Intermodal integration of public transport and micromobility: Quantifying customer benefits

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Abstract

Mystery solved: Intermodal mobility can speed up monomodal car travel in urban areas. Can it also make public transport faster, and cheaper? That would be a triple win for consumers, providers, as well as for cities and their citizens.

Digitalization is coming to transportation and transforming the business of incumbents, such as automakers, bus manufacturers, car dealerships, public transport agencies, etc. Yet, lo and behold, digitalization is not an altogether new phenomenon. It has already affected and transformed other sectors, such as the print publishing, music and television business, where important lessons have been learned on how to succeed digitally (Schlueter Langdon & Shaw 2002, 1997). Examples include responding to disintermediation and direct to consumer (DTC) competition. We have already seen a first wave of pioneers in mobility who learned lessons early, such as Uber and Lyft with their ride-hailing and ridesharing services. They have established themselves as transportation companies without even owning any means of transportation. When automakers' new mobility ventures, including Daimler's Car2Go and BMW's Now, got involved they all bought cars right away. Instead, Uber and Lyft seem to have learned from social media companies and entered with a focus on smartphone apps, data, and analytics. A second wave, micromobility, has now emerged which includes shared bikes and electric scooters. Big cities in particular seem to be dotted with colorful bikes and electric scooters on every street corner. Many can be picked up here, there and everywhere and then dropped off anywhere else, which makes them a very convenient choice for short trips. Indeed, usage measurement (which is more accurate than surveys) confirms our intuition: in the U.S., trips on shared bikes, e-bikes, and electric scooters 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 (see Figure 1, NATCO 2020, p. 4). Offers have also become more diverse as some vendors have been adding subscriptions, which can make them more convenient for the user and provides the operator with the opportunity to retain customers (see our story on "Stuck in Traffic," link).

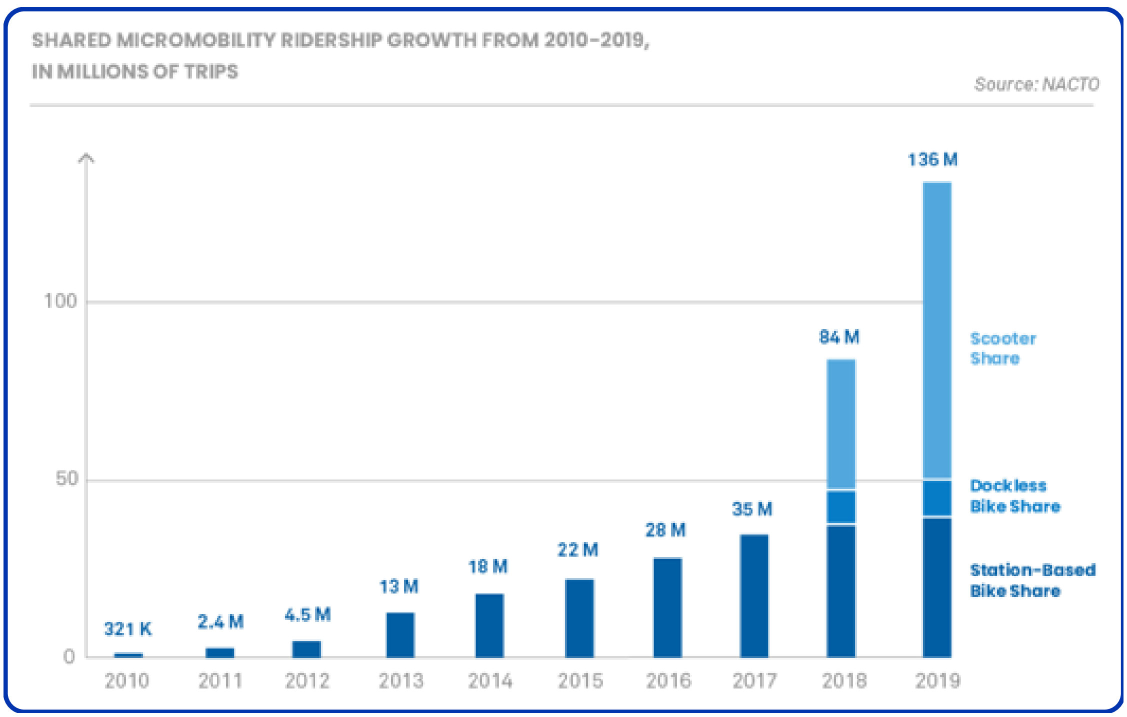

Figure 1: Shared micromobility ridership, U.S., 10 years, 2010-2019 (NATCO 2020)

First aggregators or "portals" have also emerged (the term 'portals' became popular in electronic publishing during the first internet boom in the late 1990s, see Schlueter Langdon & Bau 2007a/b). Examples include offerings in Germany's two largest cities, Berlin and Hamburg. Berlin's Berliner Vekehrsbetriebe (BVG) is currently offering Jelbi and Hamburger Hochbahn (HHA) has introduced Switch. As of 2020, both are multimodal offerings providing access to different modes of transport in a single app, just like a supermarket offers different types of food. If bread is OK for you, then you'll be happy. If you prefer a sandwich like a BLT, with bacon, lettuce, and tomato between two slices of bread, or an intermodal trip, a seamless journey involving different modes of transportation, perhaps transferring from subway to scooter, then you are on your own. Multimodal transport is not a sandwich. And a multimodal platform is not a sandwich joint or restaurant, it's a supermarket.

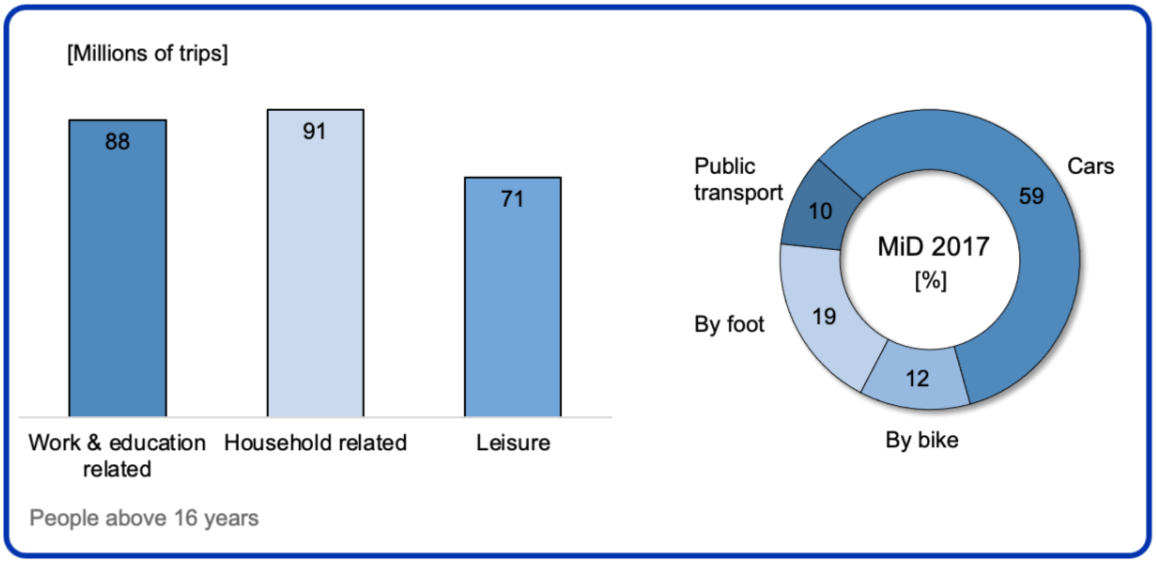

Figure 2: Trip count, modal split, Germany, 2017 (adapted from Nobis & Kuhnimhof 2018)

Intermodal mobility: "Money for nothing"

Since we consumers love the convenience of fast food or ready-made or pre-prepared meals – no surprises here – there is talk about intermodal travel, the linking of different modes of transport to create a seamless journey from point A to point B. Convenience is key here. This could be seen as a challenge and extra cost – a glass half empty; or instead as a big opportunity to increase sales and profit – a glass half full. Experience with other consumer goods tells us that convenience can be an excellent opportunity to (a) differentiate offerings and (b) increase margins (Crosby & Schlueter Langdon 2014): the silver, gold, and platinum version or extension of a basic product (Kotler famously introduced his 'five product levels' in the 1960s, Kotler & Keller 2016). Take air travel, another transportation business, for example: 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 the added convenience if they like or not, depending on how much they are willing to pay (willingness to pay, WTP). It would be a win-win for both sides of the transaction, users and operators.

Another possible advantage for intermodal transport is the cost. Dire Straits sang “Money for nothing” to illustrate how musicians get paid for doing what they like to do anyway. Similarly, intermodal transport could be provided using what is already in place anyway, such as the subway. Uber has demonstrated how reusing 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 want the same or something like it, only cheaper? We love discounts, we love getting better value … some might even say we are stingy (“Geiz ist geil,” Dougherty 2007). Furthermore, in an urban setting there would be another clear winner: all of us, the wider public and the environment. Intermodal transport would reduce traffic and, therefore, reduce negative effects such as air pollution. On top of all that, better utilization of existing roads and parking lots would also create more space (see our story on “Space Race,” link).

	Simple **intermodal** model with **smart mobility** (see Schlueter Langdon 2020)		
	A to B		
	First leg	Near B	Last leg
	Segment 1	Segment 2	Segement 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**					
	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					
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

Figure 3: Intermodal travel models and scenarios for simulation experiments

How micromobility can speed up a monomodal car trip

All these new micromobility choices are seen as enabling intermodal solutions in big cities, electric scooters being welcomed in particular (see our story on “Stuck in Traffic,” link). In order to substantiate this view, we asked: are users indeed better off? And since travel is first and foremost about getting from point A to point B, we specifically asked: can intermodal transport do the job faster? One difficulty in answering the question is that there is no intermodal mobility. How can you do the impossible to predict the probable? Fortunately, you can carry out a simulation, a tried-and-true research method used in all different fields, from medicine to management (see our brief overview of "Simulation," link). A simulation requires (a) a causal model setup (*X* causing *Y*), (b) a baseline scenario as a goal post for our target or dependent variable, *Y* (speed in our case), and (c) scenarios to investigate how some independent variable, factor, or diversion from the baseline (a combination of mobility choices in our case), *X*, is affecting *Y*. For ease of argumentation, we developed a simple model that corresponds with a very common use case, the daily commute to work. According to MiD 2017, this covers approx. one-third of all traffic in Germany (see Figure 2, adapted from Nobis & Kuhnimhof 2018, p. 45, p. 62). Figure 3 depicts how our simple model divides a trip from point A to point B into three segments: the first leg, near B, and the last leg (for details, please see Schlueter Langdon 2020). It also reveals our choice of baseline scenario, $S_{0,}$ and how this evolves toward "smarter" scenarios in 2 steps. "Smart" is used to indicate new, data-driven innovation. For example, in scenario S_2 we first substitute self-parking near B with an app-based parking recommendation. Consumer apps such as Telekom Park and Joy collect parking data and mine it in order to calculate the likelihood of available street side parking. And in scenario S_3 smart parking recommendations are linked with electric scooter offers to reduce the walking time for the last leg. Figure 4 presents our results which show real time savings for both scenarios. Firstly, intermodal travel can be faster and secondly, the smarter it is, the higher 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).

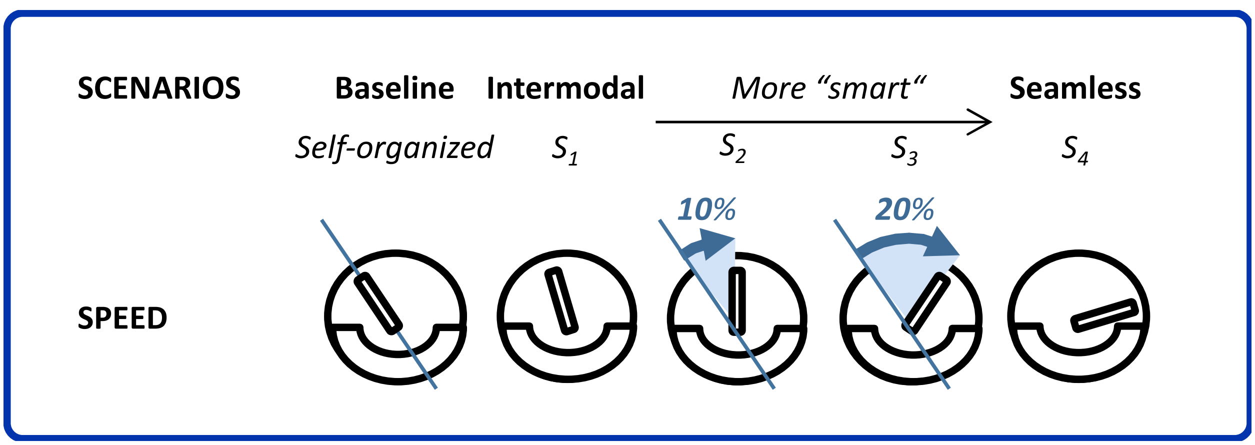

Figure 4: Time savings with intermodal mobility (Schlueter Langdon & Tuescher 2020)

Could micromobility speed up public transport?

The Cambridge Dictionary defines public transport (including 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). Industry observers and consultants have written extensively on the subject of the future of public transport. Examples include BCG, Deloitte, and Roland Berger. Let's quickly find a consensus and list a few considerations as to why finding an answer to our question is important:

- *Public utility:* Public transport furnishes an everyday necessity to the public at large and subject to special governmental regulation (Webster's dictionary). For example, many of us rely on it to commute to work every day. It makes other public services, such as schools or museums, accessible to all of us, young and old.
- *Size:* It presents a sizable segment of today's modal split, particularly in urban areas where it presents approx. 20 % of all trips (BMVI 2018, p. 47).
- *Climate protection:* Public transport can reduce traffic, which in turn reduces air and noise pollution. Furthermore, less traffic is safer for vulnerable road users (VRUs), such as pedestrians and bikers.
- *Innovation:* Municipal transport agencies are investing in digital tools, such as multimodal travel apps to expand ridership (Jelbi by Berliner Verkehrsbetriebe / BVG, and Switch by Hamburger Hochbahn / HHA) as well as mobility stations.

While public transport is important because of its role as a utility, its size, and environmental friendliness, oh boy, it is in a pickle. It suffers from one big problem that severely constrains new initiatives: public transport is notorious for its financial losses. It already requires taxpayer funding in one form or another just to remain viable as is – and substantially so. Even ever-increasing ticket prices for citizens have not erased deficits (see cost versus performance in "Stuck in Traffic," link). This deficit problem is compounded by performance issues, because despite higher fares the bus doesn't go any faster but gets stuck in traffic, too. It seems public transport as a whole is stuck as a monopoly provider selling essentially a basic commodity product with a price cap. This is where micromobility could be advantageous, potentially helping public transport improve its economic model. Historically, public transport required (a) an extensive network of dedicated infrastructure, such as train tracks, from day one and often (b) land expropriation to secure passage and right of way. The former is a hallmark of a natural monopoly assumption (Baumol 1977, Baumol et al. 1977), the latter is indicative of a government monopoly (Walrass 1875). And indeed, to this day, cities typically have just one, dominant public transport provider. With micromobility the picture is different – and quite literally more colorful: multiple competitive providers are dotting cities with bikes/e-bikes, electric mopeds, and electric scooters like sprinkles on an ice-cream sundae (in Berlin, 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 space or "overlay" networks that run independently on top of existing infrastructure. So far, as of 2020, micromobility networks have been limited to bigger cities. In order to find out if public transport could benefit from it, a combination of both would have to be better than each one on its own. Since we have already established that intermodal is faster than traveling by car alone (or monomodal travel), we ask now whether intermodal could also speed up trips with public transport.

Simulating intermodal mobility with public transport

Many industry observers and experts have been supportive of micromobility and electric 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). Despite all the excitement, as of 2020 there is little quantitative support for this. Therefore, we have to resort to simulations again and expand our simple intermodal model and experiments to add public transport. Figure 3 shows how this is done. We start off with the same three-segment baseline scenario, S_0: The driver is going from point A to point B with a transfer point near B where the vehicle is parked. The journey is then completed on foot from this point. Adding public transport increases the model’s 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 future analysis and compatibility with the economics literature). Less obvious are transfer segments (to recognize transfer issues or “Umsteigewiderstände”), for example, the walk from a parking lot or bike rack in front of the station to the platform. Then, of course, the time spent circling around the block to find a parking spot in the first place, which might not be in front of the station. In a first step, scenario S_{PT1}, public transport is added. Instead of driving to B and find parking nearby, the driver parks near a public transport station near A in order to use public transport to get somewhere nearby B. In this scenario, not only does the driver want 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 by sitting on a train instead. Scenario S_{PT2} replaces self-organized parking near hub A with “smart parking.” Scenario S_{PT3} builds on scenario S_{PT1} and replaces walking the last leg from Hub B to B with a micromobility solution such as a shared bike. Finally, scenario S_{PT4} combines the smart parking of S_{PT2} and the last leg micromobilty solution of S_{PT3} to create a seamless intermodal journey from A to B.

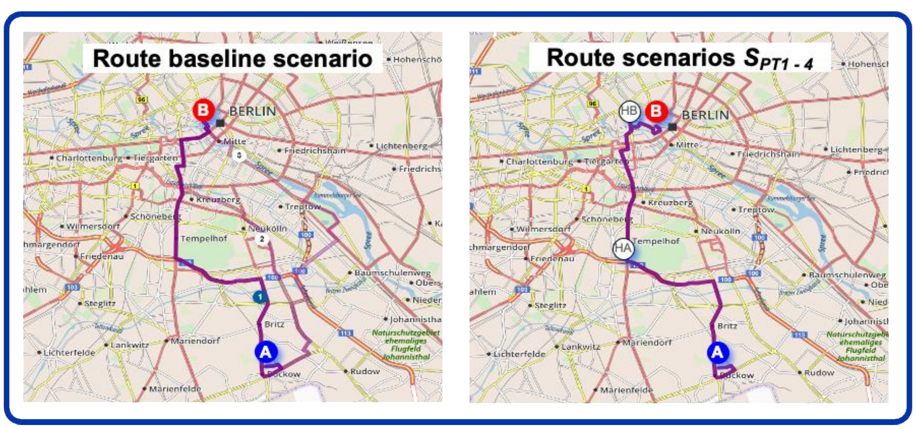

Figure 5: Start point, destination and travel routes in Berlin (Oehrlein 2020)

Selecting simulator settings for generalizability

All settings have been carefully selected to ensure the high validity and robustness of our results. The former refers to how well our approach measures what it is intended to measure and how well it corresponds with real properties and characteristics. The latter ensures that the results remain unchanged if small changes are introduced, such as starting the trip 30 minutes earlier or later.

The key settings for our simulator experiments include:

- Start point A
- Destination point B
- Day of the week
- Time of day

The choice of location is a key decision that has to satisfy multiple requirements. For one, the start and end points have to be in relevant locations, one where people live, point A; the other one where many end up, point B. The distance from point A to point B then ought to be in line with average or median values for the city in question. In addition, and in order to include public transport, the start and end points need to be in "average" proximity of at least one public transport station. Based on these requirements, our start point A is located in Berlin-Buckow, a district of Neukölln with a high population and an extraordinarily high rate of private car ownership (see Senatsverwaltung für Umwelt, Verkehr und Klimaschutz 2017, p. 8, p. 20). It is therefore very reasonable to assume that many citizens in this area use their private car for travel. Incidentally, we checked and, as of 2020, there is no comprehensive car sharing offer available in this district either, which further strengthens our case (Mortsiefer et al. 2019). When choosing destination B, we first had to specify reasons for travel. In order to maximize its generalizability, we were looking for the main purposes for travel in Germany. According to the most comprehensive government statistics, these are shopping and leisure (see BMVI 2018, p. 61). Consequently, end point B is selected at Hackeschen Höfen, a very popular and well-known shopping and leisure destination in Berlin Mitte, the busy, most central borough of the city of Berlin. Sticking with this setting, the day of travel is set as Saturday, and time of day to around 1:00 p.m., since this is the time when most people in Germany go shopping or enjoy their free time according to the government statistics (see BMVI 2018, p. 67; hystreet.com 2020). Both locations, A and B, are in the proximity of public transport stations. A is located near Tempelhof, while B is near Oranienburger Straße. This selection results in an overall travel time that corresponds well with "average" values for Berlin. It also provides us with a marginal case setting. This means that the travel time from public transport station, Hub A, to end point B is similar for drivers and public transport users (using travel time estimates from Google Maps). This makes it easy to isolate causal effects and argue that any time advantage is indeed caused exclusively by getting users out of their cars and into a different transportation solution. Figure 5 depicts our locations A and B on a map of Berlin.

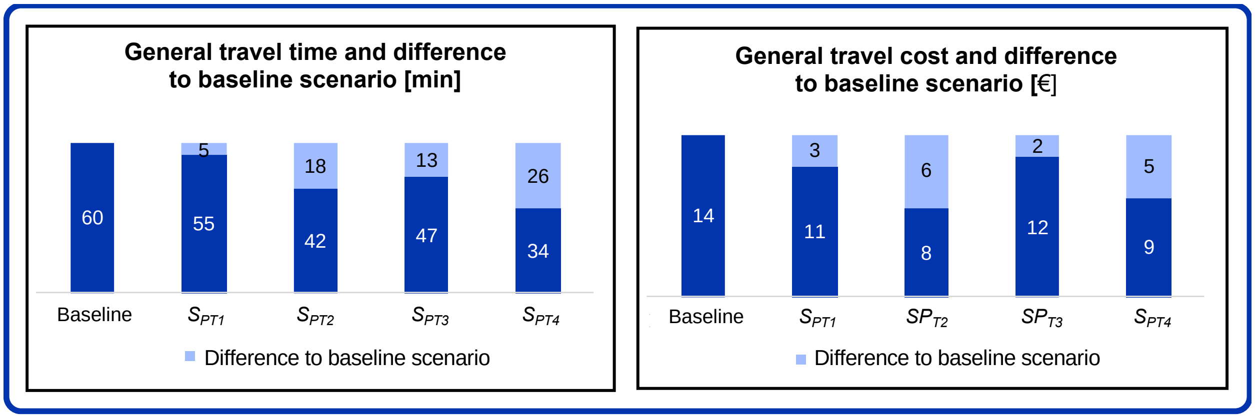

Figure 6: Faster and cheaper intermodal travel with public transport (Oehrlein 2020)

Results: Speed, savings …

Speed. Figure 6 depicts the results for all scenarios and compares them with our baseline. On the left is the chart for travel time, on the right the one for cost. Even on the surface, without looking closely at the details, the results are very clear, with all of the bars smaller than the one for our baseline. Our simulation experiments prove quantitatively that intermodal travel with public transport can reduce travel time, increasing the overall travel speed. The savings are also substantial: adding some “smart” features, such as parking predictions, increases time savings by more than 10 %, which is consistent with our previous findings that “smarter is faster” (see S_2 in Figure 4). Time savings for the smartest scenario with public transport (S_{PT4}) came to approx. 40 % (26/60), exceeding all other scenarios. Time savings for S_{PT4} are even double the size of the smartest scenario without public transport S_2 (see S_3 in Figure 4). So, in terms of travel time, the outcome strongly supports the idea that intermodal methods can also help speed up public transport. In terms of robustness of findings time savings are so substantial, you could even miss a subway or light-rail connection in Berlin (during the day they typically run in intervals of 4 and 5 minutes respectively) and still be faster.

Cost. Travel time is probably the top criterion involved in 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 matters, and for obvious reasons: if you don’t have it, you can’t buy anything. And even if you have money, funds are typically limited, and you have to budget. As a result, some may have to forgo time savings for budgeting reasons. Our analysis has therefore been extended to include cost as well. Figure 6 reveals the cost of scenarios S_{PT1}- S_{PT4}. Here too, anything is cheaper than the base scenario. How did we arrive at end user cost? Our calculation first considers the different cost categories of (a) car usage per kilometer, (b) parking, (c) public transport, and (d) micromobility; it then uses average prices for each category as a starting condition. Finally, price levels for each category are adjusted on a scenario basis. For example, parking: our calculation recognizes that parking in the inner city near B is approx. 100 % more expensive than outside the center, near A (see parkopedia.com 2020). Similarly, the act of searching for parking is also costly. With smart parking a driver is guided straight to an empty spot. Without smart parking, the driver has to circle and keep driving around the block. This process is much shorter, and therefore cheaper, near an off-site location such as A than at an inner-city location B, which suffers from dense traffic during peak shopping times. What's more, the costs involved in using a car usually exceed the price of a public transport ticket. For trips farther than six kilometers, a car tends to be more expensive than public transport (in inner cities a distance of six kilometers translates into a travel time of approx. 17 minutes; see INRIX 2020, p. 16). As a result, it is no surprise that a combination of moving from car via smart parking to public transport for the greater part of the journey to B beats using a car to go from point A all the way to B, not only in terms of time but also cost.

Comfort. We did not talk about it initially, because most anybody will publicly agree that time and cost are paramount. However, we have to admit that we love comfort. And we are willing to pay for it or forgo time and cost advantages, especially if the amounts involved are small. Here humans struggle with the psychological trap of absolute versus relative effect (see Nobel prize winning economics research by Tversky & Kahneman 1981). For example, paying one euro more doesn't seem much in absolute terms; it is small change. However, in relative terms, compared 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, what is the case with comfort in these scenarios? We argue that there is something to gain from comfort. A key advantage of public transport is being driven or chauffeured. Some of us love to drive around like in the car ads, zipping through the mountains or along the shore on empty winding roads. However, urban traffic is something else entirely. Instead, traffic is often one big 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 monotony, drivers need to pay attention at all times because mistakes can be downright deadly. According to the latest data, deaths of vulnerable road users like pedestrians and bikers are indeed on the rise (54 % of those dying on the world's roads are vulnerable road users, WHO 2020, link; while the total number of road deaths in Germany in 2019 was 16.5 % lower than in 2010, a decade ago, the number of cyclists killed has increased by 16.8 % over the same time, Destatis 2020, link). 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 can be used productively, such as to get a head start on emails for the day. It seems that with a smart intermodal upgrade such as 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.

Stations?

In addition to being "faster, cheaper, and better," our experiments revealed another gem of insight, an unintended lesson learned, one that would warrant further investigation: the importance of public transport stations or hubs. We stumbled upon this when assessing the amount of on- and off-street parking around candidates for A and B. For a mobility station, the right amount of parking is a key design attribute and, in hindsight, quite obvious. Similarly obvious is having the right location for a mobility station. However, it seems that the importance of right location is much less obvious. Why? Because it is hardly mentioned anywhere. Neither recent nor extensive studies seem to cover it. For example, the big "Handbook Mobility Stations North Rhine-Westphalia", which is already in its 2nd edition just four years after its publication in 2015, and therefore, could be considered to be quite popular, covers numerous topics from regulation and signage to operations; yet "identification of location" is only mentioned once in the entire report and then simply as a check list item (Zukunftsnetz Mobilität NRW 2019, 47). There is no reference to its importance, no warning label, and probably because this is lacking, there is no guidance either as to how to select the right location. At the same time, there is plenty of advice on absolutely everything else, including bike racks and aspects for the station's look & feel, such as nice signage. Yet, a mobility station's success may be mostly down to "location, location, location," an old truth in real estate concerning home values. Put in the wrong place, all could be lost, despite cool signage, logos, etc. The right location seems to be what mathematicians describe as a first order or necessary condition as opposed to a second order or sufficient condition. How do we know? When scouting for our A, we also consulted a list of "Park and Ride" (P+R) stations. Why not take a shortcut and pick a station explicitly designed to facilitate switching from car to public transport? We were surprised, however, about the high variance of occupancy and quality indicators (see for example, ADAC, 2019, link). Maybe stations were created where space was available and not necessary based on demand. This convinced us to avoid cutting corners. Instead, and as outlined earlier, we pursued a bottom-up, demand-driven selection approach, targeting locations based on real people and traffic flows using numerous data sources, including government statistics and true micromobility usage data as well as motion data from anonymized signaling data from mobile networks. Even so, the question of success factors for these mobility stations and their relative importance surely warrants a deeper look, so stay tuned.

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