Paper ID 438

Integrated public transport: Quantifying user benefits – Example of Hamburg

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Abstract

We are stuck in traffic. It is taking longer and longer to get from point A to point B – and we are all paying the price: drivers, commuters, cities, the public, and the environment. Motorized individual transport has liberated citizens around the world. However, progress has shifted into reverse in many urban areas nowadays. One possible solution is integrated public transport, the linking of public transport with micromobility, such as electric scooters and on-demand shuttles. As of 2021 micromobility has established itself successfully, but integrated, intermodal offers are nowhere to be seen. Why? One reason could be a lack of user value. So, we ask: are there user value problems associated with integrated public transport? Due to a lack of integrated public transport, our investigation resorts to utilizing simulations. Scenarios are tested in the city of Hamburg. Results would be crucial to designing successful integrated public transport solutions.

Keywords:

Intermodal travel, micromobility, mobility-as-a-service (MaaS), mobility on demand (MOD), recommendations

Introduction

We all know it, many of us have even fallen victim: it is taking longer and longer to get from point A to point B. Cities in particular are suffering. More and more vehicles and trips, longer commute times, more traffic jams, longer delays, air pollution, noise, and accidents. It seems progress with mobility has gotten stuck. How can we get unstuck? Many cities would like to trigger a modal shift, shifting travel from individual cars to public transport and other, more sustainable modes of transportation. Experts agree that the trick for pulling off such a modal shift must involve digitalization or data-driven and "smart" or on-demand solutions; wherever it has gone, it has delivered better service at a lower cost – and the key to changing consumer behavior. Other industries provide proof, such as the newspaper, music and television business, which show where important lessons have been learned on how to succeed with digital methods (Schlueter Langdon & Shaw 2002, 1997). In mobility, we have already seen a first wave of pioneers who learned lessons early on, like Uber and Lyft with ride-hailing and ride-pooling services. They established themselves as transportation companies without owning any means of transportation. Years ago, when the offspring of automakers jumped into the business, such as Daimler's Car2Go and BMW's DriveNow services, they immediately bought cars. Instead, Uber and Lyft seem to have learned from digital media companies and entered with investments in smartphone apps, data, and analytics. A second wave has since emerged in the form of micromobility, which includes shared bikes and electric scooters. It seems like big cities in particular are dotted with colorful bikes and electric scooters on every street corner. Many can be picked up anywhere and dropped off at any other location, which makes them a faster and more convenient option for short trips. And indeed, usage measurements confirm our intuition: in the U.S., trips on shared bikes, e-bikes, and electric scooter have soared by more than 60% to 136 million trips from 2018 to 2019; specifically, people took 86 million trips on electric scooters, 40 million trips on station-based bike share systems, and 10 million trips on dockless e-bikes (NATCO 2020). First aggregators or "portals" have also emerged (the terminology portal became popular with electronic publishing during the first internet boom in the late 1990s, see Schlueter Langdon & Bau 2007a/b). Examples include offers in Germany's two largest cities, Berlin and Hamburg. Berliner Verkehrsbetriebe (BVG) is now offering Jelbi, while Hamburger Hochbahn (HHA) has introduced Switch. As of 2020 both are multimodal offerings providing access to different modes of transport within a single app, as opposed to intermodal transport, which refers to the linking of different modes of transport into a seamless journey from point A to point B. Multimodal transport is like a supermarket selling different types of food for a do-it-yourself meal. If you don't want to cook yourself but prefer a takeout meal instead, you will have to look for a fast-food place, for example. That being said, what exactly is the problem with intermodal travel and particularly with integrated public transport, i.e., the integration of public transport into an intermodal travel chain? The most obvious answer would be a lack of user value. So let's investigate this issue for the city of Hamburg.

Problem, background, literature

Public transport dilemma

The Cambridge Dictionary defines public transport (also public transportation, public transit, mass transit, or simply transit) as "a system of vehicles such as buses and trains that operate at regular times on fixed routes and are used by the public" (link). While public transport is important due to its role as a utility and public commodity, as well as its size and environmental friendliness, it suffers from one big issue that severely limits new initiatives and innovation – public transport is notorious for losses. It already requires taxpayer funding in one form or another just to remain viable as is, and substantially so. Even ever higher ticket prices for citizens have not erased deficits (see cost versus performance in "Stuck in Traffic," link). Therefore, public transport would certainly benefit from an increase in customers and business. This is where integrating with micromobility could be advantageous, potentially helping public transport services improve their economic models.

Intermodal mobility

While public transport is often a monopoly, with one dominant local provider (Schlueter Langdon & Oehrlein 2021), for micromobility the picture is very different – and literally more colorful: multiple, competitive providers are dotting cities with bikes/e-bikes, e-mopeds and electric scooters like sprinkles on an ice-cream sundae (in Hamburg, for example, Bird is black, Lime is white, Mobike is orange, Next is silver, Tier is green, Voi is red). They have emerged without public funding to build "virtual" service networks using existing public spaces … or "overlay" networks that run independently on top of existing infrastructure. Many industry observers and experts have been supportive of micromobility and e-scooters in particular because they "can perfectly complement buses and trains for the remaining kilometers to the destination. This makes public transport more attractive and can reduce car journeys" (Achim Berg, President of Bitkom, the country's largest digital association, Bitkom 2019). In Germany, cities have been encouraged to explore the linking and integration of micromobility with traditional public transport (Agora Verkehrswende 2019). However, despite all the excitement there is little quantitative support of this argument as of 2020.

Integrated mobility benefits: money for nothing, convenience and speed?

Dire Straits has sung about "Money for nothing" to illustrate how musicians get paid for doing what they like to do anyway. Similarly, intermodal could be provided using what is already in place anyway, such as the subway. Uber has demonstrated how reuse of existing assets can result in a lower cost offering with a win-win scenario for everybody involved: vehicle owners, customers, and a new third party, Uber, as the orchestrator. Who wouldn't like the same or similar but cheaper? Another advantage could be convenience. Consumers love it. Fast food is just one example of this. From a provider perspective it may be seen as a challenge, yet business practice points to a clear positive effect for sales and profits. Convenience can be an excellent opportunity to (a) differentiate offerings and (b) increase margins (Crosby & Schlueter Langdon 2014): the silver, gold, and platinum versions of a base product.

Take for example, air travel, another transportation business: the economy seat without refund, the same seat with last minute flexibility, and the premium economy edition with more legroom. Provide buyers with an opportunity to pay for convenience as they see fit or according to their individual preferences and willingness to pay. It would be a win-win for both sides of the transaction, users and operators. Besides being cheaper and better, above all intermodal should be faster since travel is first and foremost about actually getting from point A to point B.

How micromobility can speed up a monomodal car trip

Despite an exhaustive body of research literature on definitions, concepts, features, case studies of MaaS (European perspective) and MOD (U.S. view) (see for example, Shaheen et al. 2020), there is surprisingly little quantitative analysis available. One exception is a quantitative test of a simple intermodal model in the city of Berlin, which reveals a speed advantage greater than 10%-20% for the daily commute to work. According to MiD 2017, this covers approx. one-third of all traffic in Germany (Nobis & Kuhnimhof 2018, p. 45, p. 62). **Figure 1** depicts how the simple model divides a trip from point A to point B into the three segments of the first leg, near B, and the last leg (for details, see Schlueter Langdon 2020). It also reveals the choice of baseline scenario, $S_{0,}$ and how it evolves in two steps toward intermodal and "smarter" scenarios. "Smart" is used to indicate the impact of digitalization and specifically, a new, data-driven and on-demand approach. For example, scenario S_2 substitutes self-parking near B with an app-based parking recommendation. Consumer apps such as Parco / Telekom Park and Joy collect parking data and mine it to calculate the likelihood of available street-side parking. A parking spot is not magically cleared but the driver is navigated to an empty one. In scenario S_3, smart parking recommendations are linked with electric scooter offers to reduce the walking time for the last leg. Testing this model and its scenarios in Berlin delivered clear speed advantages: firstly, intermodal travel was faster and secondly, the smarter the solution the greater the speed. S_2 is approx. 10% faster, while S_3 saves 20% travel time (for a detailed discussion of results as well as scenario settings and choice of parameters, please see Schlueter Langdon & Tuescher 2020, link; Tuescher 2019).

Simple **intermodal** model with **smart mobility** (see Schlueter Langdon 2020)

A to B		
First leg	Near B	Last leg
Segment 1	Segment 2	Segment 3

Experiments with **Berlin** digital twin (see Tuescher 2019)

S_0	Personal car	Self parking	Walking
S_2	Same	Smart parking	Same
S_3	Same	Same	Smart scooter

Intermodal model with smart mobility … plus **public transport** (PT)

A to B					
First leg	Hub to Hub				Last leg
A -> Near Hub A	Near HA	Hub A transfer	Inter Hub	Hub B transfer	Near Hub B -> B
Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6

Experiments with **Berlin** digitial twin (see Oehrlein 2020)

S_{PT1}	Personal car	Parking	Walking	Public transport	Walking	Walking
S_{PT2}	Same	Smart parking	0	PT	Same	Same
S_{PT3}	Same	Parking	Walking	PT	0	Smart shared
S_{PT4}	Same	Smart parking	0	PT	0	Smart shared

Experiments with **Hamburg** digitial twin

S_{PT1}	Personal car	Parking	Walking	Public transport	Walking	Walking
S_{PT4}	Same	Smart parking	0	PT	0	Smart shared

Figure 1: Intermodal travel models and cascading mobility scenarios for simulation experiments

Approach: Simulating integrated public transport scenarios

We would now like to expand our model to integrate public transport and ask the same question: are users better off? And as travel is first and foremost about getting from point A to point B, we specifically ask: can integrated public transport do the job faster? A key complication in answering the question is that there is no intermodal mobility on offer. So how do you do the impossible to predict the probable? Fortunately, we can use a simulation, a proven research instrument across fields, from medicine to management (see our brief "Overview of simulation in business," link; Schlueter Langdon 2014, 2005). A simulation requires (a) a causal model setup (X causing Y), (b) a baseline scenario or null hypothesis as a goal post for our target or dependent variable Y (speed in our case), and (c) alternative scenarios or alternative hypotheses to investigate how some independent variable or factor X or diversion from the baseline (a combination of mobility choices in our case) affects Y.

Hamburg's mobility experiments and modal shift
The choice of alternative scenarios will recognize strategies and initiatives in the German city of Hamburg, a major port city in northern Germany, which is connected to the North Sea by the Elbe River. Hamburg is the second-largest city in Germany after its capital Berlin, as well as the overall 7th largest city and largest non-capital city in the European Union with a population of over 1.84 million (Wikipedia 2021). The city makes for an interesting research object for traffic studies because of pioneering initiatives to address traffic gridlock and climate change. Specifically, the city has committed itself to driving a model shift from travel by private car to travel by public transport, cycling, and walking.

Hamburg-Takt strategy
In parallel to the update of the climate plan of the city of Hamburg, the Senate of the Free and Hanseatic City of Hamburg has committed itself to a new strategy for public transport with the "Hamburg-Takt" and, together with its cycling strategy, to a vision of a "Mobilitätswende," Germany's ongoing transition to sustainable mobility. As a central component of the climate plan, local public transport is to contribute to significant CO_2 savings in the city's transport sector. To this end, many measures have been defined that are intended to lead to a modal shift from private cars to public transport. The strategic goal is a modal split share of 30%in favor of public transport. Overall, public transport, and cycling and walking is to increase to 80%. Starting from the base year 2017 with a modal split share of 22% for public transport and a share of 36% for private cars, this translates into an increase of eight percentage points. Measured in terms of passengers, this results in an increase of approximately 50% of passenger volume. This is a tall order as it requires public transport to match and beat the attractiveness of travel using a private car for urban mobility. This has implications for all aspects of the public transport service, such as availability, quality, and comfort. These requirements were translated and summarized into the vision of the Hamburg-Takt, a public transport service that can be reached at any point in Hamburg within five minutes.

Hamburg electric scooter pilot
Furthermore, early on Hamburg viewed micromobility, such as electric scooters, as a means to complement public transport to make an integrated travel solution – the whole, greater than the sum of its parts, a key tenant of MaaS. In 2019 a pilot scheme by Hamburger Hochbahn AG (HHA) offering up to 100 electric scooters at two stations "U-Berne" and "S-Poppenbüttel" in the outer northwest Hamburg city area showed that nearly half of the tariff customers would be prepared to pay extra if they were given the option to substitute buses for a more flexible means of transport. Most interviewees did not regularly use electric scooters as they were unavailable in this outer city area. However, with electric scooters available, they were used more often than in inner city areas. Overall, more than 30,000 rides were logged with three rides per electric scooter per day and each ride with an average duration of 13 minutes. For the most part. electric scooters were especially used in the afternoon where commuters are out and about. As there is a bus line serving this area this pilot scheme demonstrated that the bus schedule differed from demand. Hence, this example emphasizes how micromobility can effectively speed up travel time and complement public transport.

Smart modal shift scenarios

The simple intermodal model in Figure 1 provides an excellent foundation for adding public transport. We start off with the same three segment baseline scenario S_0: The driver is going by car from point A to point B with a transfer point near B where the vehicle is parked and from which point the journey is completed by foot. Adding public transport increases the complexity considerably, doubling the number of segments to six. An obvious addition is the station-to-station leg (we refer to stations as hubs to aid upcoming analysis and compatibility with the economic literature). Less obvious are transfer segments (to recognize a transfer issue or "Umsteigewiderstand"), for example, the walk from a parking lot or bike rack in front of the station to the platform. And then of course, the time spent circling around the block to find a parking spot in the first place, which may not be in front of the station. In a first step, scenario S_{PT1}, public transport is added (see **Figure 1**). Instead of driving somewhere close to B and finding parking nearby, the driver parks near a public transport station close to A in order to use public transport to get close to B. In this scenario the driver is not only trying to avoid parking near B (maybe too time-consuming, too expensive, impossible to find parking … or all of the above) but also to save the stress of operating a vehicle in stop-and-go traffic and just sit on a train instead. The next evolutionary step is reflected in scenario S_{PT2}, where a seamless A to B journey is created. First, self-organized parking near hub A is replaced with "smart parking", then walking the last leg from Hub B to B is replaced with a micromobility solution, like an electric scooter. "Smart" is used to indicate new, data-driven innovation. For example, in scenario S_2 in **Figure 1** we first substitute self-parking near B with an app-based parking recommendation. Consumer apps such as Parco/Park and Joy collect parking data and mine it in order to calculate the likelihood of finding available parking, such as street-side parking. In scenario $S_{3,}$ smart parking recommendations are linked with electric scooter offers to reduce the walking time for the last leg. Scenarios S_{PT1} - S_{PT4} have already been run for Berlin; now, we will test a subset, hypotheses S_{PT1} and S_{PT4}, in the city of Hamburg.

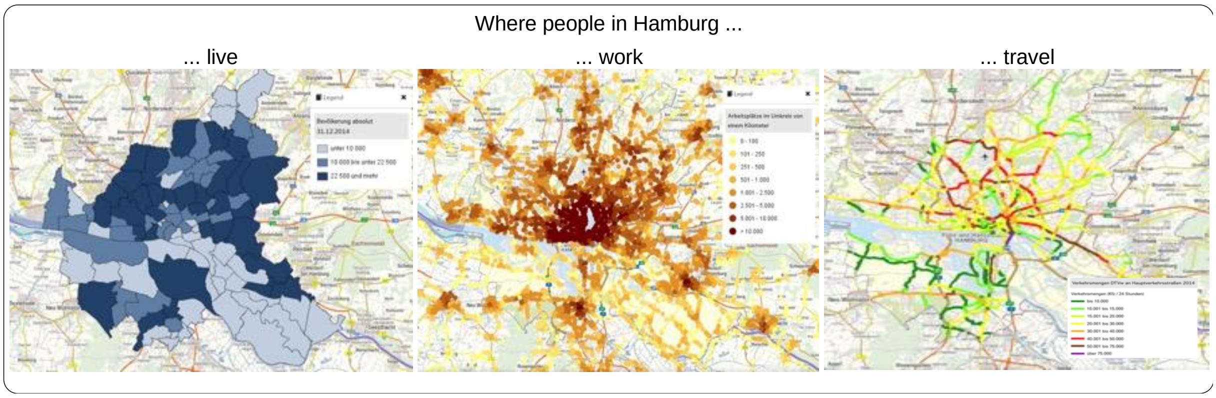

Figure 2: Macro-selection of A and B areas with government statistics, Hamburg (LGV 2021, link)

Experimental design for Hamburg digital twin

Selecting simulator settings for generalizability and robustness

When conducting experiments, it is crucial to ensure that the results are relevant and generalizable, and truthful. Consequently, our scenario settings have been carefully and transparently selected to ensure our results are of high validity and robust. The former refers to how well our approach can measure what it is intended to measure as well as how well it corresponds with real properties and characteristics of the phenomenon we are focusing on. The latter ensures that results remain unchanged if small changes of key parameters are introduced, such as starting a trip 30 minutes earlier or later, for example. Based on prior experiments, such as with our intermodal travel simulations with Berlin digital twin, a 3-step best practice calibration approach has emerged to systematically specify key settings for our simulation experiments (Schlueter Langdon & Oehrlein 2021, Schlueter Langdon & Tuescher 2020):

a) Reasons for travel (work, household errands, leisure)
b) Areas of travel (starting point A, destination B – from areas to specific locations)
c) Time of travel (day of week, time of day)

Reasons for travel

Firstly, we will consider the purpose for travel. Using the most comprehensive government statistics available in Germany, all travel can be aggregated and categorized into three high-level and distinct buckets: work, household errands, and leisure (see BMVI 2018, p. 61; and Figure 2 in Schlueter Langdon & Oehrlein 2021, p. 3). For this experiment "work" has been selected to include the all-important use case of commuting, the regularly recurring journey between one's place of residence and place of work or study.

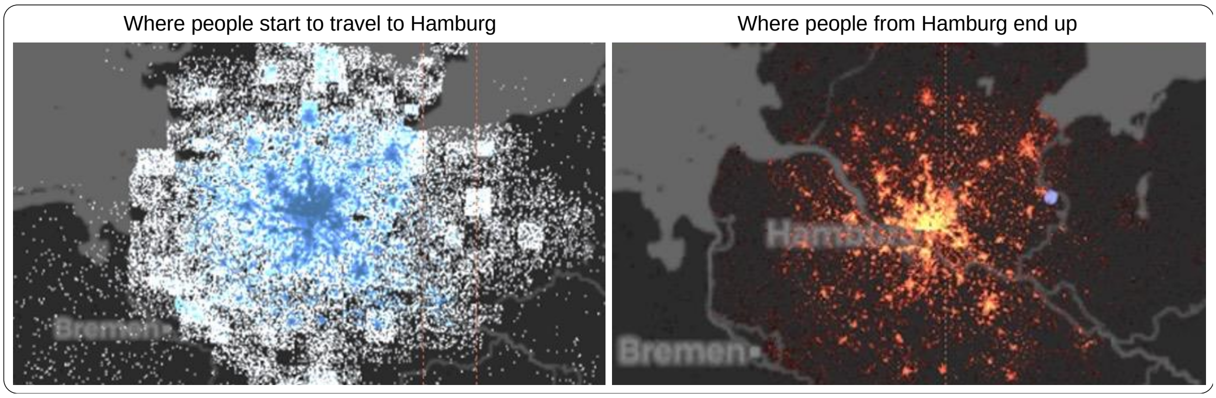

Figure 3: Confirming the B area using traffic flow simulations, Hamburg (own visualizations)

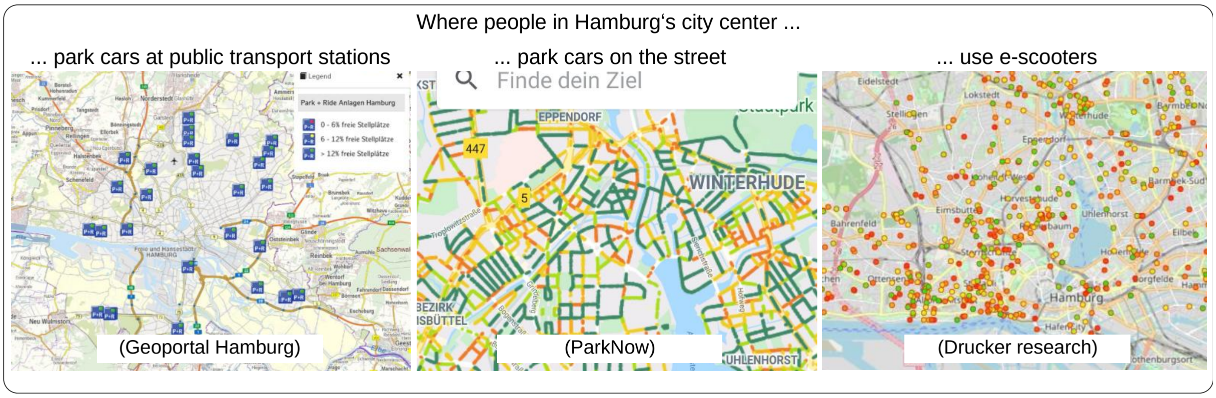

Figure 4: Micro-selection of B locations, Hamburg city center (LGV 2021, link; ParkNow 2021, link)

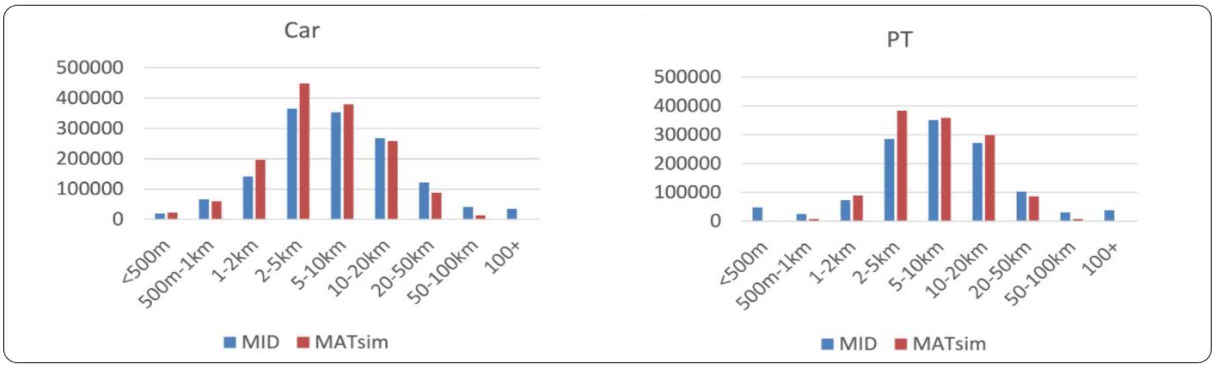

Figure 5: Distribution of travel distance, Hamburg (RealLab Hamburg 2021, p. 38)

Areas of travel – macro-selection

Secondly, choosing the areas of travel is the next key decision and it comes with multiple constraints. For one, the start and end points must be in relevant locations, one where many people live, point A; the other one, now that we are focused on work related travel, where many end up for work, point B. Furthermore, the distance between point A and point B ought to be in line with "typical" or representative travel distance and duration values for the city in question. In addition, and to include public transport to address modal shift, the start and end points need to be in reasonable proximity of public transport (which for now is limited to rail-based transport – no bus lines – as the Hamburg-Takt rollout will start within its rail-network). In order to maximize generalizability, a two-step location selection process was devised. First, we select areas, a macro-selection so to speak. Then we pinpoint specific locations or addresses within these areas, a micro-selection. Using government statistics, we identified key areas where people live and work. **Figure 2** reveals areas of high population to the northwest and northeast of Hamburg, and work destinations in the city center. This is confirmed using results of traffic flow simulations with MATSim for the city of Hamburg as prepared in the RealLab Hamburg project. The MATSim simulation system has been calibrated for Hamburg using MID survey results as well as anonymized motion data obtained from mobile phone networks. The simulation clearly confirms how travel in Hamburg overwhelmingly ends up in the city's center. **Figure 3** depicts two heatmaps: one with travel origins on the left, and the other with destinations on the right, all for a 24-hour aggregate of an average Tuesday through Thursday weekday. The heatmaps clearly indicate how starting points are widely dispersed while destinations accumulate in the city center. A closer look into origins on the left shows an agglomeration of starting points to the north of the city (dark blue), which corresponds with the dark blue areas in the government residency statistics to the left of **Figure 2**.

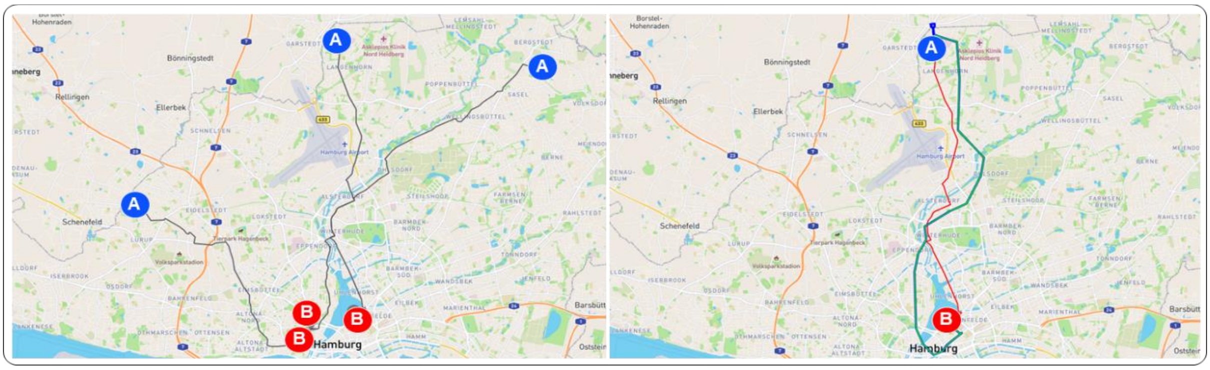

Figure 6: Select A-B pairs and routes

Areas of travel – micro-selection

Now that relevant areas have been identified for A and B, we need to pinpoint specific addresses for start and end points in these areas. For the purpose of generalization our choice has to translate into travel distances that correspond with typical values for Hamburg. **Figure 5** depicts travel distances for travel by car and public transport in Hamburg. It shows that most trips fall between 5-20 kilometers with 5-10 kilometer trips as a central tendency. Figure 7 also confirms the accuracy of the MATSim simulation as it compares MATSim-based simulation results with MID statistics, which correspond very well. Based on this analysis we select Bs in office buildings near Hamburg's downtown area to the north of the Kontorhaus neighborhood (see **Figure 4** for approximate area) and A locations which are primarily a distance of 10km-20km to the north in districts Volksdorf, Langenhorn and Lurup as depicted in **Figure 6**. A further relevancy crosscheck confirms that these districts exhibit average or above average rates of private car ownership (362 cars per 1,000 citizens, see Statistik Nord 2020, link), making it reasonable to assume that many citizens in these neighborhoods are using their private car for travel.

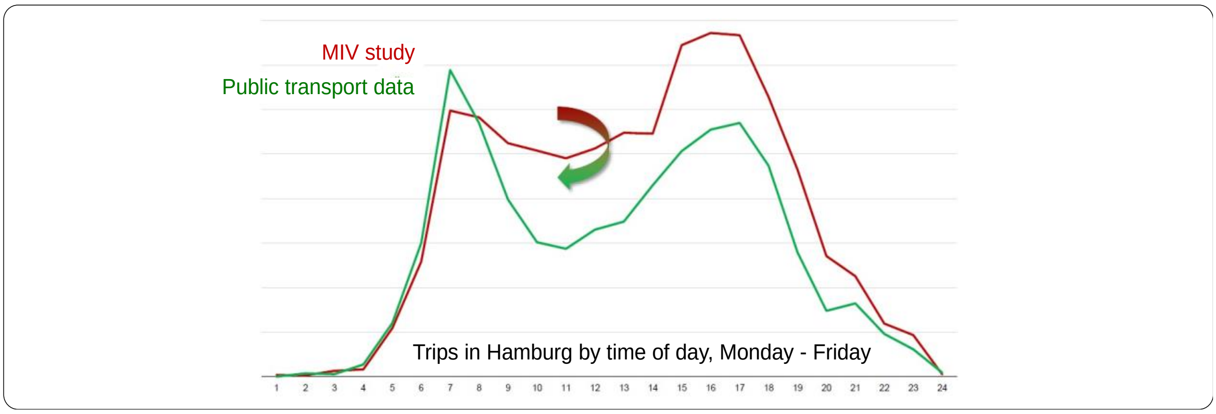

Figure 7: Distribution of travel time by time of day, Hamburg (Kerinnis 2020, p. 22)

Time of travel
Thirdly, the timing has to be finalized. This is also a two-step process: first, selecting the day of week; then, secondly, deciding on the time of day. Since we are focusing on travel to and from work, our day of travel is set as an average working day (Tuesday to Thursday). Then we need to decide how to select the time of day. In order to demonstrate the advantage of any of our alternative travel solutions (our alternative hypotheses), it would be best to select worst possible conditions. This would show that if it works during the worst of times, it should work anytime. Therefore, we will select rush hour traffic. **Figure 7** indicates two distinct phases of rush hour traffic (Kerinnis 2020, p. 22, link). One in the morning, the other in the afternoon. This corresponds with the official definition of the Hamburger Verkehrsverbund (HHV), the regional public transportation authority: "The HVZ (Hauptverkehrszeit / rush hour) includes the periods Monday through Friday from 6 a.m. to 10 a.m. (early HVZ) and from 3 p.m. to 7 p.m. (late HVZ) (HHV 2021). Based on the diagram we chose a starting time between 7-8 a.m. for our route calculations.

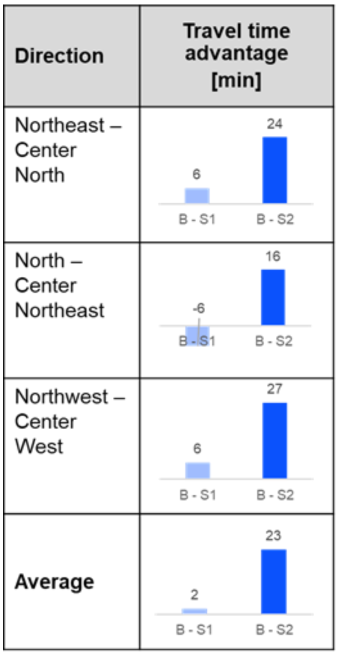

Figure 8: Hamburg results

Results: Speed, Savings …

Speed
Figure 8 depicts results for key routes shown in **Figure 6** in all scenarios and compares them with our baseline. Even on the surface, without looking closely at details, the results are very clear. For one, the results for S_{PT1} confirm that routes have been selected such that there is little time difference between using a private car and public transport, which makes it easy to isolate causal effects and argue that any time advantage is a consequence of the modal shift to integrated mobility. For another, our simulation experiments do indeed prove quantitatively that intermodal travel with public transport can reduce travel time, increasing overall travel speed. Adding “smart,” data-driven solutions in S_{PT4}, such as parking recommendations, and making electric scooters available at public transport stations (pre-loading stations) increases time savings by about 20 minutes or more than 30% to 40% depending on the routes. This result is consistent with our previous findings that “smarter is faster” in the case of Berlin (see **Figure 1**). Time savings for the smartest scenario with public transport in Berlin, $S_{PT4,}$ came to approx. 40% (Schlueter Langdon & Oehrlein 2021), double the savings of the smartest scenario without public transport, $S_{3,}$ in **Figure 1** (Schlueter Langdon & Tuescher 2020). This means that, in terms of travel time, the simulation results strongly support the idea that intermodal travel can also speed up public transport in the city of Hamburg. Time savings are so substitutional, you could even miss a subway or two and still be ahead.

Cost

Travel time is probably the top criterion for choosing how to get from A to B. "Time is money" as they say, a phrase originally coined by Benjamin Franklin, one of the Founding Fathers of the U.S. (Franklin 1748). Money itself does matter, and for obvious reasons: if you don't have money, you can't buy anything. And even if you do have money, funds still tend to be limited, and you have to budget. So, some people may have to forgo time savings for reasons of budget. Therefore, let's have a quick look at the costs involved for the results in **Figure 8**. Coming from experiments in Berlin, we know that parking can easily make or break the economic value of private vehicle use. Without employer-provided or sponsored parking, the rates for public parking can be prohibitive. For example, parking your car right across from Chilehaus, a 10-story historic office building in the Kontorhaus district near the downtown area (the center of our inner-city office area for location B), costs €0.50 per 12 minutes or €3 per hour, which would come to approx. €30 per working day. That's a lot. And to top it off, even if it was worth paying €30, it is not even possible to park there for more than one hour. Instead, you would have to use a big parking structure a few blocks to the north for €2.50 per hour. If there are spaces available, of course. Otherwise, there is an additional cost, the cost of searching for a parking spot. This is where "smart" parking comes in, which can guide a driver to an empty spot. Without smart parking, it takes circling and additional driving around the block, which is quicker, and therefore cheaper to do near an off-site location A than at an inner-city location B, which sees dense traffic during peak shopping times.

Comfort

We did not discuss it initially because most anybody will publicly agree that time and cost are paramount. Yet, being honest, we do love comfort. We are even willing to pay more for it or forgo time and cost advantages. This especially applies when the amounts involved are small. Here humans struggle with the psychological trap of the absolute versus relative effect (see Nobel prize winning economics research by Tversky & Kahneman 1981). For example, one euro more doesn't seem much in absolute terms, it is seen as small change. However, in relative terms, relative to the cost of a one-way bus fare of 2 euros, it is a very hefty 50% increase, which we would not tolerate with a bigger ticket item. Knowing that we may be willing to forgo hard, quantitative time and monetary advantages for something soft and fuzzy, so, what about comfort with our scenarios? We argue that there is more comfort. A key advantage of public transport is being driven or chauffeured. Some of us love to drive around like in car ads, zipping through the mountains or along the shoreline on empty winding roads. However, urban traffic is far from it. Instead, driving in the city is often one big traffic jam, a stop-and-go crawl with bumper-to-bumper congestion (according to TomTom's traffic index real life congestion often far exceeds 50% in urban areas, link). Despite this everyday monotonous procedure, people need to pay attention at all times because mistakes can be downright deadly. According to the latest data, deaths of vulnerable road users such as pedestrians and bikers are indeed on the rise (54% of those dying on the world's roads are vulnerable road users, WHO 2020; while the total number of road deaths in Germany in 2019 was 16.5% lower than in 2010, a decade ago, and the number of cyclists killed has increased by 16.8% over the same period, Destatis 2020). The comfort advantage of public transport is twofold: for one, it relieves the driver from the stress of operating a vehicle. What's more, it frees up time that can be spent on more enjoyable activities, such as reading, or productive use, such as getting a head start with your emails. It seems with a smart intermodal upgrade, as seen in scenarios S_{PT2}-S_{PT4}, public transport could provide the best of two worlds: the comfort of a chauffeured ride, and the speed and cost advantage previously only associated with car use.

Key findings

Our hypothesis is highly focused, and the experimental footprint is small (see scenario section), yet the results already pack a punch, pointing to a much larger story with three key takeaways: firstly, the system wins; secondly, parking is important - particularly for a model shift; and thirdly, by inference, the location of mobility stations or hubs may be critical for the success of such a system. All of it may surely warrant broader and deeper analysis, but the contours are clearly visible.

System beats parts: Who is optimizing it?
If there's a pivotal takeaway from our simulation, then it's that having a system wins. The system as a whole is better than the sum of its parts. Some may say: “Ah! Isn't it obvious?” Public transport is affordable and great for long distance travel but the nearest station is often too far away for many people; while electric scooters are everywhere but riding them over a long distance can be tiring and there is always the chance of getting wet. Together, as an integrated system where one part complements the other, it is a winning combination. Whether it's obvious or not, the immediate issue is: who takes care of the system, who focuses on optimizing the system as opposed to the individual parts on their own? Today, public transport is focused on public transport, and micromobility is focused on micromobility.

Parking: high fees make integrated public transport more attractive
Any simulation-based approach will typically face doubts that a desired outcome is known and that the simulator and sample data have been constructed to confirm it (e.g., Schlueter Langdon 2005). That is why we took great care to make our selection of scenario choices and settings very transparent (see scenario section). However, if we were to fudge the results, then parking would allow us to do so effectively, elegantly, and cheekily. It would be effective, as rates are a big lever. They tend to be high and therefore represent a big chunk of the trip's total cost – and they are still climbing. It would be elegant, since it is already built in as an important variable in many modal shift scenarios (see S_{PT4}). It would be cheeky, since we need to construct parking rates anyway - and who would notice, if we were to doctor the fees to fit results, because parking rates are much less transparent than the price of a subway ticket, for example. With parking there is a hodgepodge of pricing; there are on- and off-street parking fees with and without time limits, hourly rates, mixed rates with free first minutes, daily maximum rates, etc. Turning this insight – how to cheat with parking fee data in simulations – on its head, parking rates can be used in urban reality to shift economic advantage from private vehicle use to integrated transport. Whoever assumes a system view (see “system beats parts”) could influence outcomes, such as modal shift, easily (effectively, elegantly, and cheekily) with parking rates.

Mobility stations or hubs: location, location, location
And finally, one last big insight relates to mobility stations – or hubs as these transfer points are called in the economic literature. In a nutshell: so far, it seems that marketing considerations like awareness and signage overwhelm any efforts to pinpoint the right location. On the one hand it is easy to see and agree that mobility consumers have to be made aware of stations and should be able to find them quickly. On the other hand, similarly obvious is having the right location for a mobility station. However, it seems that the importance of having the right location is much less obvious. Why? Because it is hardly mentioned anywhere (Schlueter Langdon & Oehrlein 2021). How come? We can only speculate at this point. But one explanation ties in with the lack of a system view. In order to optimize locations for faster and thicker traffic flows it takes a system view, a view of the entire network and the interplay of different transfer nodes, much like an airline with its service network and hubs … and probably a few data science PhDs. This warrants a deeper look, so please stay tuned.

Acknowledgement

We are grateful to Lenny Hofmann, Tim Ganther and Luca Loeffler, all from Deutsche Telekom, for assistance with select travel time estimates using a novel computational simulator, which is based on an intermodal travel routing calculator developed with the Telekom Data Intelligence Hub (link) in RealLab Hamburg. This calculator is part of an intermodal travel demonstrator based on a data space prototype with International Data Spaces (IDS) technology and has been funded by the Federal Ministry of Transport and Digital Infrastructure (BMVI) under grant agreement FKZ 01MM2016HH (“Verbundprojekt: RealLabHH – Reallabor Nationale Plattform Zukunft der Mobilität; Teilvorhaben: VRUDaten”).

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