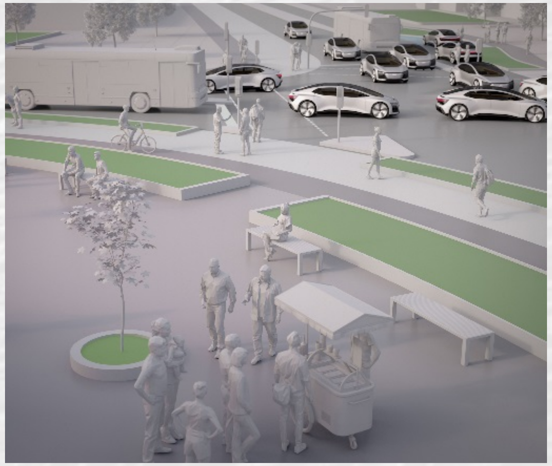
RESULTS

AV SHARE, in %	now	20	40	60	80	100
TRAVEL TIME	24 min	-12%	-15%	-15%	-23%	-33%
TIME LOSS, all vehicles in network	2,500 h	-27%	-35%	-36%	-47%	-69%
TRAVELERS IN THE SYSTEM	59,500	+4%	+6%	+9%	+11%	+12%

SCENARIO 2

STREET LIFE

Awareness of a sustainable lifestyle is growing. More people might prefer to walk, travel by bicycle, or use public transportation. In addition, smart ride-sharing is gaining ground. According to several academic studies, people under 40 years of age are quicker to accept ride-sharing than previous generations. This might increase the number of passengers per car, the so-called occupancy rate – a very influential parameter for traffic flow. If convenient and low-cost services mean that an average of only **one and a half (1.5)** people share a car, and, at the same time, the traffic infrastructure becomes a thoroughly transformative digital network to orchestrate the different means of transportation efficiently, the effects would be impressive. In this “Street Life” scenario, traffic in Ingolstadt flows at all times – even without robo-taxis. With a share of only **20 percent** of AVs, travel time on a commute from the Ingolstadt main station to the Audi Forum could already be cut by **34 percent**. With an increasing number of AVs, this gain in time would build up to **39 percent**. On the other hand, if people don’t mind sitting longer in the car, because they work or relax, the city could opt to invest this spare capacity into valuable space for living. With **100 percent** AVs on the roads, **33 percent** of the areas devoted to major arterials become superfluous.



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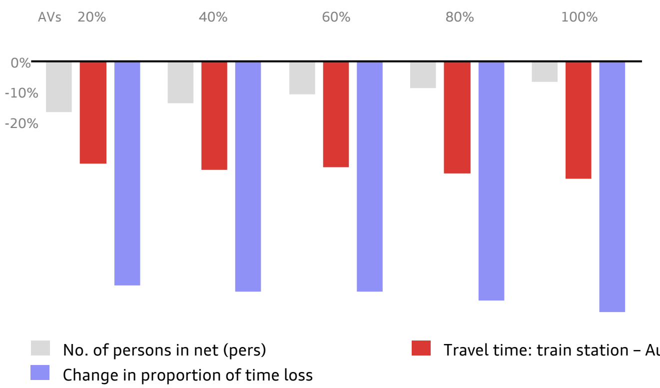


Travel time reduction up to 1/3

Automation, ride-sharing and innovations in traffic management help to **decrease the travel time by up to 39 %** by decreasing the overall time loss by up to **83%**. Alternatively, in the 100% AV scenario it would be possible to forego the shortening of the travel times and instead to **reduce the area covered by major arterials by about one third**.

PARAMETERS

PERSONS PER VEHICLE

1.5

DISTANCE TRAVELLED PER PERSON

LESS

INNOVATIONS IN TRAFFIC MANAGEMENT

REVOLUTIONARY

RESULTS

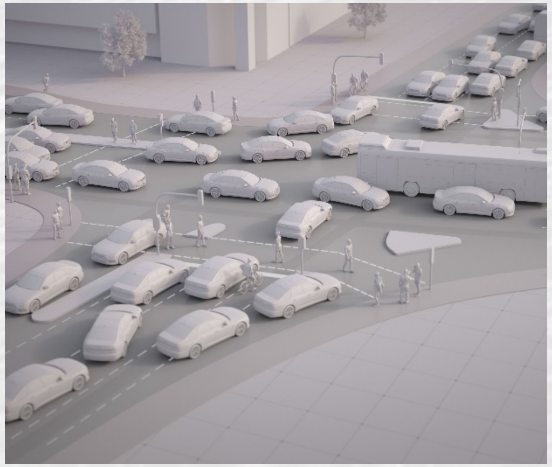
AV SHARE, in %

	now	20	40	60	80	100
TRAVEL TIME	24 min	-34%	-36%	-35%	-37%	-39%
TIME LOSS, all vehicles in network	2,500 h	-74%	-76%	-76%	-79%	-83%
TRAVELERS IN THE SYSTEM	59,500	-17%	-14%	-11%	-9%	-7%

SCENARIO 3

DIGITAL DETOX

Compared to the “Balance” scenario, things might turn out very differently: if we assume that cities do without digitalized infrastructure. In this “Digital Detox” scenario, the conditions for autonomous driving do not exist – AVs are far in the future. App-based ride-sharing is not given a chance. And traffic management, too, develops quite slowly... while demand for mobility rises as a result of urbanization and higher urban density. Taking the example of Ingolstadt, only with **80 percent** AVs would the traffic system be slightly more efficient than today; with **24 percent** more people on the roads. However, if basic reservations towards digitalization prevail, it will be quite a challenge to ever reach such a substantial share of AVs or, on the other hand, a smart and networked traffic management. Even in a mid-sized city like Ingolstadt, congestion would be the inevitable consequence according to our traffic simulation.



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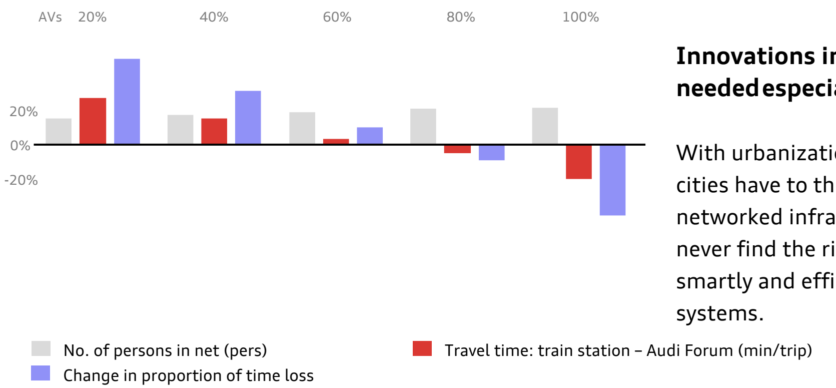


Innovations in traffic management are needed especially with rising automation

With urbanization and higher urban density, cities have to think about smart services and networked infrastructure. Otherwise AVs will never find the right conditions to blend smartly and efficiently with urban mobility systems.

PARAMETERS

PERSONS PER VEHICLE

1.1

DISTANCE TRAVELLED PER PERSON

MORE

INNOVATIONS IN TRAFFIC MANAGEMENT

EVOLUTIONARY

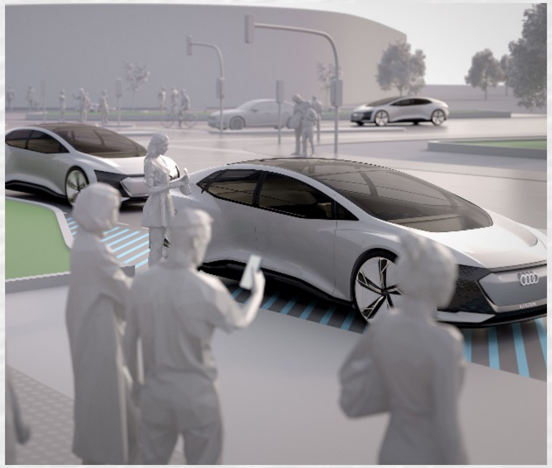
RESULTS

AV SHARE, in %	now	20	40	60	80	100
TRAVEL TIME	24 min	+31%	+18%	+4%	-5%	-22%
TIME LOSS, all vehicles in network	2,500 h	+57%	+36%	+12%	-10%	-46%
TRAVELERS IN THE SYSTEM	59,500	+18%	+20%	+22%	+24%	+25%

SCENARIO 4

SHARED VALUE

Lively interactions and the wish to take social and ecological responsibility reduce inhibitions and call for a sustainable mobility system. Ride-sharing is the natural course when walking or cycling is not an option. The average occupancy rate rises to an average of **1.7 persons** per car (> 50% more than today). Personal privacy in the car then becomes a genuine premium benefit. Consistent ride-sharing also leads to more trips with no passengers. Low costs on the dense market for mobility services also contribute to the car remaining the number-one mode of transportation. Thus, despite the high occupancy rate, the number of miles driven remains at today's level. Nevertheless: with a proportion of only **20 percent** AVs, the solution works. Thanks to increasingly efficient traffic management, the car fills gaps in the traffic mix in urban centers, in a convenient and time-saving way. Therefore with a proportion of **60 percent** AVs, significantly more people can be transported (**+11%**). With **100 percent** AVs, the travel times in commuter traffic are greatly reduced (**-37%**). The time lost compared to a commute without any stops at all ("time loss") shrinks to a fifth (**-80%).**



PARAMETERS

PERSONS PER VEHICLE

1.7

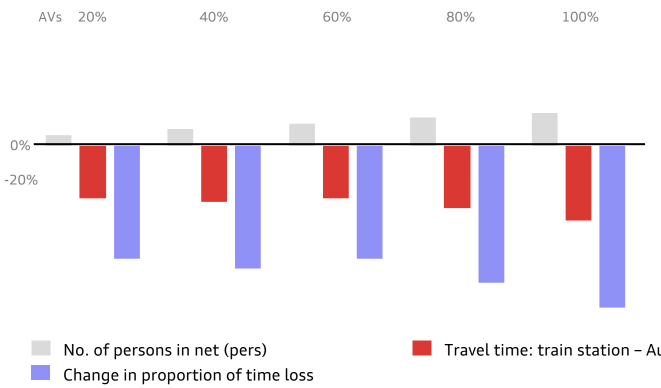
DISTANCE TRAVELLED PER PERSON

EQUAL

INNOVATIONS IN TRAFFIC MANAGEMENT

AMBITIOUS

KEY FINDING



Less congestion

Ride-sharing and new mobility services are the key to reducing the time spent in congestion by up to **80%** although more people are travelling in the network.

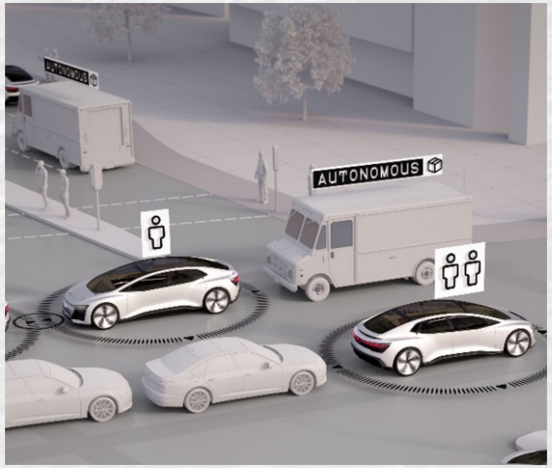
RESULTS

AV SHARE, in %	now	20	40	60	80	100
TRAVEL TIME	24 min	-26%	-28%	-26%	-31%	-37%
TIME LOSS, all vehicles in network	2,500 h	-56%	-61%	-56%	-68%	-80%
TRAVELERS IN THE SYSTEM	59,500	+5%	+8%	+11%	+14%	+16%

SCENARIO 5

DELIVERY

Online shopping is so convenient, cheap and fast that almost every purchase is made via an app. Of course this leads to a high level of logistical traffic, with so-called zero-occupancy trips. If smart ride-sharing services are not established at the same time, the average rate of occupancy could fall dramatically. For this scenario our simulation is calculated with less than one person per car (**0.9**). Although, with a rising proportion of AVs, the willingness to make longer trips to work rises, the mobility of city dwellers is limited to the journey to the office or to leisure activities. Trips to the supermarket, post office or pharmacy are no longer made. In this way, a smaller mileage per person is traveled in total than today. This scenario clearly demonstrates the relevance of the occupancy rate for transport planning. At a **20 percent** proportion of AVs, the time loss rises by **37 percent**. Here **10 percent** fewer people are on the road. The traffic flows better than today only with a **60 percent** proportion of AVs and better traffic management.



PARAMETERS

PERSONS PER VEHICLE

0.9

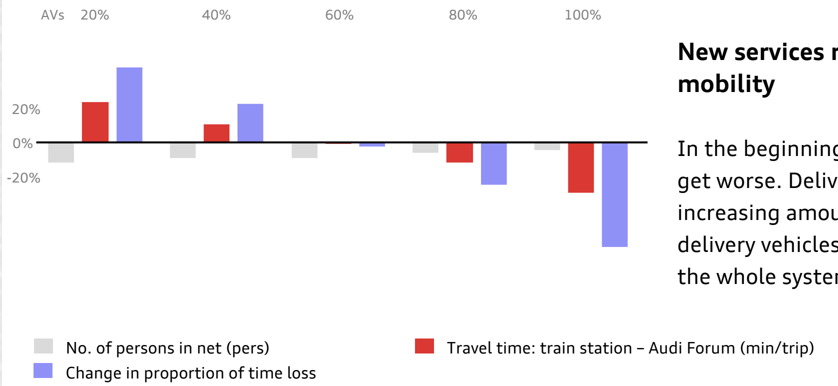
DISTANCE TRAVELLED PER PERSON

LESS

INNOVATIONS IN TRAFFIC MANAGEMENT

EVOLUTIONARY

KEY FINDING



New services reduce our demand for mobility

In the beginning with mixed traffic it will get worse. Delivery traffic with an increasing amount of non-occupied delivery vehicles increases time losses for the whole system.

RESULTS

AV SHARE, in %	now	20	40	60	80	100
TRAVEL TIME	24 min	+20%	+9%	-1%	-10%	-25%
TIME LOSS, all vehicles in network	2,500 h	+37%	+19%	-2%	-21%	-52%
TRAVELERS IN THE SYSTEM	59,500	-10%	-8%	-7%	-5%	-4%

PARTNERS

KIT

With more than 9000 employees and an annual budget of close to one billion euro, the Karlsruhe Institute of Technology (KIT) is one of Europe's largest research institutions. The Institute for Transport Studies at KIT (IfV) covers a broad range of research topics in transport, focusing on three areas: travel behavior research, e.g. the annual national travel household survey "German Mobility Panel"; transport demand modelling, developing the agent-based model "mobiTopp"; and traffic flow simulation, especially in the context of highway capacity analysis. ***www.kit.edu/english***

MOBILITY PARTNERS

MobilityPartners specializes in various questions around traffic and mobility and advises OEMs, Tier-1, local authorities, startups and transport companies as well as other organizations in the mobility market. They offer individually tailored methods and solutions and support concept development. They have many years of extensive experience in the monitoring and implementation of research and industrial projects from the initial idea to their successful completion.
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Press Kit
ENG: www.audi-mediacenter.com/en/25Stundeflow
GER: www.audi-mediacenter.com/de/25Stundeflow
The study in animation
https://25thhour.rndr.studio

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