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RESEARCH PAPER

The Economics of Multi-Hop Ride Sharing

Creating New Mobility Networks Through IS

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Abstract Ride sharing allows to share costs of traveling by car, e.g., for fuel or highway tolls. Furthermore, it reduces congestion and emissions by making better use of vehicle capacities. Ride sharing is hence beneficial for drivers, riders, as well as society. While the concept has existed for decades, ubiquity of digital and mobile technology and user habituation to peer-to-peer services and electronic markets have resulted in particular growth in recent years. This paper explores the novel idea of multi-hop ride sharing and illustrates how information systems can leverage its potential. Based on empirical ride sharing data, we provide a quantitative analysis of the structure and the economics of electronic ride sharing markets. We explore the potential and competitiveness of multi-hop ride sharing and analyze its implications for platform operators. We find that multi-hop ride sharing proves competitive against other modes of transportation and has the potential to greatly increase ride availability and city connectedness, especially under high reliability requirements. To fully realize this potential, platform operators should implement multi-hop search, assume active control of pricing and booking processes, improve coordination of transfers, enhance data services, and try to expand their market share.

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1 Introduction

Ride sharing, i.e. the joint travel of two or more persons in a single car, has long been a common way to share the costs and benefits of private cars (Furuhata et al. 2013). Today, dedicated platforms allow drivers to post their rides online. Such information systems have helped to mitigate many issues which previously limited ride sharing. Trust among strangers is established through rating and review systems, meaningful profiles, user verification, and automated booking and payment processes (Gefen and Straub 2004; Kim et al. 2010; Slee 2013; Teubner et al. 2014). Online platforms have also dramatically decreased transactional cost for ride listing and search (Beul-Leusmann et al. 2014). Fueled by these developments, large ride sharing platforms like RelayRides, BlaBlaCar, or Carpooling.com have emerged.

Yet, these platforms have not developed new ride sharing concepts. The underlying matching process still resembles a billboard of posted rides waiting for interested riders. Consequently, despite its obvious advantages (reduced cost, congestion, environmental impact), ride sharing remains a somewhat niche transportation option with limited route choice (mostly connecting larger cities) and sparse schedules (only few rides per route per day). However, today's ubiquitous information systems offer the possibility to greatly extend ride sharing capabilities through real-time monitoring and live matching. Such IS improvements can help to better utilize existing resources. This is well-aligned with the recent emergence of Green IS advocating the idea that IS research can and should play a more active role in solving problems of ecological and societal relevance (vom Brocke et al. 2013; Dedrick 2010). Recognizing that mobility is one of the largest energy-consuming systems globally and the only sector with increasing emissions in most countries (Bicocchi and Mamei 2014), the notion of IS-enhanced ride sharing also resonates well with the objectives of the Energy Informatics movement (Watson et al. 2010; Goebel et al. 2014).

One apparent option for augmenting ride sharing is to facilitate chained ride connections with transfers similar to multi-leg flights or train rides. While this requires robust multi-party scheduling capabilities, it also promises to increase ride liquidity as well as destination choice. In this paper, we explore the benefits and economic implications of such multi-hop ride sharing (MHRS) systems. To this end, we rely on empirical ride sharing data to assess MHRS potentials. Furthermore, we consider economic and transactional challenges, leveraging results from platform economics (Rochet and Tirole 2003) and service value networks (Basole and Rouse 2008; Blau et al. 2009). In particular, we address the following central research questions:

1. How *competitive* and *reliable* are multi-hop ride sharing networks?
2. Which *operational* and *strategic challenges* does multi-hop ride sharing pose to platform operators?

By addressing these research questions, our study contributes to the literature on shared and IS-enhanced mobility systems. We assess properties and potentials of multi-hop ride sharing systems by leveraging empirical ride sharing data. This approach allows us to reveal structural and economic properties of such online mobility platforms.

The remainder of this paper is organized as follows: In Sect. 2, we briefly summarize current research on direct and multi-hop ride sharing. Furthermore, we recapitulate key insights from platform economics and service value networks. Based on empirical ride sharing data, we simulate multi-hop offerings and evaluate their potentials and competitiveness in Sect. 3. Section 4 explores challenges for platform operators with respect to pricing, network effects, and platform envelopment. Finally, we discuss practical implications of our findings and indicate paths for future research in Sect. 5.

2 Related Work

Multi-hop ride sharing touches upon different research branches. Firstly, shared mobility systems are a central part of the Sharing Economy which has recently seen great attention (Botsman and Rogers 2010; Cusumano 2014; Teubner 2014). Furthermore, ride sharing can be considered a two-sided market as platform operators cater to two inter-dependent customer groups – drivers and riders (Eisenmann et al. 2006). Finally, the process of creating multi-hop rides resembles concepts from complex service composition in networked service systems (Basole and Rouse 2008; Blau et al. 2009). This section serves to develop these links and provide the theoretic underpinnings for our subsequent analysis.

2.1 Shared Mobility Systems

Comprehensive overviews on the emergence and development of ride sharing are provided by Chan and Shaheen 2012) and Furuhata et al. 2013). Ride sharing is as old as the car itself and experienced particular attention during the 1970’s energy crisis and World War II, where the U.S. government encouraged “[...] four workers to share a ride in one car to conserve rubber for the war effort” (Chan and Shaheen 2012, p. 5). Teal (1987, p. 203), almost three decades ago, noted that ride sharing “occupies a rather curious status as a commuting mode, for in some ways it is inferior to both driving alone and public transit riding, whereas in other respects it is superior to both.”

Brereton et al. (2009) investigates how ride sharing participation can be supported, e.g., by high occupancy vehicle lanes or priority parking. Recent research has also conceptualized real-time and data-enhanced ride sharing (Amey et al. 2011; Lequerica et al. 2010; Bicocchi and Mamei 2014). Such systems rely on mobile and location-based technology and various trust mechanisms alike – enhancing ride sharing by reducing transaction costs and uncertainty (Jones and Leonard 2008; Cohen and Kietzmann 2014). These technologies may also facilitate new business models. Clearly, intra-city transportation has been heavily impacted already, considering the advent of chauffeur services like Uber or Lyft (Rayle et al. 2014). Ride sharing, however, usually covers inter-city connections: according to Carpooling.com, the average distance of a shared ride in Europe is 200 km.

The literature on *multi-hop* ride sharing is still in its infancy. So far, most articles focus on algorithmic and computational aspects of determining optimal multi-hop schedules (e.g., Coltin and Veloso 2013; Herbawi and Weber 2012; Hou et al. 2012; Drews and Luxen 2013). However, this stream of research does not appropriately capture the actual nature of most ride sharing platforms with decentral matching of supply and demand among drivers and passengers. Hence, empirical and practical insights on multi-hop ride sharing remain limited. Our research complements these contributions by exploring real-world potentials of implementing MHRS based on actual market data.

To better understand the role of ride sharing in today's mobility systems, we distinguish the concept from other forms of shared mobility. We propose a novel framework (Fig. 1) to help with this challenge. Our framework maps out the shared mobility ecosystem and how it relates to the Sharing Economy landscape. We consider the main dimensions *customer role* and *asset provision*. Ride sharing, the focus of the remainder of this article, is the market reflected by the top-right sector.

Customer Role – For the case that customers have the car at their (active) disposal, we differentiate between car sharing and car rental. In traditional car sharing programs (e.g., Zipcar or Stadtmobil) customers become members (usually associated with an annual membership charge) and get access to a fleet of cars. Powered by ubiquity of mobile IS, free-floating car sharing systems with ad-hoc access have recently emerged (e.g., Car2Go or DriveNow). These systems allow car pick up and drop off (almost) anywhere within downtown areas. Besides car sharing, of course there is car rental with companies like Hertz, Avis or Sixt. In recent years, car rental platforms for private vehicles have emerged, e.g., Getaround, RelayRides or Tamyca (Shaheen et al. 2012; Bardhi and Eckhardt 2012).

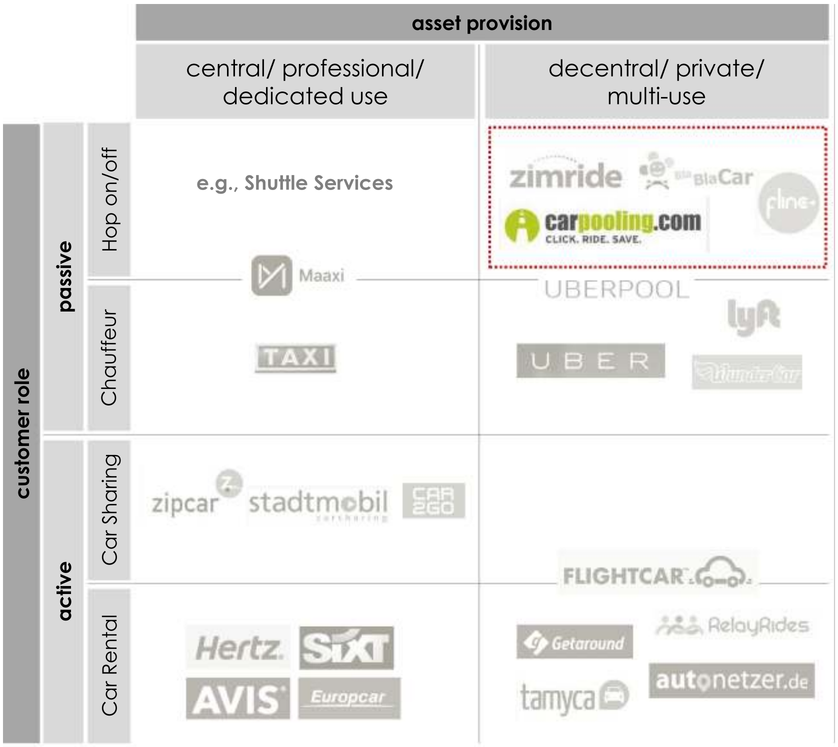
If customers are in the (passive) passenger role, they may specify the destination individually – as is the case of chauffeur services such as traditional taxicabs and emerging on-demand mobility services (e.g., Uber). The route may, in contrast, also be pre-defined like in the case of shuttle services or most ride sharing platforms where drivers determine the ride specifics such as meeting point and destination beforehand. There is a natural logic to this supply-driven paradigm: Drivers can typically accommodate multiple riders and are hence expected to remain active in the matching system for a longer period.

Asset Provision – Car sharing programs, car rental, as well as shuttle and taxi services rely on dedicated resources which are centrally owned and maintained. Their decentral counterparts are private vehicles – after all, the average private car sits idle for 23 h a day (Shaheen et al. 1998). Such better utilization of available resources is a central theme behind the recent up-rise of the Sharing Economy (Sundararajan 2013). Besides the ownership dimension, asset provision also entails an organizational aspect: Decentral systems cannot rely on a central dispatcher matching supply and demand. Rather, there are platforms serving as intermediaries between drivers *and* riders. The attractiveness of such a platform simultaneously hinges on both the number of active drivers and the number of riders. Such two-sided structures are a common theme throughout the Sharing Economy (Malhotra and Van Alstyne 2014).

2.2 Platform Economics and Two-Sided Markets

Eisenmann et al. (2006, p. 92) succinctly note that "companies in [two-sided markets] make money by linking [...] different sides of their customer networks." Such markets are omnipresent and include, among others, credit card systems (merchants and buyers), video gaming platforms

Fig. 1 Taxonomy of car-based shared mobility systems



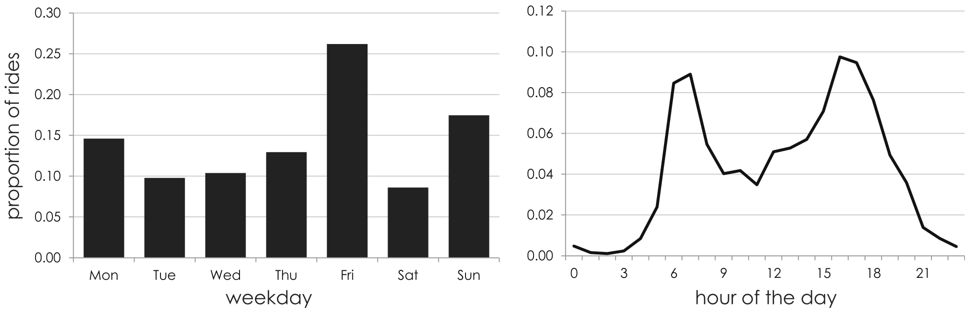


Fig. 2 Carpooling.com – distribution of rides across weekdays and hours

(game developers and gamers), classifieds (sellers and buyers) or dating sites (men and women). Evans (2003, p. 43) more precisely defines two-sided markets by means of the following three criteria: "at any point in time there are (a) two distinct groups of customers; (b) the value obtained by one kind of customers increases with the number of the other kind of customers; and (c) an intermediary is necessary for internalizing the externalities created by one group for the other group." For the case of ride sharing, the distinct customer groups are given by riders and drivers. Riders benefit from more rides offered by more drivers whereas drivers can better utilize their vehicle capacity in the face of many riders. Finally, platforms are required to enable the decentral coordination of drivers and riders, including the challenge to overcome problems related to (a lack of) trust. Consequently, ride sharing can be considered a two-sided market and platform operators need to internalize the economics therein.

2.3 Service Networks

Traditional value chains emphasize isolated transactions in the context of stable business relationships to efficiently provide standard products. Yet, they are less less suitable to respond and quickly adapt to dynamic and uncertain customer demand. Against this backdrop, (Heck and Vervest 2007, p. 32) characterize Smart Business Networks as a new, ICT-enabled organization form "where business is conducted across a rapidly formed network with anyone, anywhere, anytime." Such networks can enhance customer value through rapid adaption as well as provision of complex and bundled products. This idea is generalized by the notion of service value networks (SVN) where decentralized service providers act in a networked context. By combining individual service offers, these networks are capable of augmenting basic services to *complex services* which offer superior value to customers (Blau et al. 2009). Key obstacles to overcome include interoperability, service composition, and pricing. Following Basole and Rouse (2008), value in SVNs is created through B2C and C2C relationships, and depends on the technological and economic context. Leukel et al. (2011) adopt this vision to characterize supply chain systems as a network of services. Bohmann et al. (2014 p. 76) reiterate the potentials and importance of networked service systems. They note that "by focusing on economic and societal needs, service systems innovation can improve the impact of research on business and society, e.g., by improving [...] sustainable mobility [...]."Our research explores such a scenario with drivers, riders, and platform operators advancing singular trips towards interlinked, complex mobility services: Where current ride sharing systems consider individual rides in isolation, multi-hop ride sharing platforms use ICT systems to create a network of "ride services." Service value networks offer a theoretical framework to model MHRS as a combination of mobility services, provided by independent individuals, and to consider crucial properties like compatibility, pricing, revenue sharing, and default risks. Recombination of individual simple ride services enables higher transport efficiency through improved driver-rider mappings and increased mobility options for riders.

3 Analysis

Our analysis is based on data from the main European ride sharing company Carpooling.com.[1] On all its country-specific platforms, drivers post ride offers and specify departure time, meeting point, ride rules (e.g., smoking, pets or oversize baggage) as well as prices. Ride seekers send booking requests. The driver may then demand additional information, or simply confirms or declines the request. The company charges an 11 % provision on the ride's listed price, paid by the driver.

3.1 Data Description

Figure 2 illustrates the platform's activity on a weekday and daily basis. Our data sample comprises rides that were

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[1] While writing this paper, Carpooling.com has been taken over by its France-based competitor BlaBlaCar which, however, does not reduce the validity of our data, analyses, or conclusions as the market models of both firms are virtually identical.

listed for Friday, February, 15th in 2013, two days prior to that date, connecting the 21 largest German cities (based on population).[2] We chose Friday as it is the most busy ride sharing day with respect to both the number of rides offered as well as the total distance covered. In total, there are 3847 direct rides in our dataset for that particular day and city-to-city network.

We extracted the following properties for each ride offer: origin and destination city, date and time of departure, cost in EUR (as specified by the driver). Distance and duration of the rides were extracted using Google's directions web service.

3.2 Generating 2-Hop Rides

Based on this body of ride offers, we now consider the generation of 2-hop rides and its potentials. To this end we present a method to generate *tight* multi-hop schedules from a set of direct rides. We generate 2-hop rides as follows: Assume you wish to travel from origin A to destination B. The number of direct rides from A to B may, however, be limited so that one cannot find an adequate ride. Hence, we consider the option to travel from A to X, and then onward from X to B instead.[3] We use the following operations to generate a schedule of feasible 2-hop rides:

First, a join of the table of direct rides (T) with itself on `T(1).destination == T(2).origin` generates all theoretical 2-hop rides. This data set is instantaneously reduced by considering only feasible combinations of rides with respect to time and route constraints. These constraints entail that the connecting ride must start after the feeder ride has ended, including some buffer time ($l_b \geq 0$) and a limit for waiting time ($l_w > l_b$). Formally, this yields $t_1 + l_1 + l_b \leq t_2 \leq t_1 + l_1 + l_w$ where t_i denotes the start time of ride i and l_i its duration. Also, we assume a limit for the extra distance travelled along the path A-X-B in comparison to the direct distance from A to B $((d_{AX} + d_{XB} \leq \delta d_{AB}, \delta > 1$, where d denotes distance and the parameter δ specifies the constraint). In the following, we assume $l_b = 15\,\text{min}$, $l_w = 90\,\text{min}$, and $\delta = 1.25$ for generating the MHR set.

Note that a specific ride from A to X may facilitate multiple follow-up rides from X to B within the acceptable time frame. In order not to overestimate the number of rides in the MHR set, we eliminate all dominated connecting rides in terms of cost and time of departure, where lower cost and earlier departure time are assumed to be preferable. Similarly, two or more rides of the first leg may be covered by the very same ride on the second leg. Again, this redundancy is reduced by eliminating all dominated rides. In this case, lower cost and *later* departure time are preferable. In doing so, we generate a tight schedule and avoid inflating the set of MHRs with dominated alternatives.

3.3 Liquidity Effect

Based on the set of 3847 direct rides and the time and detour constraints, we generate an additional set of 3594 multi-hop rides. The direct rides alone cover 346 of the 420 edges in the directed ride sharing graph, whereas this value increases to 396 when including 2-hop rides. Being a sequence of basic database operations, this approach should be easy to implement as a search option by any online ride sharing platform.These results are naturally influenced by the parameter selection used for MHR set generation (admissible detour δ, minimum buffer l_b and maximum waiting time l_w). To assess their influence we conduct sensitivity analyses with respect to these parameters. While varying a single parameter, the remaining two are held fixed at their original values. The analysis results are depicted in Fig. 3.

Interestingly, the results are fairly insensitive with respect to the transfer time buffer (left panel). With respect to the maximum waiting time, the number of trips is also insensitive around our base case $l_w = 90$ minutes (center panel).[4] However, in the interval [20, 40] min, the sensitivity of waiting time is much higher. Finally, the maximum detour value (default value: $\delta = 1.25$) plays a central role for facilitating additional multi-hop rides (right panel). Besides providing information on the robustness of our results, the sensitivity analysis can also be used to assess the relative importance of different dimensions in MHR matching. Service providers can leverage these insights to optimize processes, e.g., synchronize departure times or suggest routes to drivers.

Of course, a direct ride (if available) will always be preferred over a 2-hop ride.[5] However, the additional

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[2] These are (in descending order): Berlin (B), Hamburg (HH), Munich (M), Cologne (K), Frankfurt/Main (F), Stuttgart (S), Düsseldorf (D), Dortmund (DO), Essen (E), Bremen (HB), Leipzig (L), Dresden (DD), Hanover (H), Nuremberg (N), Duisburg (DU), Bochum (BO), Wuppertal (W), Bonn (BN), Bielefeld (BI), Mannheim (MA), and Karlsruhe (KA).

[3] In this study, we limit the analysis to rides with one transfer (i.e., two hops). Drews and Luxen (2013), found negligible improvements when allowing for more than two hops.

[4] This observation can be explained through the temporal trip distribution as shown in Fig. 2: the morning and evening ride supply peaks are fairly compact. Hence, given a short first-hop ride, waiting times above 80 minutes fail to tap into much extra supply, as the peak has flattened out by then.

[5] Based on the edges served by both direct *and* MHRS rides, MHRS trips are on average 10 % longer in distance, 17 % more expensive, and take 40 % more time than their direct counterparts.

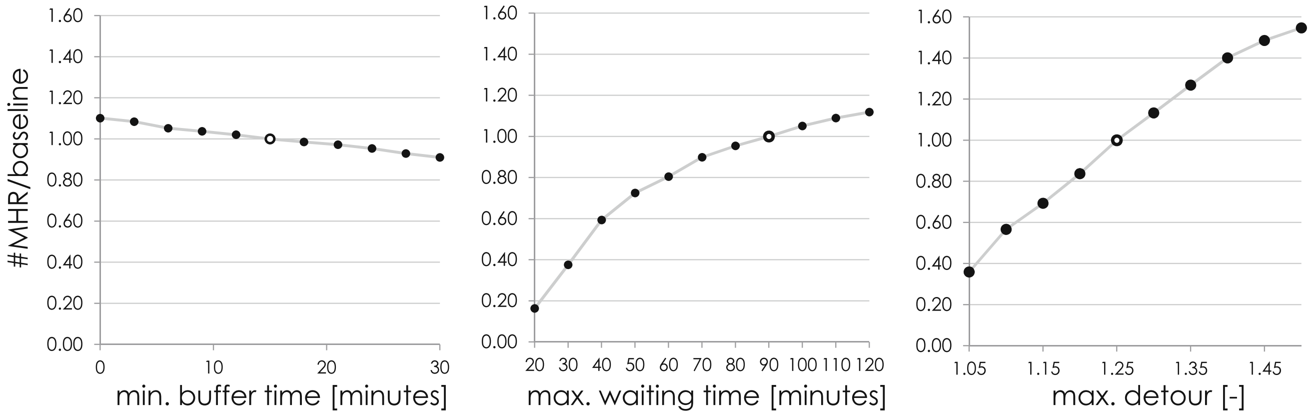

Fig. 3 Sensitivity analysis for number of rides, depending on maximal detour, minimal buffer, and maximal waiting time

offerings can help mitigate shortage situations (special events, holidays, late bookings)[6], improve schedule density or serve as backup connections. We subsequently show that the MHR connections are competitive with other modes of transportation (bus and train).

3.4 Competitiveness

Given the raw potential of MHRS to create new connections, it needs to be assessed whether or not these offering are competitive in comparison to other travel options. Drawing on price and connection data for trains and intercity buses, we compare these three alternatives with respect to travel time and prices. Figure 4a depicts train-, bus-, and MHRS city-to-city relations in terms of duration (hours/100km, x-axis) and price (€/100 km, y-axis). In this normalized time-price space, a given transportation offer for a relation would be dominated by another offer if it is (i) cheaper and at least as fast or if it is (ii) faster without being more expensive – i.e., options positioned to its bottom left. Given the distinct ordering of the three different options, directly dominated relations can hardly be found. Effectively, mode choice will depend on customers' individual value of time.

Asserting a constant opportunity cost of travel time c_t transforms the customer mode choice problem into a linear trade-off between travel time $t(mode)$ and direct monetary costs $c_m(mode)$. The preferred mode then obtains as the minimizer of total costs $C(mode) = c_t t(mode) + c_m(mode)$.[7] Figure 4b plots the share of total relations for which a given transportation option is preferred for varying levels of time value: Naturally, rather slow but inexpensive buses dominate for low values of time (e.g., students), whereas fast and expensive trains will be chosen for high values (e.g., business travel). In the intermediate range, MHRS emerges as the preferred option on most relations. This illustrates the competitiveness of MHRS.[8] Naturally, this analysis does not account for other choice-relevant aspects such as reliability or comfort. Still, the results should be informative with respect to characterizing the market which may be addressed by MHRS.

3.5 Qualified Network Connectedness

We now extend the comparison of direct and multi-hop ride sharing to more general network properties. A central measure in this regard is network connectedness, i.e., the ratio of existing edges relative to all possible edges in the network. The mere existence of a single ride on a given edge, however, may not yet constitute a truly reliable schedule between two cities. To reflect this notion of connection reliability (or width of choice), we deliberately assume a required threshold number of rides between two cities in order to establish an edge between those two cities. Let C be the set of cities, τ the threshold value for the required number of rides, and d_{ij} the number of actual rides on the directed edge between cities i and j. We then refer to qualified network connectedness as $c(\tau)$. Formally, we have $c(\tau) = \frac{1}{|C|(|C|-1)} \sum_{i \in C} \sum_{j \in C \setminus \{i\}} 1_{d_{ij} > \tau}$.

Figure 5 illustrates the ride sharing network for direct as well as multi-hop rides for selected values of τ (4 and 20). Edge thickness indicates the number of listed rides on that edge. Figure 6 reports qualified network connectedness $c(\tau)$ for both the direct ride sharing network and the MHRS network. Naturally, the fraction of

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[6] Anecdotal evidence confirms this notion, as Carpooling.com also retains fully booked rides in its search results, indicating that demand may surpass supply.

[7] The results do not change qualitatively for more complex, e.g., non-linear, relationships.

[8] This analysis is based on train prices discounted by 50 % to reflect the possibility of obtaining low-cost tickets or other discount programs ("BahnCard50"). The analysis favors MHRS even more when assuming regular train fares.

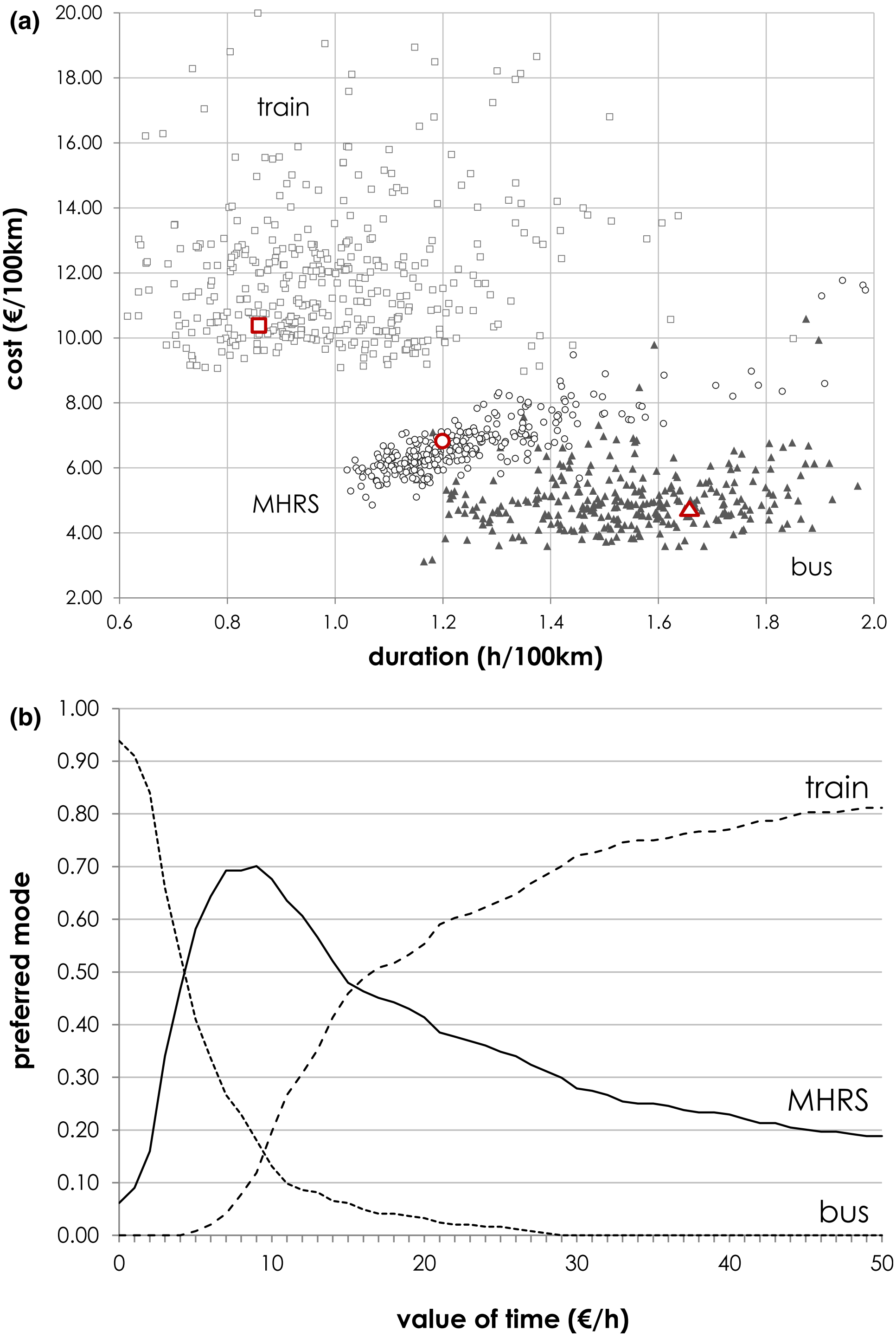

Fig. 4 Competitiveness of MHRS against other modes of transportation. **a** Duration (h/100 km) and price (e/100 km) for train, bus, and MHRS. Relation values for "Hanover to Karlsruhe" are highlighted in *red*. **b** Proportion of city-to-city relations, on which train, bus, and MHRS are the preferred modes of transportation (color figure online)

connected cities decreases as the threshold τ increases. Introducing MHRS increases average connectedness by 20 to 30 % points across all requirements.[9] In relative terms this represents an increase between 20 % (for very low threshold values) and more than 100 % (for threshold values beyond $\tau \geq 7$).

In summary, MHRS greatly increases ride availability and city connectedness. These results are robust to parameter variation and different reliability requirements. MHRS is especially valuable under high reliability requirements.

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[9] This difference is significant for any conventional threshold. Using Fisher's Exact Test with groups "direct only" vs. "direct + MHRS" and outcomes "link exists (#rides $\geq \tau$) and "no link (#rides $< \tau$)," and for all $\tau \in \{1, 2, \ldots, 20\}$, yields p-values $< .0001$.

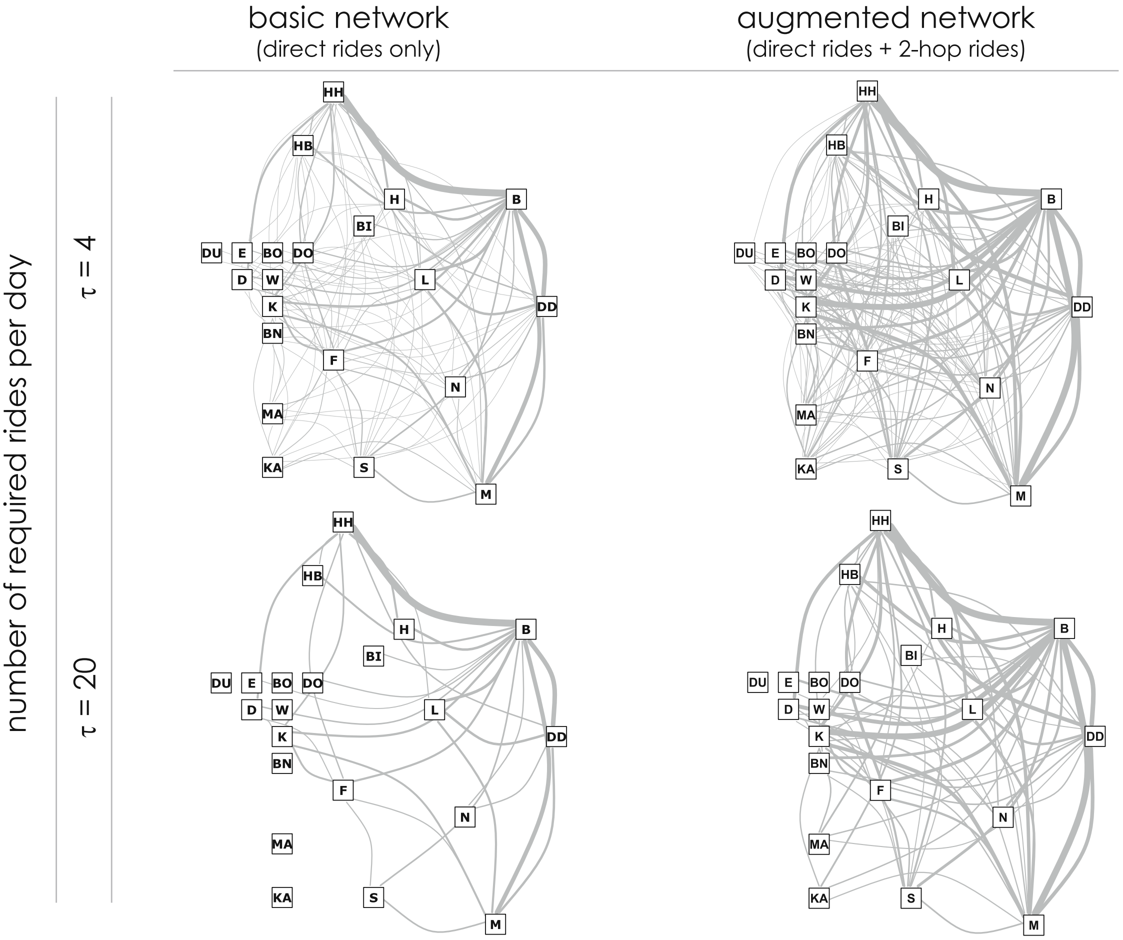
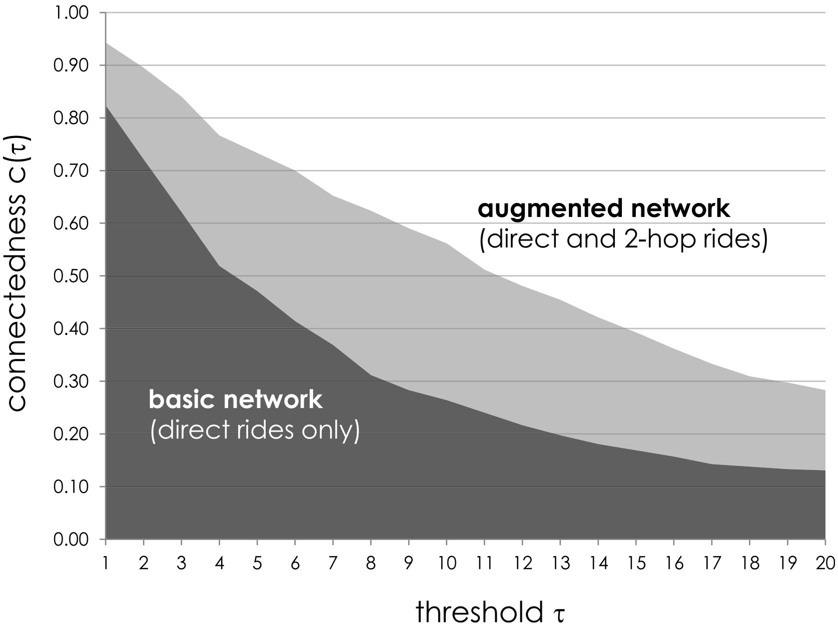


Fig. 5 Direct and multi-hop ride sharing graphs for different values of τ

Fig. 6 Qualified network connectedness for different τ values



4 Strategic Challenges for Platform Operators

As noted above, ride sharing systems constitute two-sided markets where platforms mediate between drivers and riders. Eisenmann et al. 2006) put forward three central business challenges in two-sided markets: getting *pricing* decision right, coping with *winner-takes-it-all dynamics*, and handling the risk of *platform envelopment*. We explore these success factors to analyze platform challenges for multi-hop ride sharing systems in this Section.

4.1 Pricing in Multi-Hop Ride Sharing Systems

In two-sided markets, there is no unique equilibrium price determined by the intersection of demand and supply. Rather, platform operators need to figure out pricing individually for both sides of the market. Very often platform operators will charge only one group of customers (“money side”) with the other customer group incurring minimal or zero costs (“subsidy side”). Rochet and Tirole 2006) structure payments by considering usage charges and membership charges. Current ride sharing platforms opt for free membership on both sides and usage charges only incurred by the drivers (lump sum or proportional to ride revenue). From the platform’s perspective riders are hence the subsidized market side. This does not mean that riders ride for free (payments to drivers will still apply), but they are not charged by the platform. This structure allows platforms to limit the number of individual transactions when drivers serve multiple riders. At the same time it leaves pricing decisions for individual rides with the drivers. As we will see, this may be problematic for facilitating multi-hop ride sharing.

We now explore pricing strategies for platform operators. In the absence of multi-hop services on current platforms, we base this analysis on the price data from direct ride sharing and discuss its implications for MHRS. To assess the economics of ride sharing, we use regular OLS regressions to identify the key determinants of price/100km and the number of rides on the city-to-city relation level ($n = 346$). The following independent variables are considered: trip distance (in km), square root of trip distance (in regression Model 2), as well as the geometric mean (termed “metropolity”) of the connected cities.[10] The regression results are summarized in Table 1. Additionally, we illustrate the effect of distance d and $\sqrt{d}$ on price and liquidity for different metropolity values in Fig. 7.

With regard to distance, we observe a “quantity discount:” the price per 100 km decreases in trip length. However, the results from Model 2 indicate that this effect flattens out eventually.[11] The ability to reflect diminishing quantity discounts greatly increases the explanatory power with explained variance increasing from 40 to over 67 %. Operators need to watch out for potentially adverse effects arising from distance quantity discounts: In orchestrated ride chains, riders would not qualify for such discounts, as their trip is composed of multiple shorter rides. This augments the relative price disadvantage of multi-hop rides vis-a-vis direct rides. To be competitive not only with other transportation means but also against direct rides, multi-hop rides should effectively be offered at a discount. To achieve this, platform operators need to assume pricing themselves as drivers do not take into account the context of their passengers’ journey. Taking pricing responsibility away from drivers removes the possibility of erratic pricing and undercutting (similar to Apple’s App Store) and will help to establish ride prices in an “objective” manner based on, for instance, distance, availability, type and comfort level of the car used, or the driver’s experience or reputation. Active management of booking and payment processes also allows platform operators to gain direct access to cash flows and in turn optimize their business model.

Table 1 Regression analysis of price/100 km and ride liquidity

	€/100 km		# rides	
	Model 1	Model 2	Model 1	Model 2
Distance (km)	−0.006***	0.022***	−0.026***	−0.125***
Sqrt (distance)		−0.921***		3.275***
Metropolity	−0.096	−0.385*	38.254***	39.279***
Intercept	8.395***	15.289***	−6.482***	−30.989***
n	346	346	346	346
R^2	0.396	0.671	0.611	0.651

Model 2 also suggests that there is a minimal negative effect of metropolity on price per 100 km.[12] This decrease is most likely due to higher liquidity on more populous connection relations.This assertion is confirmed when analyzing the regressions on ride liquidity (number of rides): Metropolity is a positive driver on a given connection. Distance, on the other hand, has a maximum at

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[10] Formally, this is given by $\sqrt{p_1 p_2}$ where p_1 and p_2 denote the population figures (in millions) of city 1 and 2, respectively.

[11] Note that 90 % of all relations fall within a range from 80 to 600 km.

[12] The price decrease is 38.5 cents per 100 km for a 1 million increase in the geometric population mean. For the two largest cities this would suggest a reduction of 95 cents per 100 km compared with a reduction of 36.5 cents between the two smallest cities.

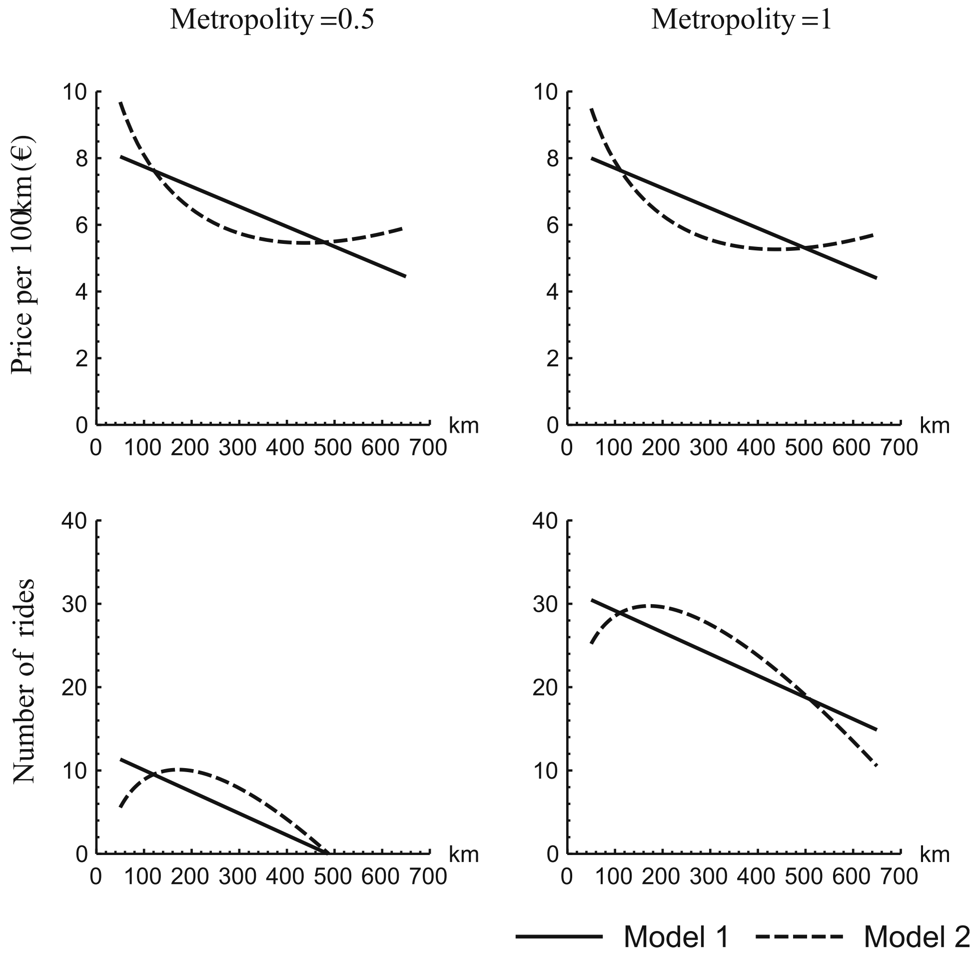

Fig. 7 Illustration of regression models for generic metropolity values

about 150 km and reduces the number of rides offered between cities for larger distances.[13] For very small distances, ride sharing like any other mode of inter-city transportation is dominated by local public transport.

Going forward, drivers may even be rewarded for offering rides which facilitate a high number of in- and outward connections. This will require more sophisticated pricing routines such as marketplaces (Deakin et al. 2010), complex service auctions (Kleiner et al. 2011; Blau et al. 2010), or dynamic pricing akin to Uber's surge pricing (Gurvich et al. 2014) to be integrated within the platform. Such changes should incite more drivers to list their rides in times of high demand. Potentially, some riders may consider becoming drivers themselves (Zhao et al. 2014). Stimulating a higher supply by dynamic pricing can then improve customer experience, increasing the rate of returning customers and overall (perceived) service quality.

4.2 Winner-takes-it-all Dynamics

Many two-sided markets are served by a single, dominant platform (e.g., eBay, Airbnb) whereas in other markets, multiple competing platforms co-exist (e.g., dating networks). The Winner-takes-it-all dynamics hence do not necessarily apply equally pronounced to all types of two-sided markets. In this section we analyze these network dynamics for multi-hop ride sharing. MHRS network effects may manifest themselves with respect to ride liquidity and qualified network connectedness. Starting off from our market data set, we assess the extent of concentration benefits by analyzing the effect of varying platform size on the values of liquidity and qualified network connectedness. Smaller platform sizes are simulated as random subsets of the complete ride data set. To minimize sampling biases, we repeat this 100 times for each value of platform size (0 to 100 % in steps of 5 %).

Liquidity Higher levels of liquidity, i.e. a higher number of available rides, offer more choice to potential ride sharing users. This typically involves more available start and end points but also a wider choice of departure times or meeting points and is thus preferable. Figure 8a shows that

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[13] These findings are in line with standard gravity models as used in transportation analysis (Erlander and Stewart 1990).

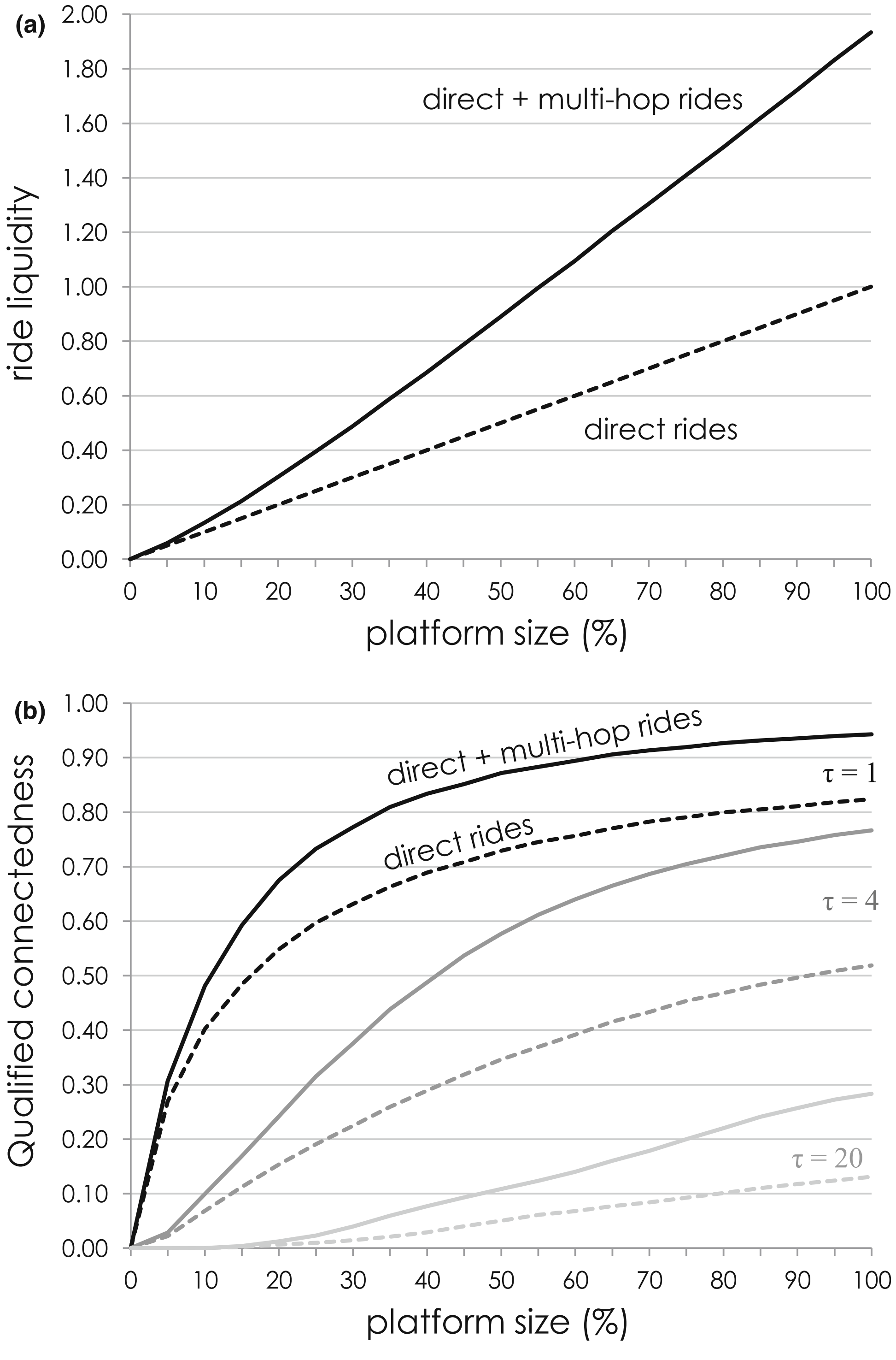

Fig. 8 Ride liquidity and qualified network connectedness for varying platform size. **a** Ride liquidity, **b** qualified network connectedness

MHRS liquidity increases much stronger than direct ride liquidity in platform size. Hence, larger platforms will benefit more from implementing MHRS than smaller platforms. Note that the cost of setting up such a system is most likely independent of the size of the underlying data base. And even more so, the *convex* structure accelerates this effect, stemming from the super-additive process of ride recombination.

Connectedness Qualified network connectedness is more specific than mere liquidity and captures the share of cities in the network connected by a minimum number (τ) of alternative rides. As noted in Sect. 3.5, qualified network connectedness is a key determinant for ride sharing service quality. This measure provides a clear quantification of how likely customers are to find suitable rides for their demand. As depicted in Fig. 8b, qualified network connectedness is naturally increasing in platform size. However, given the upper bound of 100 percent, the marginal benefit of platform size is decreasing and we observe a *concave* benefit structure. Consequently, qualified network connectedness is only weakly increasing in platform size if a critical mass is reached. In contrast, the impact of additional ride volume is considerable for small platforms. Again, the transition from direct rides to MHRS offers great potential in increasing qualified network connectedness, particular for moderate values of τ.

Multi-homing Another important factor in assessing whether a single firm dominates or not is the possibility for customers to be simultaneously active on multiple platforms. This is referred to as "multi-homing" (Rochet and Tirole 2003). Most ride sharing platforms do not charge any membership fees and both advertising and searching for rides is easy and effortless. So currently, multi-homing is possible. However, in view of automated booking processes this becomes an issue. Requests on different platforms cannot be synchronized and may likely result in double bookings. Such conflicts are extremely aggravating for drivers and users and will not increase perceived quality and trust in ride sharing services as a whole.

Taken together, MHRS may trigger significant network effects. With regard to MHRS liquidity, larger platforms will be more capable of creating a high-volume and in turn high-quality service. With regard to qualified network connectedness, ever larger platform sizes will yield limited additional benefit. Entrants, however, will struggle as they initially find themselves in a particular steep section of the curve and are hardly capable to offer reasonable connectedness – particularly for higher reliability requirements. Consequently, top dog platforms could well play out their competitive advantage and further strengthen their position by introducing MHRS. Moreover, central booking management approaches will limit multi-homing and increase customers' platform loyalty.

These findings speak in favor of a "winner takes it all" type of market for multi-hop rides (Eisenmann et al. 2006). We suggest that cooperation or acquisition of competing platforms could be a worthwhile consequence. In fact, the European ride sharing market currently experiences a process of such concentration.[14] In the U.S. in contrast, there still exists a large variety of (local) ride sharing platforms (Chan and Shaheen 2012). However, extensive distances between areas may limit the concentration potentials.

4.3 Platform Envelopment

The business potential of platforms can be severely eroded or "hijacked" by adjacent platforms catering to similar customers (Eisenmann et al. 2011a). Consequently, compatibility and inter-operability decisions are of strategic importance (Eisenmann et al. 2011b).

Platforms adjacent to the ride sharing market include railway and long-distance buses. Given their different positioning in the price-quality space, the risk of envelopment may not be imminent. Still, multi-hop ride sharing platforms may want to consider establishing interfaces with other transportation modes. If properly executed, such multi-modal mobility platforms may emerge as a new dominant business model. Companies like goeuro.com, moovel.com, fromAtoB.com, or rome2rio.com have started into this very direction.

To succeed in establishing such solutions, platform operators need to incorporate appropriate search functionality to enable users to specifically retrieve suitable ride combinations, possibly routing via cities not taken into account before. This could be supported by GPS- and live traffic data. Suppliers of connecting rides may be informed in case feeding rides are stuck in traffic and – if the delay is unacceptable for waiting – alternative connecting rides may be preselected and reserved. For such systems to function, ride sharing platforms would ideally provide standard interfaces for other service providers to access their ride base. However, they will only offer such an API if the booking process remains in their hands and is not circumvented. A possible path establish customer loyalty of both drivers and riders is to offer auxiliary services such as support for creating more successful ride offers (e.g., by using profile photos, descriptions, choice of auspicious stopovers), insurance, or customer loyalty and bonus programs (e.g., awarding miles). To this end, traditional mobility operators and other protagonists of the Sharing Economy like Airbnb may serve as an inspiration (Malhotra and Van Alstyne 2014).

Transaction management, in addition to pricing and booking, may eventually entail the coordination and potentially even the maintenance of suitable meeting points to facilitate MHRS.[15] This may even lead to new strategic partnerships, e.g., with gas station operators.[16]

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[14] http://techcrunch.com/2015/04/15/blablacar-acquires-its-biggest-competitor-carpooling-com-to-dominate-european-market/.

[15] Making it from one meeting point to another introduces hassle. Everyone who ever changed trains from Gare de L'Est to Gare de Lyon in Paris will certainly agree.

[16] These are conveniently located and should be interested in ride sharing activities for at least two reasons: i) Drivers are likely to fuel their cars and purchase other products and ii), petrol companies may improve their image by actively supporting ride sharing – a fuel-efficient and thus sustainable activity beyond all doubt.

5 Conclusion

Ride sharing is a sustainable form of transportation. Information systems have improved its accessibility and transparency by providing online supply data and facilitating access and search. Consequently, it may be about to leave behind its niche status in low-income and student milieus. To achieve this, ride sharing platforms need to embrace new operational paradigms and leverage IS in more sophisticated ways. In this paper, we have illustrated that MHRS can greatly increase market liquidity and city connectedness. The impact on connectedness is particular pronounced when requiring a high number of daily trips, i.e. robust schedules. Smaller cities benefit most from allowing multiple hops, our study, however, is based on the largest German cities. We hence surmise that our analysis most likely underestimates the potential of MHRS. Furthermore, we have shown that MHRS represents a highly competitive mode of inter-city transportation in terms of time and cost when compared to its most likely alternatives train and bus.

Our analysis is based on actual market data from a platform without MHRS capabilities. By doing so, we contribute to the understanding of ride sharing and MHRS as much of the previous research on that subject was limited to modeling and computational aspects. Moreover, we argue that leveraging IS technology and e-business practices will help to further grow ride sharing and the novel concept of MHRS towards a more generally adopted mode of transportation. In particular, ride sharing platforms may benefit from the following strategies:

Implementing multi-hop search Given the great potential of combining direct rides, operators should offer efficient and simple search procedures for realizing MHRS. To ensure usability, this function should also provide appealing and informative schedule visualizations.

Active management of pricing, booking, and payment processes Platform operators need to assume pricing themselves to gain access to user cash flows and hence to establish a profitable provision model. Moreover, this enables active pricing of MHRS with the perspective of creating an even more competitive service, potentially even in comparison to direct rides.

Coordination of transfers Unlike central railway stations or airports, there is usually no single meeting point for riders and drivers in a given city. Hence, MHRS-oriented systems need to encourage the synchronization of transfer time and location.[17]

Improvement of data services Current ride sharing IS are rudimentary. The use of real-time and location-based services allows to provide advance information on schedule updates, delays, or alternative ride opportunities. Also API provision to third party intermediaries will increase reach, customer base, and interoperability.

Market share expansion As the two-sided ride sharing market entails winner-takes-it-all properties, data integration or acquisition of competing platforms strengthens an operator's position.

Information technology is omnipresent in day to day life and users start to deal with complex services like peer-to-peer market platforms in a natural way. Ride sharing can play a greater role in future mobility systems, as it compares well against other modes of transportation in terms of cost and travel time. Going forward, the emergence of self-driving cars will transform streets into cyber-physical systems and blur the borders between "passengers" and "drivers." This will further reduce the importance of car ownership and affect every category of car-based mobility (Fig. 1). Information systems can thus contribute to build a better world by creating novel, connected, and shared mobility services. Multi-hop ride sharing may play a vibrant part therein.

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[17] Such optimization could leverage the rich body of research on optimal transit design and train scheduling. See Cordeau et al. (1998) and Guihaire and Hao (2008) for comprehensive reviews.

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