Transportation Planning and Technology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/gtpt20

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To cite this article: Mirko Goletz & Francisco J. Bahamonde-Birke (2021): The ride-sourcing industry: status-quo and outlook, Transportation Planning and Technology, DOI: 10.1080/03081060.2021.1943128

To link to this article: https://doi.org/10.1080/03081060.2021.1943128

Published online: 29 Jun 2021.

TRANSPORTATION PLANNING AND TECHNOLOGY
https://doi.org/10.1080/03081060.2021.1943128

Routledge
Taylor & Francis Group

The ride-sourcing industry: status-quo and outlook

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ABSTRACT
Ride-sourcing, the use of private cars to provide on-demand mobility services, first appeared in San Francisco around the year 2010. Since then, transportation network companies (TNCs) who offer ride-sourcing services have expanded all around the world. By examining three case cities (San Francisco, Mexico City, Paris) we explain what facilitated this growth and how the regulation of TNCs differs. Subsequently, an economic analysis discusses the current expansionary strategy of TNCs and their future. We show that TNCs adapt their strategies to local contexts, with first priority to establish themselves in the market, if necessary, using gray regulatory areas, even if they face resistance from city authorities, taxi drivers and other groups, and despite being unprofitable. Our economic model explains this. We show that an unregulated ride-sourcing market leads to monopolistic situations once autonomous vehicles become available. We hence conclude that city authorities need to develop a regulatory framework to maximize social welfare.

ARTICLE HISTORY
Received 28 July 2020
Accepted 6 April 2021

KEYWORDS
Ride-sourcing; transportation network company (TNC); autonomous car sharing; mobility as a service (MaaS); ridesharing; ride-hailing; case studies

1. Introduction

This paper addresses the global phenomenon of ride-sourcing and the strategies of companies that lie behind them. Several names have been proposed to describe services that are offered by companies such as Uber (USA), DiDi (China) or Yandex (Russia), including (on-demand) ridesharing, for-profit ridesharing, ride-hailing, and ride-sourcing among many others. Zha, Yin, and Yang (2016) present a discussion on this subject, suggesting use of the term ride-sourcing which they define as private car owners who drive their own vehicles to provide taxi-like services for profit. This term will be used throughout this paper. We will also use the term transportation network company (TNC) that has been introduced by the California Public Utilities Committee (CPUC) to categorize transportation companies who offer ride-sourcing services.[1]

Ride-sourcing appeared publicly for the first time in the San Francisco Bay Area/California in 2010 (see Flores and Rayle 2016), becoming globally available since then. Today, TNC services are offered in almost 100 countries around the world, as shown in Table 1. Market leading TNC Uber alone offered its service in 63 countries by the end of 2018 (Uber 2019). In many cities, intense competition between different companies takes

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Table 1. Countries with at least one TNC service.

	Africa	Asia	Europe	Latin America and Caribbean	North America	Oceania	World
Countries	58	51	48	49	5	23	233
Number of countries with at least one TNC service available	10	36	31	17	2	2	97
Share of countries with at least one TNC service available	17%	71%	65%	35%	40%	9%	42%

Source: Own research as at August 2019; 13 TNCs were identified and their presence in each country was verified. Included TNCs: 99, Bolt/Taxify, Cabify, Careem, DiDi Chuxing, Easy Taxi, Gett, GO-JEK, Grab, Lyft, Ola, Uber, Yandex.-Taxi/Yango. Definition of Countries and Regions as in UN World Population Prospects: The 2017 Revision (UN 2017)

place. This leads to the first research question to be addressed in this paper: What makes TNCs become so successful, and how can their fast uptake and growth of TNCs be explained?

TNCs have managed to expand quickly around the world during the last decade, aiming at fast gains in market shares through rapid market entrance and aggressive expansion. This could result in fundamental changes in the mobility behavior of people (see Section 2). While the success of TNCs in expansion and attracting ridership is undoubted, their economic outlook is less clear. In April 2019, the Initial Public Offerings (IPOs) of Uber and Lyft were announced. The IPO prospectus revealed that both companies made high financial losses in 2018, losing US$ 1.8billion and US$ 0.9billion, respectively (Uber 2019; Lyft 2019). Citing future risks, Uber even stated that it 'may not achieve profitability' (Uber 2019). This leads to the question of whether and how TNCs can ever become profitable? Horan (2017) concluded in an analysis of Uber that, since its start, the company has been making losses every year, and may never be able to become a profitable company under its current business model of *selling rides*. He foresees profitability, however, if the company can gain monopolistic market power, being in the position of implementing price discrimination schemes, leading to research question two: How can TNCs gain monopolistic market power (that allow them to implement price discrimination schemes) and what should be done from a regulatory perspective?

2. Literature/State-of-the-art

Hitherto the North American ride-sourcing market has been particularly targeted by researchers, and there again research focused on the developments in California, the origin of the ride-sourcing industry. Tirachini (2020) has delivered an extensive review of the existing research on the impacts of ride-sourcing on travel behavior, car ownership, environmental effects/externalities, prospects and regulation/policy implications. We will, therefore, only touch some key studies in the following account that are of specific relevance for our research and to provide the reader with a brief overview.

Clewlow and Mishra (2017) studied the usage and adoption of ride-sourcing in seven major US cities (study phases from 2014 to 2016), finding that 21% of adults had already used ride-sourcing, indicating a rapid adoption that only took several years. Almost a quarter (24%) even used it daily or weekly, albeit the vast majority (91%) of ride-sourcing users did not change their vehicle ownership status, while on average there was a

tendency to use public transit less (6% reduction in trips). Young and Farber (2019) found, based on household travel data from 2016, for the city of Toronto that ride-sourcing was mostly used by the wealthier, younger generation (mainly from the 'Millennials generation' aged between 20 and 39 years) and linked it to a decrease in taxi ridership and a rise in active mode of travels. Schaller (2017) showed for Manhattan (New York) an overall increase of 600 vehicle miles traveled between 2013 and 2016, and a substitution of taxi trips by ride-sourcing trips, relying on multiple datasets for his analysis. Circella and Alemi (2018) reported, based on a dataset covering millennials and Generation X, a reduced usage of personal private cars by ride-sourcing users, and a replacement of public transit trips and active modes.

Mohamed, Rye, and Fonzone (2020) studied usage patterns and usage groups for shared and non-shared ride-sourcing services in the Greater London Area, surveying riders ($n = 907$) of UberX and Uberpool. They found that users had mostly completed higher education (92.6% UberX / 89.5% of Uberpool) and the majority were aged 18–35 (67.5%/51.5%). Trip purposes differed between non-shared and shared Uber services (UberX's top responses were 'to/from social events/activities' (59.3%), 'visiting family/friends' (39.3%), and 'to/from work' (34.4%); Uberpool users' top responses were 'to/from social events/activities' (83.2%), 'visiting family/friends' (64.1%), and 'to/from PT station/stop' (37.0%)), with a preference for using the service at night and at the weekend for both service types. Further findings included a decrease in car ownership between 6.5% and 9.4% (non-shared and shared ride-sourcing, respectively). Users preferred ride-sourcing over taxis because of being 'quicker', 'safer' and 'cheaper'.

Zha et al. (2016) studied the market structure of ride-sourcing markets (monopoly and competition) and different regulation policies, using an aggregate economic model. They found that regulating the share of the commission that platforms charge is a suitable approach for a regulator. Further studies assessed the role of TNCs in future urban transport systems and for Mobility-as-a-Service operations (Pangbourne et al. 2018). Tirachini and Gómez-Lobo (2019) showed that ride-sourcing increased overall vehicle miles traveled in Santiago (Chile). Furthermore, the media has extensively covered the rapid expansion course of TNCs in the light of high financial losses (CNBC 2017), and rumors about market consolidations/mergers (WSJ 2016).

Along these lines, other authors have analyzed the labor market for ride-sourcing. Zoepf et al. (2018) have conducted this analysis for the American ride-sourcing market. They found below-average net incomes of drivers, frequently going even below the minimum wage. This could indicate that the rapid expansion is more a failure of the labor market than a sustainable business model. In absence of real data from TNCs, the study relied on a survey amongst ride-sourcing drivers who were mainly active for Lyft and Uber. The paper by Zoepf et al. (2018) was heavily criticized by Uber and the media because its calculations may have been based on ambiguous questions amongst ride-sourcing drivers.[2]

The substantial backing of TNCs by private capital shows that there are strong expectations that TNCs can become profitable in the future, especially within the wider context of Mobility-as-a-Service that is becoming more common in cities. Taking into account the loss-making of TNCs, the technological advances in the field of automation and the dynamics of the expansion in recent years, the current market structure likely represents a state that will not prevail, and changes in the market structure regarding the

companies, diversification of supply and users' demand, regulation and other aspects must be expected in future. The question that presents itself is: What will the market for ride-sourcing look like in the future?

In this paper, we focus attention on two aspects: first, we provide a description of the current ride-sourcing industry on an international scale, with a focus on drivers and factors that explain how the industry evolved and finally established itself. For this purpose, we rely upon primary empirical data that we collected during the year 2018 in a qualitative field study in three selected case study cities and areas of Paris, Mexico-City and California-State. The on-site research relies mainly on qualitative interviews with key experts in the field of ride-sourcing. Second, we derive an outlook for the future of the market regarding business models and pricing strategies. This part is based upon theoretical economic derivations in order to discuss possible market structures for the ride-sourcing industry in the future. We finally derive policy implications that can be drawn from our analysis.

3. Empirical work: data and methodology

In our attempt to offer a better depiction of the global evolution of TNCs and ride-sourcing, we first focus on the history and current situation of TNCs in several markets. The research was divided into different phases.

First, a preliminary market analysis (including about 50 cities[3]) was conducted, which was extended by a review of the scientific literature as well as press reports, internet documentation, and information provided by TNCs. The goal was to identify cities where ride-sourcing was available and had a considerable size, while achieving a geographical distribution amongst the world and different stages of economic development (cities in high-income/high-middle-income and low-middle-income countries, following UN income classifications). This approach was chosen as the recent developments in the market have not yet been sufficiently covered by the academic literature and we had to include non-scientific material in different languages. On the basis of previous research, the set of cities was narrowed to 16 for a more detailed analysis, mainly because for these cities a sufficient amount of information was available.[4] The analysis included the collection of data related to TNC operators (number of operators, vehicles and drivers), price structures and basic regulation of TNCs. Further qualitative aspects about the history of TNCs and about the context in each city were added.

Finally, we selected three cities as case study areas. Selection criteria were as follows: our preliminary analysis showed different mechanisms/triggers steering the ride-sourcing market in different regions which we wanted to better understand. We therefore focused on three regions: USA, Latin America and Europe. For each of these regions, we selected one representative case city. In each region, we aimed at selecting a leading city in terms of ride-sourcing, which, at the same time, could be considered to be representative cases for the development in their respective regions (see Flyvbjerg 2006 for case study selection). San Francisco was selected as a leading city in the ride-sourcing market in the US (and likely worldwide) as well as having been the first city where TNCs started to operate, serving as a prototype for the expansion to other US cities. Mexico City was selected as the first Latin American city to introduce TNC regulation (the regulation is now serving as a blueprint for other Latin American cities). Paris

was selected as a European case city, as it includes typical characteristics of European TNC markets: good provision of public transport, spatial heterogeneity, strict regulation and several TNCs operating in the market.

In these three cities we conducted an in-depth analysis, which included a case specific literature review as well as field visits, in which we interviewed key stakeholders from the 'triple helix' (Etzkowitz and Leydesdorff 1995, see also Table 2) in the case study area. The interviews were conducted in January and February 2018 as semi-structured open interviews, covering the topics as in Table 2. For the selection of the case cities, we faced the challenge that in many places, TNCs had just established themselves and that little or no data were openly available (as TNCs and other private companies provide very limited information).

Table 2 presents an overview of the stakeholders contacted in each city as well as the topics discussed with them.

4. Empirical work: the ride-sourcing industry – a global perspective based on research in three exemplary case study areas

As outlined in the introduction, ride-sourcing became a global phenomenon in less a decade, and companies such as Uber, Cabify or Lyft have entered the market in numerous cities around the globe, competing for users and rides in the urban mobility market. In this section, we will contribute to the knowledge about the current strategies of TNCs by a context dependent description of the developments in three case cities and their regulatory approaches. This input is based on qualitative data, intending to describe facts that are statistically unobservable and dependent on the context in each city.

4.1. San Francisco: case description

San Francisco (population 0.8 million inhabitants) is located in California's San Francisco Bay Area (population approx. 7.7 million). The urban mobility in San Francisco and its catchment area is car-centered. San Francisco's public transport system comprises an urban rail system (BART, with six lines), streetcar cars, buses and regional trains, but the reach and capacity of the system is limited (Flores and Rayle 2016).

San Francisco is the city where ride-sourcing firstly appeared (around the year 2010). It is home to the world's leading TNC Uber, as well as to Lyft, Uber's main competitor in the US. The development of TNCs in San Francisco was extensively analyzed by Flores and Rayle (2016)[5], who vividly describe how ride-sourcing started and expanded in

Table 2. Qualitative research overview.

Target Group	Topics
Administration, Cities	Mobility supply in the city Regulations to deal with TNCs Collaboration with Public Transport
TNCs	Service characteristics Strategies and cooperation, such as with public transport
Research and NGOs	Effects on mobility choice User and usage patterns Outlook
Total interviews completed: 15 - 5 per city (Additional background interviews were carried out)	

San Francisco. They describe a situation, in which tech-companies quickly developed the market for ride-sourcing in San Francisco, taking advantage of several favorable conditions that existed during that time, namely:

- an overregulated taxi market that provided unsatisfactory service and, hence, had little local support,
- very favorable regulatory and jurisdictional arrangements governing the for-hire vehicle industry,
- tech-oriented and skilled entrepreneurs willing to take high risks (and users willing to try out new mobility options), and
- political support helping TNCs to maneuver a regulatory shift, shifting regulation at the state level (see CPUC 2013 for details on the regulation).

Flores and Rayle (2016) concluded that the regulatory changes adopted in California cleared the path for the expansion of ride-sourcing to other US cities and the world. In most cities TNCs have entered, they aimed at replicating the San Francisco strategy, entering the market, rapidly growing their user base, and then, once regulators became involved, mobilizing the support of passengers and drivers to lobby elected and politically appointed authorities on their behalf, mostly at state level. This statement also holds when looking at the other case studies presented in this work, especially Mexico City and, to a lesser degree, Paris, where similar strategies finally allowed TNCs to make their way into the countries' mobility sector.

San Francisco was the first case, where the quick expansion of TNCs by externalizing capital cost and risks (to the drivers) was successfully demonstrated, and it is the blueprint followed in other cities (Flores and Rayle 2016; Shaheen 2018, own interviews). It is now a city with a great diversification in the TNC products, such as pooling or specific vehicles. Uber itself states that the pooling market is one of the biggest around the world, with UberPool representing around 50% of the requests (source: interviews/own field notes). However, and despite the extraordinary expansion, the industry is far from becoming profitable according to press reports and expert opinions. The focus on market presence was explained by a researcher in the US, who depicts the aggressive expansion strategy of Uber in light of rising losses as follows:

> '*Uber is basically a bet of the tech-VCs on robo-taxis: whoever dominates this market when the technology is ready, will become market leader.*' University researcher, USA

In fact, this opinion seems to be shared by most of the experts consulted, as summarized in the following statement:

> '*There is no pathway to profitability without automation.*' University researcher, USA

4.2. Mexico City: case description

Mexico City is Latin America's most populated capital with a total population of over 20 million inhabitants. The city is covered by a metro system featuring 12 lines and an extensive street network, as well as some recently inaugurated Bus Rapid Transit (BRT) lines. Additionally, numerous informal buses run in the city, essentially providing

the backbone of the public transport feeder system. The city, however, is infamous for its severe traffic problems and traffic jams, overcrowded public transport system, and where personal security is an issue in public transport or when using taxis.

The first TNC to enter Mexico City, Uber, started its operations in June 2014. Cabify followed a little later. (Source: information provided by *Secretaria de Movilidad* – SEMOVI, Garcia (2016) reports August 2013 as the date of first appearance). It quickly became successful, growing in both usage numbers and drivers. However, at the same time, it faced heavy opposition from taxi drivers and the local government. The taxi drivers, themselves being heavily regulated and in a restricted market, were afraid of the competition by TNCs, which they claimed to be illegal, unregulated and unfair. The government, on the other hand, blamed Uber for essentially providing a transportation service without a license and under no regulation, but failed in effectively preventing Uber from offering its service platform (source: own interviews). Despite heavy opposition, Uber kept its platform open and continued operating, keeping their foothold in the market and successfully defending their market leader position against the competing TNC Cabify that, by then, had also entered the market. Meanwhile, public support in favor of TNCs started to grow and online petitions to keep Uber (*#ubersequeda* – en: Uber stays) became a trending topic on Twitter in May 2015. In July 2015, regulation was finally enacted in order to regulate digital platforms, allowing TNCs to operate legally when complying with certain rules (initially, the regulation was a provisional agreement, that later, in September 2017, became part of the *Reglamento de la Ley de la Movilidad* – Mexico City's mobility law, Art. 57, see SEMOVI 2017).

At the time of our research (January 2018), two companies operated in the TNC market: Uber and Cabify. We conducted our own calculations on prices for equal origin-destination-relations and different times, and found that very similar prices were requested by the two companies (in both cases, for their basic products UberX/ Cabify Lite). Prices for TNCs, in general, were about the same as the regular taxis in Mexico City, but exceeded them under surge pricing (Uber's dynamic pricing scheme to balance supply and demand) and high demand surcharge (Cabify). This was an interesting finding due to the fact that prices of TNC services are lower than those of regular taxis in most markets (also in the other two case studies, TNCs' fares were, on average, 10-30% below the standard taxi fare).

The reasons behind this phenomenon in Mexico City can be attached to the regulation and to the customers. First, the regulation sets higher vehicle standards for TNCs than those required for basic taxis: a minimum vehicle price of 200,000 MXP$ (approx. US $ 10,000) and a maximum vehicle age of 5 years (in comparison, the maximum age permitted for taxis is 10 years); and second, pooling, which could threaten the minibus market, is explicitly forbidden. A researcher of an international NGO outlines the reasons behind the regulatory conditions:

> '*The regulation was enacted in order to satisfy all, especially the existing lobby groups of taxi-drivers and minibus-drivers, but also the upper middle-class riders that had gotten used to Uber in short time.'* NGO, Mexico City

Third, the perception of enhanced security standards as well as entrance barriers, such as cashless payments only (excluding low-income groups, who do not have access to credit

cards in Mexico) have contributed to position TNCs as a premium service as well as a status symbol:

'*Using Uber provides a positive status – it's modern, digital, fast.*' NGO, Mexico City

Basically, the regulation in Mexico City aimed at avoiding major resistance from existing lobby groups, while allowing TNCs to operate in a segment that would cause no major interference with existing modes (namely taxis, but also minibuses). While it is still uncertain whether similar regulatory schemes will be applied in other, still unregulated Latin American markets, the market entrance of TNCs in Mexico City closely resembles the current situation in other major Latin American urban areas, where TNCs started operating in a legal gray zone (at best), quickly expanded and tried to stay in the transportation market under any circumstances. Such strategies can currently be observed in the Colombian cities of Bogotá (Puche 2019) or Medellín and in Santiago de Chile (see Tirachini and del Río 2019) where TNC operation has been illegal.

4.3. Paris: case description

Paris is the principal city of the Île-de-France region, one of Europe's most populous metropolitan areas with a population of over 10 million inhabitants. The city and its surrounding suburban satellites are covered by an extensive street- and public transport network. Great differences can be observed between inner-city and suburban mode choices, with the city center being dominated by active modes, public transport and various shared-mobility services, while in the suburbs the car is the most frequently used mode of transport (Goletz, Feige, and Heinrichs 2016).

In Paris, TNCs are legally allowed to operate and the most common operational practice is the registration of drivers as VTC (*Voitures de Transport avec Chauffeur*; en.: liberally translated as 'for hire vehicle with driver'), that exists since 2009 (Darbera 2014). Uber launched in Paris in 2012, firstly through its service UberPop, which relied on private cars used as for-hire vehicles. The service quickly expanded as well as the opposition by taxi drivers and politicians (source: interviews/own field notes). Uber was forced to withdraw its service UberPop in 2015, but started operations again quickly with UberX. Opposed to UberPop, UberX complied with the new, stricter French VTC regulation, relying upon professionalized drivers. Since then, the numbers of users and drivers have grown significantly. Landier, Szomoru, and Thesmar (2016) report that about 10,000 VTC drivers were active in Paris by 2016, but this figure has further grown to approxiamately 15,000 VTC in 2018 (source: own interviews).

Besides Uber, companies such as LeCab, Chauffeur Privée or Heetch are active in the Paris TNC market, making it a very competitive environment. Landier, Szomoru, and Thesmar (2016) suggest that the quick uptake of TNCs was due to the shortage of taxis and the comparably low taxi-to-population share, as a direct result of the stiff local taxi regulation. The shortage and problems of hailing a taxi on the street in Paris were frequently confirmed by our experts' interviews.

In Paris, registration requirements as VTC are below those required of taxis, especially the registration cost (approximately 1,000 Euro) is way lower than the cost of a taxi medallion for Paris (approximately 200,000 Euro, source: interviews/own field notes). However, becoming a VTC still requires considerable effort, both from a financial and

time perspective, as drivers have to go through a dedicated driver training scheme. Thus, almost all drivers work professionally in order to cover their investment costs. Part-time working hardly pays off. In fact, all TNCs we interviewed stated that they only work with professional drivers, who mostly work full-time. Similar to other markets, VTC drivers are independent, and TNCs serve solely as intermediaries, connecting passengers and drivers. Interestingly, TNCs actually motivate their drivers to work for other TNC platforms too, in order to minimize the TNC's and drivers' risk of being accused of being only fictionally independent, which may lead to the obligation of social security payments (source: interviews/own field notes). In summary, the Paris TNC market is highly professionalized and in direct competition with taxi services, as it provides additional capacity in the 'taxi-like market' and the added benefit for users seeking the advantages of digitalization (such as the pre-trip price prediction, cashless payment, etc.).

Table 3 presents an overview of the different regulation policies enacted in the three case studies.

5. Future outlook and economic analysis

As highlighted in the previous section, the ride-sourcing industry is involved in loss-making expansion processes. We therefore conclude that the current main strategy of TNCs is to gain market shares worldwide and to position themselves as market leaders. While some authors have explained these schemes in light of eventual future revenues or as a strategy to generate consumers' loyalty (Horan 2017), the main reasons behind this could be focused more on future expectations. As our empirical work revealed, TNCs seem to have their eyes set on the automation of transport systems. Because of this, ride-sourcing providers might be waiting for the advent of autonomous vehicles (AV) in order to cash in on the expansion processes they are currently involved in. Such hypotheses seem plausible, especially in light of the changes that vehicle automation are expected to cause for transport behavior and on transportation systems. Furthermore, ride-sourcing users may be more open to adopt self-driving vehicles due to reduced uncertainty (Sener and Zmud 2019), which could mean a competitive advantage for TNCs.

A well-documented possible consequence of automated vehicles is the expansion of Mobility-as-a-Service operations (MaaS). In this context, it is expected that currently different MaaS services, such as ride-sourcing, taxi and car-sharing companies would evolve into the same kind of service, as the differences among them are no longer significant in the absence of a driver. Hence, it is expected that current TNCs, taxi and car-sharing companies will be competing for the same market in the future.

Table 3. Overview of TNC regulation policies.

	San Francisco (California)	Paris (Île-de-France)	Mexico (Federal District)
Regulator	State of California	Region Île-de-France	*SEMOVI*, federal district
Driver status	Private and professionals	Professionals only	Private
Driver registration with city	Only with TNC	Yes, as VTC	Yes, at city
Vehicle limit	No	No	No
Vehicle standards set by	TNC	VTC regulation	*Reglamento*
Regulated fare	No	No	No
Data sharing with cities?	Yes	No (in planning)	No
Additional tax	Yes, 1.5% of revenue	No	Yes, 1.5% of turnover

The key behind MaaS services becoming more relevant when AVs become available relates to the cost structure. Dispensing with the necessity of a driver will result in a substantial cost reduction, making the alternative more attractive and/or accessible for most potential users. Thus, a significant increase in the market share of MaaS can be expected. However, the lack of drivers will not only result in lower costs, but in a substantially different cost structure.

Let us consider a provider offering MaaS services, with a fare per kilometer F and a fleet size of N vehicles. This MaaS provider would face a yearly demand for kilometers $K(F,N)$, which is a function of F and N. If we assume that all vehicles are equal and can be driven for q_{max} kilometers/miles before being retired, in a stationary condition, we observe that:

$$RR = \frac{K(F, N)}{q_{\max}} \tag{1}$$

where RR represents the number of vehicles being replaced on a yearly basis (replacement rate). Under these conditions, the average age A of the fleet is given by:

$$A = \frac{1}{2}\frac{N}{RR} = \frac{1}{2}\frac{N \cdot q_{\max}}{K(F, N)} \tag{2}$$

Consequently, the cost structure faced by the TNC provider (expressed in monetary units per year) will take the following form:

$$C = c \cdot K(F, N) + RR \cdot P_{veh} + M(A) \cdot K(F, N) \tag{3}$$

where c stands for the operational cost of the vehicles per kilometer and P_{veh} for the price of purchasing a new vehicle minus the residual value. Finally, $M(A)$ represents the maintenance costs per kilometer, which are dependent on the average age of the fleet (as well as on the average mileage, although the latter can be considered to be constant in stationary conditions). Then, replacing eq. [1] in eq. [3], we obtain:

$$C = c \cdot K(F, N) + \frac{K(F, N)}{q_{\max}} \cdot P_{veh} + M(A) \cdot K(F, N) \tag{4}$$

Then, calculating the average costs (AC) and marginal costs (MC) per driven kilometer:

$$\begin{aligned} AC &= c + \frac{P_{veh}}{q_{\max}} + M(A) \\ MC &= c + \frac{P_{veh}}{q_{\max}} + M(A) - \frac{1}{2}\frac{N \cdot q_{\max}}{K(F, N)} \cdot \frac{\partial M(A)}{\partial A} \end{aligned} \tag{5}$$

with $((\partial M(A))/\partial A) > 0$ (as maintenance costs increase with the average age of a fleet).

First, it is important to note that the operational costs per kilometer as well as vehicles costs per kilometer (the first and second terms in both the average and marginal costs) do not depend on the number of kilometers driven. This situation substantially differs from the current situation, where the operational costs depend on the availability of drivers, and therefore they increase as the demand for kilometers increases (increasing wages are required to keep drivers working or, eventually, to recruit more drivers). Second, it

is clear that the marginal costs will always be lower than the average costs. This implies that we are in the presence of a natural monopoly, in which the market leader will face lower costs than the competition. It explains why it is fundamental for TNCs to secure a leading position in the market before the advent of AVs and the consequent change in the cost structures as well as the collision with car-sharing companies.

Recognizing that the MaaS market will become a natural monopoly when AVs become available has important consequences: it implies that the provision of MaaS with AVs will require external regulation, not only because of the negative externalities, such as congestion, emissions, etc. (Smith 2012; Zmund, Sener, and Wagner 2016; Bahamonde-Birke et al. 2018; Bahamonde-Birke, 2018) but also because of the very nature of a natural monopoly: deregulated provision of MaaS with AVs will lead to social losses.

6. Policy implications

The analysis outlined in the previous sections shows that the current structure of the TNC business creates the need for rapid expansion in the wake of the arrival of automated vehicles. This brings up the question what the short-term outlook for ride-sourcing is, and what challenges will arise for cities where such services are becoming increasingly popular and common.

Firstly, as automated vehicles become visible on the horizon, it is unlikely that the expansionary strategy of TNCs will soon come to an end. This is due to a set of reasons:

(a) Many cities and countries all around the world are still not served by TNCs, leaving further room for expansion. After the 'Global North', the 'Global South' has been put into focus, which our example from Mexico City illustrates.
(b) The market is likely to experience knock-on effects in monopolistic structures, which will allow the monopolist to generate significant rents/income. Hence the motivation for TNCs to grow and push competitors out remains strong.
(c) So far, TNCs have been making significant deficits, and recovering these deficits requires them staying in the market until a profitable status is reached.
(d) The IPOs of Lyft and Uber raised significant financial resources, which will allow them to operate for many more years – even if losses continue at the current level.

The expansion strategy and status-quo of loss-making TNCs allows further deductions, including the existence of a supply above optimal levels, as a direct result of current prices below average costs. Due to this, modal shifts from other modes of transport are likely to be already occurring. Evidence from Clewlow and Mishra (2017) for California indicates that about half of all ride-sourcing trips would have been made either by public transit, walking, biking, or avoided altogether. Consequentially (under the assumption that the aforementioned phenomenon also holds in new markets), the expansion of TNCs would result in decreases in the use of public transport (which may lead to a need for additional subsidies), as well as to an increase in vehicle kilometers traveled (VKT) on the streets.

Both developments may require immediate action by city authorities. This is especially important as a TNC can develop rapidly in a very short timeframe, by attracting private suppliers who may already fulfill the necessary requirements (in the absence of regulation

the entry barriers are low). Further regulation is needed to address the expansion of TNCs towards monopolies in order to capitalize future revenues. This situation will not lead to welfare optima (this is in line with the findings from Zha et al., 2017) and, hence, regulators should introduce appropriate policies. These policies could include quality regulations such as vehicle standards, quantity regulations such as vehicle limits and price regulation (for instance, Ramsey pricing). Further research about the impacts of such regulations would be needed to understand the effects they induce and to determine the optimal capability of such regulatory inventions. Further research on how such policies should be tailored to the individual cities' context would be needed.

Context-dependent solutions are especially important in the 'Global South', where the provision of public transport is deficient and regulation is scarce (Behrens, McCormick, and Mfinanga 2016). Under these circumstances, the implications of TNCs may differ substantially: TNCs that serve as intermediaries between suppliers and riders could reveal the potential to fundamentally change the governance structure of a market that currently is based on informal services, bilateral negotiations and a self-organizing structure (Olvera et al. 2016; Ehebrecht, Heinrichs, and Lenz 2018; Heinrichs, Goletz and Lenz 2017) and, consequentially, TNCs can effectively increase social welfare by fulfilling mobility requirements not being met today or being met by informal transport services. The case study of Mexico City constitutes an example of the former. However, other urban areas, where the provision of public transport is poorer provide additional insights, especially on the swift capacity of TNCs to adapt to local requirements. For instance, in some African cities such as Dar es Salaam (Tanzania) or Nairobi (Kenya), TNCs have departed from offering taxi-like services only, but they also provide services with two- and three-wheeler motorbikes (these services are being provided by regional and international platforms such as SafeBoda or UberTukTuk). Consequentially, regulation would need to be tailored to the special characteristics of each city's context, reflecting the characteristics of the existing public transport system, existing regulations as well as the characteristics of the local economic system. The latter is of particular importance due to the, possibly disruptive, effects on the labor market that could follow the expansion of TNC services.

7. Conclusions

In this paper we have described and discussed the uptake of transportation network companies (TNCs) on a global scale. We embedded our discussion in local developments and examined their regulatory frameworks to better understand the various developments and structures of the ride-sourcing industry. We highlighted three research questions:

(a) What makes TNCs become so successful, and how can the fast uptake and growth of TNCs be explained?
(b) How can TNCs gain monopolistic market power (that allow them to implement price discrimination schemes) and what should be done from a regulatory perspective?
(c) What will the market for ride-sourcing look like in the future?

Responding to the first questions, our research in the selected case cities underlines that the TNC business is quickly expanding. Wherever TNCs enter the market, they rapidly aim at expanding and gaining market shares. Companies quickly adapt to local contexts and tailor their products to cope with the specific local needs. Everywhere, establishing themselves in the market seems to be their first priority, even if it results in large financial losses. Facing governmental opposition or opposition from taxi drivers is common, but as long as the companies can keep providing their services, they do so. The rapid expansion and high-losses are apparently related to each other, as they allow TNCs to offer their services at below-market prices.

Whenever possible, TNCs become involved in the regulatory process. In San Francisco, a very TNC-friendly regulation was established. It has proven highly beneficial for TNCs and has helped them to expand further by relying on their intended business model, and to compete with other transportation modes quite freely. In Mexico City, TNCs were regulated to fit into a specific niche-market for a wealthy, new middle class. The regulation that was 'made to satisfy them all' (citation from interviews) allowed TNCs to establish their position without major resistance in the city, serving the quickly growing new middle class. In Paris, the competition amongst TNCs was as vital as the competition of TNCs with other modes such as public transport, cycling or the car. Here, the impact of TNCs may be the least of all cities in our case studies, which can be partially explained by the rather strict regulation (the differentiation with taxi services is not as big as in the other two cases) and partially by the good provision of public transportation.

Responding to the second and third questions, we found that the rapid expansion policies of TNCs and constant loss-making have hardly been discussed let alone explained in the academic literature. Therefore, we conducted a theoretical economic analysis in order to analyze the expansion strategies of TNCs in the light of current losses and the future outlook of the industry. The analysis reveals that not requiring a driver would result in decreasing marginal costs. As a result, the industry is likely to become a natural monopoly once automated vehicles (AVs) become readily available. Hence following economic theory, the market leader will face lower costs than the competition and will be in a position to drive them out of the market. This monopolistic power could make it possible to recover the substantial financial losses that TNCs are currently experiencing during their expansion process and calls for a future change in their regulation.

Notes

1. CPUC defines a TNC as 'an organization, whether a corporation, partnership, sole proprietor, or other form, operating in California that provides transportation services for compensation using an online-enabled app or platform to connect passengers with drivers using their personal vehicles. The primary distinction between a TNC and other Transportation Charter Party (TCP) is that a TNC connects riders to drivers who drive their personal vehicle, not a vehicle such as a limousine purchased primarily for a commercial purpose.' (CPUC 2013)
2. Zoepf released a statement including newer calculations (Zoepf 2018), however still concluding that between 41% and 54% of drivers earned less than the minimum wage. Another interesting finding of Zoepf et al. (2018) was that many drivers could generate negative tax income from their ride-sourcing activities, due to standard mileage deduction

values lying above their real costs per mile. This means that they could declare negative overall income from ride-sourcing activities, which could imply that they are receiving a hidden tax subsidy, which could be another argument against the financial viability of the current TNC business.

3. The following cities were included in the preliminary quantitative analysis: Amsterdam, Bangkok, Barcelona, Berlin, Brussels, Cape Town, Charlotte, Chengdu, Chicago, Chongqing, Columbus, Guangzhou, Hyderabad, Istanbul, Lahore, Leeds, London, Los Angeles, Madrid, Milan, Marseille, Mexico-City, Moscow, Munich, Nairobi, New York City, Osaka-Kobe, Paris, Beijing, Philadelphia, Phoenix, Port-au-Prince, Portland, Prague, Puebla, Rom, Sao Paulo, San Antonio, San Diego, San Francisco, Seattle, Seoul, Shanghai, Sofia, St. Petersburg, Teheran, Tokyo-Yokohama, Valencia, Vancouver and Zagreb.
4. The following cities were considered in the second phase of the study: Atlanta, Amsterdam, Beijing, Bogotá. Cape Town, Nairobi, Mexico City, New York, Paris, London, Los Angeles, San Francisco, Sao Paulo, Shanghai, Vancouver, Vienna.
5. Another description of the evolution of TNCs in the early 2010s can be found in Shaheen (2018).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was carried out as part of two projects: 'Urban Mobility', financed by the Helmholtz Foundation (DE), and 'Sharing Cities', financed by Volkswagen AG (DE).

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