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Travel-chains / mode choice for the taxi of the future

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Travel-chains / mode choice & the taxi of the future¹

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Introduction

1. The best way to travel, beyond walking distances, is to travel by car. The nice things about the car is that it is comfortable, it has a trunk for your luggage or for a cartload of groceries and you can sing while driving or listen to your favourite music or chat with chosen companions. You can even select the room temperature best suited to the clothes you wear. If you cannot drive, you can get a similar treat hiring a taxi with the added benefit that you do not need wasting time finding a parking space at your destination. It is a real seamless door-to-door service.

2. Unfortunately, big cities, and especially the metropolises where most of the value added is created, cannot accommodate everybody traveling by car, for a sheer question of space. To be accessible, cities have to resort to public transport, and metropolises to metro systems, both modes generally more or less heavily subsidized.

3. The problem with public transport, besides missing most of the user’s benefits of the car, is that it does not operate seamlessly. Most journeys combine several stages, and connexions take time, may be uncomfortable, and require a good knowledge of the network together with, for each segment, its schedule or headway and its tariff system.

4. For their daily commute, urban travellers are familiar with this information: they know the best combination of stages, they know the

¹ Discussion paper commissioned by the International Road Union (IRU) for the Taxi of the Future Reflection Group together with two other papers: “What regulation for the taxi of the future?” and “Business-models for the taxi of the future”

length of the journey and its variability. They also know its pricing and probably have inter-modal travel ticket. Thanks to online journey planning and integrated fare systems, planning an infrequent public transport journey is no longer the chore it used to be. Real-time public transport journey planning apps are already available in most metropolises. This should very soon combine with app-based payments for fares.

5. In the near future, most metropolises, like Los Angeles today, may have journey planning apps integrating all transport modes. Users would be allowed to select the modes for which they already have a subscription and ask for the fastest combination, or the cheapest, or the most environment friendly.

6. But the inconvenience of transfers between stages remains, together with the absence of public transport in time and place of low demand.

7. The staggering technological advances of the past decade have made dynamic ride-pooling a viable solution in many cases, making it possible to partially replace fixed-route fixed-scheduled bus services by demand responsive minibuses that serve pop-up stops on demand and provide transfer-free rides. In places and times of low demand the minibuses can even be replaced by shared taxis that offer on-demand, door-to-door or curb-to-curb shared rides.

8. Such systems have already been implemented several years ago in rural areas in Northern Europe. One can imagine their progressive penetration in urban areas. For this, four kinds of problems will have to be overcome: technical, economic, institutional and political.

9. We will first present the case study of ridesharing in rural Scandinavia and in the Gelderland province of the Netherlands since it gives a good idea of the difficulties ahead: technical with computing limitations of assignment software, economic with the procurement process for both the platform and the transport operators, institutional with the proper role of public agencies and political with the public acceptance.

10. We will then present the prospects of high-capacity ridesharing in dense urban areas with the simulations that have been carried out in New York City and in Lisbon.

11. We will finally see under which conditions trip-planning apps will include taxis in the travel-chains.

Subsidized ridesharing in rural Scandinavia²

The “Planet” system in Scandinavia

12. In Sweden and Denmark, all the responsibilities for providing subsidized transport are obligations of local bodies only, at the county and municipal levels. In several counties, the jurisdictions and agencies have been able to agree to pool their needs and create a single authority or organisation in charge of making calls for tender, selecting the

² This case is studied in details by Cazemier *et al.* 2012.

carriers, ensuring the logistics system, paying the carriers, and charging the different agencies of the consortium the transportation costs of the people to whom they must ensure mobility.

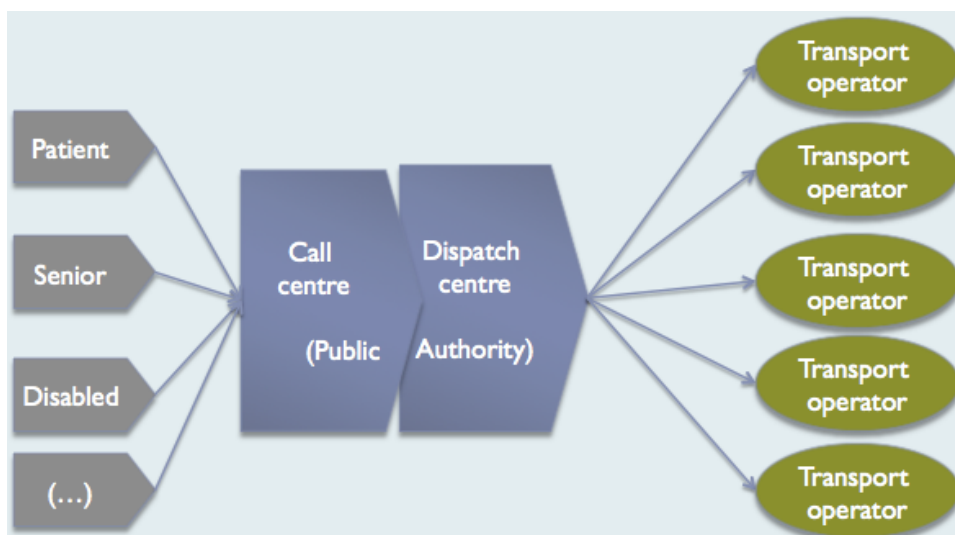
Coordinating the demands and billing clients

13. Consolidating markets as diverse as transportation for seated patients and public transportation in low-density area requires that one can put in the same vehicle people who are within different programs.

14. The first challenge in Denmark and Sweden was to coordinate as much as possible the various subsidized transport services to increase the volume of travel to be treated, and thus increase the likelihood that several passengers could share the same vehicle, thus increasing the vehicle occupancy rate. A larger volume to be treated can also bind the various trips optimally to reduce the dead mileage between the different assignments.

15. This requires a suitable tool. Large parts of the Scandinavian subsidized transports are built around a booking, planning and dispatching system originally developed by Volvo in Sweden in the mid 80's that, over constant improvements, took the name "Planet". The public transport authorities of Denmark have created a public company, FlexDanmark, which has purchased a license for Planet, has adapted it to its needs under the name FlexTrafik, and makes an original use of it. FlexDanmark uses the Internet to make the system usable by regions that wish to coordinate their demand responsive transport (DRT) services. Several regions in Sweden now also use this booking and logistics system. FlexDenmark is a nation wide information and communication technology (ICT) infrastructure and competence centre. Its services allow for coordinating trips for various regional and municipal clients and for assigning them to transport operators (Figure 1) selected through the procurement process that will be described later in the paper.

Figure 1 — When the public authority operates both call & dispatch, many small transport operators can be contracted (Denmark & some Swedish counties)



16. In this system, vehicles are located by GPS and route calculation is based on an origin-destination road distance matrix instead of precise point-to-point road distances to save on computing time.

17. Two counties on the west coast of Sweden: Västra Götaland and Halland, use a system very similar to the Danish system, adapted from the Planet software.

18. When a user calls to book a trip, the software first checks if he is entitled to subsidized transport. It then notes the starting address of the trip, its destination and the time at which the person wishes to leave or to arrive. It searches for the vehicle that will make the trip's (generalized) cost lowest depending on the scheduling algorithm. This vehicle can be a vehicle available that is not yet in service and located at its base, or a vehicle to which one or more trips have already been allocated and will be diverted to take this additional traveller. The different parameters such as time of booking, pickup window, or potential detour, allow the software to optimize, within certain limits, the path of the vehicle to increase its occupancy rate.

19. When the passenger boards, its identification allows the software to spread the cost of running the vehicle between all the passengers on board and to charge the various agencies that fund the mobility of these travellers. The cost that will be billed to the payers depends on the filling ratio of the vehicle. This is an incentive for hospitals to coordinate the treatments of their long-term patients and for municipalities to encourage their citizens to travel at the same times.

20. Regularly, a sample of travellers is surveyed to assess their trip of the day before on a scale of satisfaction with different aspects of service such as timeliness, quality of care, comfort, etc. The transport authority uses these evaluations to apply any sanctions to operators who do not deliver satisfactory service. They are also used during the renewal of tenders.

An original tendering system for transport services

21. FlexTraffic manages calls by phone and by Internet, records orders, selects the vehicle, optimizes its route, and spread the cost of transport between the different entities responsible for the different passengers sharing the vehicle. The specificity of the FlexTraffic system over all the other DRT management software available on the market place lies in its own way of selecting the vehicle that will perform the transportation and in the way it spreads the cost of this transport between different payers. The vehicle selection is intimately linked to the tendering system.

22. A complex tendering system was designed to make sure to get the lowest prices by opening competition to all the transport operators on the market, including the smallest. Indeed, in Denmark as in Sweden, the regional transport authorities make extensive use of taxis to provide DRT services.

23. This bidding system distinguishes two types of contracts: "day" contracts and "occasional" contracts:

24. In "day contracts", the transport operators provide FlexDenmark with a fixed number of vehicles for a given period of time, usually the day. This availability is paid whether the vehicles are used or not. The contracts also specify a "home area" where the vehicle is based. This

type of contract is normally used for special vehicles, or for more or less regular circuits. The contract period is usually 2 to 4 years.

25. In “occasional contracts” the transport operators undertake to make available to the agency a maximum number of vehicles at certain times of the day (generally by the hour). Transport operators are paid only for vehicles actually used, including the return trip to the base or “home area”. The contract period is usually shorter than for day contracts. In Denmark, carriers can update their prices annually by Internet. The “occasional contracts” generally involve taxis, and the “day contracts” make use of both taxis and providers with “special vehicles”, often minibuses adapted to transport disabled persons in wheelchairs.

26. For both types of contracts, transport operators bid a price per minute. Prices per minute are generally lower for “day contracts”.

27. When it gets a booking for a trip, the software selects the vehicle with the lowest cost. This can be a vehicle from the operator who offered the lowest price per minute, but it can also be the vehicle whose home base is the closest to the starting point of the journey, or even a vehicle already assigned that the change in route will not too much delay the travellers already in the vehicle and will be cheaper than the use of an empty vehicle, coming from farther away or more expensive by the minute. Normally, the system also takes into account the remuneration of the empty return to base. As the vehicle is also monitored in real time while returning empty to its base, it may at any time be reassigned to a new journey if it is the best placed.

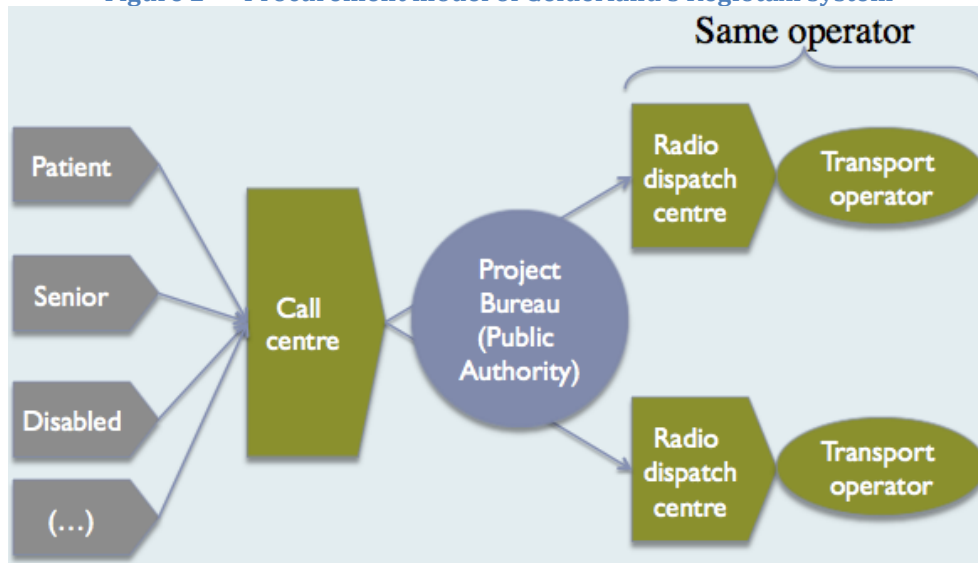
Tendering for the platform

28. How to entrust private providers with the organization and operation of DRT systems while maintaining transparency? The province of Gelderland provided original solutions to this dilemma. In the Netherlands, most subsidized DRT services come under the name Regiotaxi. Unlike other regions of the Netherlands who entrust the whole Regiotaxi service to one company selected by tender, this province has segmented its tender for Regiotaxi into six distinct elements: one tender for the call centre and five tenders for dispatch and transport services in five predefined areas within its jurisdiction. These areas, which include an average of half a dozen municipalities, have been designed so that taxi companies or taxi cooperatives can be put in competition to place bids within each. Without this segmentation of the tender, these companies would be too small to bid and would be forced to be only sub-contracted by the regional taxi company or, more likely by the nationwide company that would have won the contract. Of course, the five selected companies can in turn make use of subcontractors, that is to say, to smaller taxi companies, or even individuals, for whom they handle the logistics. At the last tender, twenty subcontractors were involved this way.

29. When it receives a request for a trip, the call centre of Gelderland transmits it directly to the one of the five operators that is concerned. This operator reviews the request, plans his route, and returns its proposal to the call centre that takes care of communicating it to the person who ordered the trip. Besides this market segmentation, the

other original feature of the province of Gelderland model is that between the call centre on the one hand and dispatch and transport operators on the other hand stands a “Projectbureau”, a regional public authority, to monitor the whole system in real time (Figure 2). All information exchanged between the operator of the call centre and transport operators passes through the computer system of this control office managed by the region which also receives real-time GPS coordinates of each vehicle. All these data are recorded and a statistical analysis is done regularly. The total transparency resulting from this organization can provide all the necessary information to competitors during the bidding at contract renewals, but it also allows the regional government to assess the quality of the service, and even track failures in real-time.

Figure 2 — Procurement model of Gelderland’s Regiotaxi system



30. When it comes to the tendering, in Gelderland operators place their bid with a price per passenger-zone. The zone has an average size of 4,5 km cross-section, and the operator will be paid the number of zones a passenger travels plus one. For a local trip (one zone) an operator gets paid two zones, for a two zone trip three zones, etc. The cost price of one zone is approximately € 3,75.

Lessons from the rural subsidized ridesharing experience

31. Several lessons can be drawn from the case study of ridesharing in rural Scandinavia and in the Gelderland province. They address the four issues mentioned above: (i) technical with computing limitations of assignment software, (ii) economic with the procurement process for both the platform and the transport operators, (iii) institutional with the proper role of public agencies and (iv) political with the public acceptance.

32. Regarding the technical issue, the Planet software had to take some shortcuts. Indeed, designing the optimal vehicle assignment and route selection to minimize the total time cost of the system is a task that today computers are barely able to carry on in real-time. For this reason, Planet requires that trips cannot be booked with less than 30 minutes antecedence and uses a pre-calculated zone-by-zone distance matrix to save computing time during the route assignment. However

progress is being made both on computer processing speed and on the research in the “traveling salesman” type algorithms.

33. The economic problem has to do with the procurement process for both the platform and the transport operators.

34. First come the tasks of receiving calls and dispatching vehicles. In the Scandinavian case, these tasks are jointly devolved to a public agency. This allows it to resort to a very specific procurement process to contract transport operators. Its most interesting feature is that it can contract from medium size companies down to individual operators with only one car. Furthermore, all are guaranteed to be retained and get assignments, even if they are not the cheapest provided that their base is close enough to isolated ride requests. This feature is particularly interesting in countries where, by law, a sizable part of the taxi industry consists of individual owner-operators.

35. When the platform is tendered to a private operator as in the case of the Gelderland province, it is important that its operation can be closely monitored by an *ad hoc* public agency not only for quality control, but more importantly to prevent the incumbent contractor from retaining the information that would give him a competitive advantage when the contract is tendered for renewal.

36. Regarding institutions, the rural case study has shown the importance of getting the various agencies dealing with transport at different jurisdiction levels to coordinate for ensuring coherence in the policies, economies of scale and fair distribution of costs and revenues.

Prospects of high-capacity ride-sharing in dense urban areas

An algorithm issue

37. Due to computational difficulties, taxi-sharing has for a long time only been approached on small scales, such as within airport perimeters. In 2013, researchers at MIT’s Senseable City Lab produced a new algorithm to optimize shared taxi operation at a city scale. The algorithm was validated in 2014 by making use of the unique database³ the New York City Taxi & Limousine Commission (TLC) collects on all the taxi trips in Manhattan. The results, published the same year [Santi *et al.*, 2014] showed that with increasing but still relatively low passenger discomfort (e.g. 150 seconds delay), taxi cumulative trip length could be cut by 40% or more, reducing congestion, pollution and cost.

38. Since mid-2015 app-based Commercial Transport Intermediaries⁴ (CTIs) have offered and heavily promoted “pooled” options such as UberPool and LyftLine, where drivers make multiple

³ For 2011 the database recorded 150 million trips with the geographic coordinates (longitude and latitude) and time of each trip’s origin and destination

⁴ “Commercial Transport Intermediary” (CTI) are defined as follows “Digital intermediaries or marketplaces that canvass or solicit for a passenger to connect with a licensed professional driver, meeting the requirements of the relevant jurisdiction and operating a validly registered vehicle under the laws of the relevant jurisdiction.”

pickups and dropoffs and riders get a discount. Despite these companies' claims that are impossible to verify⁵, it seems that a large part of the rides booked with this option eventually end up as solo-rides and very few combine more than two rides. More precise data should be available when, under a recently adopted TLC rule, New York City CTIs will be required to indicate which trips are actually pooled [Schaller 2017, p. 7].

39. Two reasons explain this provisional shortcoming: the relatively small size of the customer base of each CTI in the cities where they implement their ride-sharing apps and the limitations of their algorithms.

40. These algorithms are probably similar to the one produced by MIT's Senseable City Lab in 2013. Its method and analysis was limited to two riders for an optimal allocation, and three riders with heuristics, it was intractable for larger number of passengers, and more importantly did not allow for allocation of additional riders after the start of a trip.

41. However, these limitations will soon disappear with the advance of computer science and artificial intelligence. In 2016, researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) developed a new algorithm, that, unlike its predecessor, works in real-time to reroute cars based on incoming requests with no limitations, and can also proactively send idle cars to areas with high demand, a step that speeds up service 20% [Alonso-Mora et al., 2016]. Making use of the TLC taxi trips database, the study found that 3,000 four-passenger cars could serve 98% of taxi demand in New York City, with an average wait-time of only 2.7 minutes. The team also found that just 2,000 ten-person vehicles, compared to the nearly 14,000 taxis that currently operate in New York City, would cover 95% of demand.

42. The MIT study suggests that using ride-pooling options from companies like Uber and Lyft could reduce the number of taxis on the road by 75% without significantly impacting travel time.

Shared taxis as the dominant mode

43. Pushing the MIT demonstration further, it can be demonstrated by model studies such as ITF (2016), that shared taxis and shared minibuses together, could potentially replace all private car and scheduled bus trips in big cities that would only retain their rail transit network.

44. The ITF simulation was based on real mobility and network data from a mid-size European city, namely Lisbon, Portugal. It examined a configuration where shared mobility was delivered by a fleet of six-seat vehicles ("Shared Taxis") that offer on-demand, door-to-door shared rides in conjunction with a fleet of eight-person and 16-person minibuses ("Taxi-Buses") that serve pop-up stops on demand and provide transfer-free rides. Rail and subway services were kept operating in the current pattern.

45. The simulation gave some striking findings: 97% reduction of vehicle fleet and 95% reduction in required parking space, total vehicle-

⁵ Uber says that 20% of its rides globally are now on UberPool [Lunden, 2016]

kilometres would be 37% less even during peak hours and prices for journeys in the city could be 50% or less of today even without subsidy.

46. The study does not underestimate the political difficulties of implementing such a system, especially with the car owners, with the incumbent bus companies and their employees, even with the car industry. But it insists, “While there are many ways to manage dispatching in a shared mobility system, one of the most promising approaches would be to charge a single entity with matching demand and supply. However, authorities must carefully reflect on its statute and the supervision of its performance in order to protect consumers from market power abuse and to ensure efficient outcomes.”

47. ITF model that was applied to the city of Lisbon will very soon be tested in other cities like Dublin, Helsinki and Auckland.

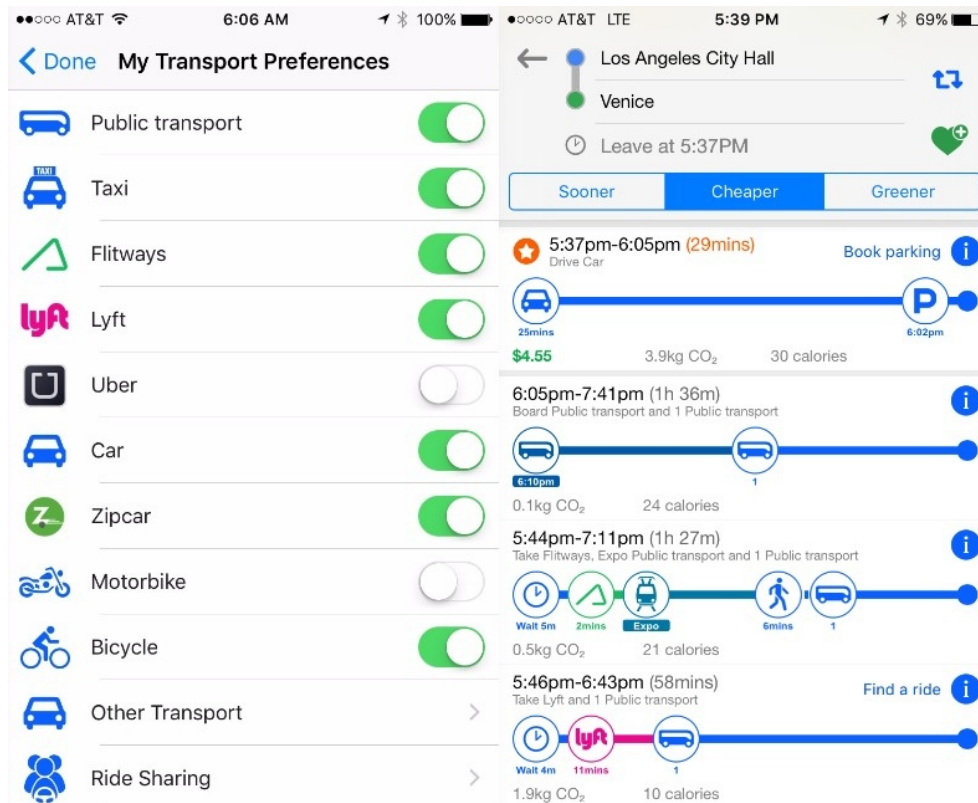
Involving taxis in the urban travel-chains

The promises of journey-planning apps

48. As mentioned in the introduction, today’s technology allows journey-planning apps to integrate all the transport modes available in a given city. These apps could include online payment for each leg of the journey and take into account whether the user is entitled to specific subsidies on some of the legs or some of the modes.

49. The Figure 3 below shows a screenshot of the Go LA app that gives a good idea of how users could select options and get a choice of combinations together with their duration, price, and other attributes like environmental friendliness or health impact (e.g. calories burnt).

Figure 3 — Screenshots of an early version of Go LA app



Source : <https://itunes.apple.com/us/app/go-la/id1069725538>

50. The screenshot at left shows selected mode options to include in route searches. It should be noted that in this app, some option are toggle options, e.g., the user cannot select together both Lyft and Uber. The screenshot at right shows suggested routes filtered by which are cheapest. User can also select "Sooner" or "Greener" as filters. The Go LA app also offers car users the possibility to book a parking space at destination, which cost will add to the total estimated cost of the trip.

51. These very powerful tools come with a very questionable side. The huge amount of data they process gives the app provider unparalleled market power.

Who owns the data?

52. The data ownership issue might be the biggest impediment to the dissemination of such integrated journey-planning apps. To operate, these apps need to have access in real time to the available capacity of each of the transport providers involved in the travel chain, from bike-share rentals to taxi CTIs to public transport operators, directly or indirectly.

53. As we have explained in the "Regulation" section, potentially, the best use of this data in the public interest can only accrue to the public agency in charge of the transport policy at the metropolitan level. This agency could use it for transport and city planning purposes, for monitoring the compliance of the various transport providers to the existing regulations, and to possibly levy charges on infrastructure use.

54. As the New York TLC long battle has shown, to eventually obtain from Uber the same data it already collects from the taxis, it is not easy for a public agency to have access to some CTIs' data. However the public sector controls valuable assets, like parking spaces and street

right-of-way, which can be used to negotiate for access to data. Agencies should identify their needs and seek access to these data accordingly, which will in many cases result in stronger reporting requirements.

55. Not all the city agencies in charge of the transport policy have the technical capability to develop comprehensive journey-planning apps and continuously update them. They might have to resort to third-party software development firms. These firms have larger, dedicated teams who are able to work nimbly and gather user-experience data in several cities simultaneously.

56. TransitCenter [2016, p.55] emphasizes a last point: “the public benefit of trip-planning apps can erode when one provider is able to monopolize access to app users, potentially exposing users to higher prices and a risk of service disruption if that provider leaves the market. Transit and city agencies have an important role to play in avoiding provider exclusivity in competitive market segments (not in the case of natural monopolies, like bikeshare), especially in the context of government-endorsed planning and payment apps.”

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