"Three Ps in a MOD:" Role for mobility on demand (MOD) public-private partnerships in public transit provision

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ABSTRACT

The growing number of public transportation agencies partnering with Mobility on Demand (MOD) or Mobility as a Service (MaaS) companies raises the question of what role MOD companies can, should, and currently play in the provision of public transport. In this article, we develop a typology reflecting 62 MOD public-private partnerships (MOD PPPs) in the United States and present lessons learned. We conducted 34 interviews with representatives from four MOD companies and 27 public agencies. The interviews spanned October 2017 to April 2018. The resulting MOD PPP typology consists of four service models: 1) First-Mile/Last-Mile (FMLM), 2) Low Density, 3) Off-Peak, and 4) Paratransit. The typology also includes two MOD asset contribution models: 1) Agency-Operated MOD and 2) Agency-Subsidized Private MOD. Lessons learned for limiting competition with fixed-route public transit include: a) if agencies have sufficient resources, they can generally maintain greater data access and control over the service with Agency-Operated MOD than Agency-Subsidized Private MOD; b) public agencies can supplement the Agency-Operated MOD model with Agency-Subsidized Private MOD during peak demand; c) public agencies sometimes encourage FMLM transfers to fixed-route public transit by creating service zones that divide trip generators and attractors and assigning one or two designated transfer stops to each zone; and d) one approach to protecting fixed-route public transit is to restrict Low-Density MOD services to trips that start and end outside a geofenced fixed-route service area.

KEY TERMS

Mobility as a Service, Mobility on Demand, public-private partnership, public transportation, first-mile/last-mile, typology

1. Introduction

1.1. Background

In a time of declining public transit ridership in the United States (U.S.), public transportation agencies have started partnering with Mobility on Demand (MOD) or Mobility as a Service (MaaS) companies in an effort to improve the efficiency and quality of public transit service. We use the MOD terminology throughout this paper, as it was adopted by the U.S. Department of Transportation in 2016 to describe this emerging concept. MOD, according to the U.S. DOT definition, is a concept that encompasses both passenger and goods movement as commodities that consumers can access on demand through an integrated multi-modal network (Shaheen et al., 2017). MaaS, in contrast, is a European concept that focuses on aggregating passenger mobility services and ultimately providing them as bundled subscription options (Shaheen and Cohen, 2019). Both MOD and MaaS aim to incorporate trip planning and booking, real-time information, and fare payment into a single user interface. Some operational aspects involved in MOD and MaaS preceded the development of companies like Uber and Lyft, including technological elements (e.g., integrated planning and booking systems like Cleric, a company started in the United Kingdom in 1985) and their application (e.g., Scotland's Transport to Employment service that centrally coordinated passengers' trips beginning in 2006).

The MOD companies we examine in this article include transportation network companies (TNCs, also known as ridesourcing and ridehailing) like Uber and Lyft that connect passengers with drivers who provide service in their personal vehicles, microtransit companies like Via that offer shared-ride services with flexible routing and/or scheduling, and software companies like TransLoc and DemandTrans that provide the algorithms for public transportation agencies to operate their own on-demand service. These innovative partnerships, which we call MOD public-private partnerships (MOD PPPs), seek to accomplish a variety of goals including: a) improving transportation quality for transit-dependent elderly, disabled, and low-income populations; b) serving new public transit riders; and c) enabling public transportation agencies to redistribute resources to more efficiently serve low-ridership bus routes and paratransit while increasing frequency along higher-density corridors.

For context, public transportation in the U.S. is administered at the level of the metropolitan region, county, or city. The federal government provides roughly half of the public transit capital funding and some operating funds. States often contribute both transit capital and operating funds to regional public transit districts, and many county and city governments employ local taxes to provide operational funding for regional transit agencies (TRB, 2001). Unlike Western Europe, where contracting with private bus operators is common on a route-by- route basis or for whole networks even in major metropolitan areas, contracting with private transit providers in the U.S. occurs mainly in smaller and less urban transit systems or for services like paratransit (TRB, 2001).

1.2. Existing literature

Our analysis focuses on the role MOD companies can, should, and currently play in the provision of public transportation. While empirical research shows some MOD companies may currently decrease public transit ridership, qualitative evidence also supports the potential for these companies to increase the efficiency and quality of public transportation service. This potential depends on public transit agencies addressing a variety of equity, technological, and administrative challenges to partner with MOD companies in ways that support the public good.

An examination of the potential benefits from partnerships between public transportation agencies and MOD companies prompts the question of such companies' current impacts on public transit ridership. After reaching a peak in 2014, total public transit ridership at the national level declined 7.6% by 2018 (APTA, 2014, 2018). The literature is mixed as to whether MOD companies have contributed to this de- cline. A number of empirical studies in this area focus on TNCs, with no conclusive studies on the impacts on public transit ridership from TNC pooled services (e.g., Lyft Shared rides or uberPOOL) or microtransit vans. Some studies suggest that less than 1% of TNC trips would not have occurred in the absence of TNCs, and 3% to 14% of TNC trips replace trips on public transportation (Hampshire et al., 2017; Murphy and Feigon, 2016). Others indicate a higher induced travel effect of 8% to 22% and a replacement rate of 31% (Clewlow and Mishra, 2017; Henao, 2017; Rayle et al., 2016). While the cited studies agree that TNCs draw at least some travelers from public transit, the variation in results could stem from differences in the cities analyzed, the sampling methods, and questions asked. For instance, one study asked respondents what mode they generally use TNCs to replace (Clewlow and Mishra, 2017) and another the mode they replaced with their most recent TNC trip (Rayle et al., 2016). The former approach could yield lower replacement rates for less commonly replaced modes. The same discrepancy could explain the low 1% induced travel effect in Murphy and Feigon, 2016, in which they asked frequent TNC passengers what mode they most often use TNCs to replace.

At the same time, a growing number of qualitative analyses posit that public transit agencies could take advantage of MOD services. In describing these studies, we employ the term TNC to denote research that focuses on apps that connect passengers with peer-to-peer drivers who provide service in their personally owned vehicles, while the term MOD denotes research that discusses MOD services more broadly. Shaheen and Chan (2016) assert that TNCs can complement public transit by providing a FMLM strategy during off-peak times or in less-served areas, while microtransit could also provide FMLM service and reduce overcrowding on high-ridership bus routes. Lazarus et al. (2018) recommend that public transportation agencies could reduce costs and improve transit access by replacing low-ridership bus routes and offering FMLM solutions with subsidized TNC trips. The authors identify partnership opportunities as those times when and areas where public transit service is inefficient and TNC driver pools are available. They also advise public transportation agencies take advantage of such partnerships to concentrate fixed-route service along high-volume corridors. Kuhr et al. (2017) state that partnerships between public transportation agencies and TNCs allow the public sector to innovate while sharing risk. The U.S. Federal Transit Administration (FTA) developed the MOD Sandbox Program in 2016 to provide $8 million in funding to public transportation agencies that integrate MOD services, including partnerships with TNCs and microtransit (FTA, 2016a). Objectives include generating best practices for how to develop such partnerships; measuring MOD impacts on the transportation system; and determining government requirements, regulations, and policies that help or hinder the integration of MOD services with public transit. Several qualitative reports outside peer-reviewed academic literature have also examined partnerships between public agencies and MOD companies, and some have proposed typologies for these partnerships. Tsay et al. (2016) conducted over 100 interviews with public and private sector representatives from early partnerships between public transportation agencies and MOD companies. They offer recommendations under four overarching guidelines: 1) partner to reinforce public transit strengths, 2) leverage agency-controlled assets, 3) plan for a streamlined user experience, and 4) be open to new ways of providing useful public transit. Schaller (2018) explores categories of partnerships between public agencies and MOD companies. He notes that such partnerships may be most useful for paratransit service and in dispersed travel markets. The U.S. Government Accountability Office (GAO) (2018), Schwieterman et al. (2018), Curtis et al. (2019), and Blodgett et al. (2017) present typologies for partnerships between TNCs and public agencies in the U.S. The latter three do not include partnerships with microtransit companies or companies that provide MOD software for public agencies to operate MOD service. We address that gap by introducing asset contribution as another MOD PPP

dimension to account for MOD PPPs in which the private partner operates microtransit vans instead of using a TNC model, as well as partnerships in which the private partner provides only the MOD software, while the agency takes responsibility for securing vehicles and drivers. This paper also diverges from the typologies proposed by the GAO (2018), Schwieterman et al. (2018), and Curtis et al. (2019) because we con- sider marketing and promotion, trip planning and fare integration, data sharing, and guaranteed ride home services as strategies that support four core MOD PPP service models: 1) FMLM, 2) Low-Density, 3) Off- Peak, and 4) Paratransit. We view the alleviation of parking demand as a possible impact of MOD services, rather than as a partnership cate- gory.

1.3. Overview

The questions we sought to answer with our analysis are:

a) Typology: What types of MOD PPPs exist and how do they relate to one another?
b) Benefits and Disadvantages: Based on publicly available documentation on MOD PPPs and feedback from public and private partners, what are the benefits and drawbacks of each type of MOD PPP for public transportation agencies?
c) Trends: At what rates are public transportation agencies implementing each type of MOD PPP and how do the identified benefits and disadvantages help interpret these trends?
d) Implications: In light of the identified benefits and disadvantages, how do representative public and private partners recommend that public transportation agencies decide between MOD PPP models and optimize implementation of the chosen model for the agency and its passengers?

The next section includes a discussion of our methodological approach for analyzing existing MOD PPPs and identifying the answers to each question listed above. We then present three sections of findings corresponding to the first three questions. We conclude by examining key implications of the findings for public transportation agencies considering MOD PPPs.

2. Methodological approach

The literature review highlighted three critical gaps in the academic literature: 1) a conceptual framework for MOD PPPs, especially one that includes microtransit services and “agency-operated” partnerships in which the private partner provides only the ride-matching and routing algorithm, 2) trends in the number of public transportation agencies employing each MOD PPP model, and 3) comparative benefits, disadvantages, and recommendations for public transportation agencies regarding the implementation of each type of partnership. While some articles have discussed challenges and recommendations from a case study examination (e.g., Westervelt et al., 2017, 2018), we broadened our review to a comprehensive examination of existing MOD PPPs.

To address the first gap, we compiled a database of MOD PPPs in the U.S. by reviewing online newspaper articles and public transit agency and MOD company websites. Inclusion criteria for MOD PPPs involved public agencies and private companies collaborating to provide MOD services that meet the FTA definition of public transportation: “regular, continuing shared-ride surface transportation services that are open to the general public or open to a segment of the general public defined by age, disability, or low income” (FTA, 2016b). These include MOD company partnerships with public transportation agencies, transportation authorities, and cities. For simplicity, we refer to public transportation agencies throughout the text, except in Table 6, where we explicitly include only public transportation agencies in the table and describe transportation authority and city partnerships in the footnotes. Due to the rapid growth in the number of partnerships, some MOD PPPs may have been omitted from our analysis. The database we developed informed our first draft of a MOD PPP typology, which we refined through expert interviews.

Between October 2017 and April 2018, we conducted 34 interviews with representatives from four MOD companies, 21 public transit agencies, two transportation authorities, one regional planning agency, and three cities. We chose organizations to interview based on their involvement in MOD PPPs that were the “first of their kind” or that experienced notable success or challenges with a unique partnership feature. The partnerships examined through the interviews span each category of the typology and represent a range of geographies, densities, use cases, and target populations. We identified individual interviewees based on their familiarity and involvement with the development and implementation of the partnerships. Table 1 below summarizes interviewees' roles by organization type. Interview questions included: a) how the organization decided to create the partner- ship; b) how it identified partners; c) how the MOD service fills gaps in the public transit network; d) the benefits and disadvantages from the partnership for the organization and how these are quantified; and e) how the partners share data, lessons learned, and next steps. Interviews were documented with written notes, and we sought written clarification from the interviewees after the interviews, as necessary.

We processed the interviews to refine the typology by tagging defining characteristics of the partnerships, identifying themes in how these characteristics varied across the partnerships, cross-checking the themes against all identified partnerships to ensure they helped de- scribe variation throughout, and organizing the themes into a typology with descriptions of each level and category.

To analyze trends, we classified each identified MOD PPP according to the typology and graphed the occurrence of each model by start and end date. The initial classification enabled us to isolate interactions between the asset contribution models and the service models, while the graphs enable a comparative analysis of changes in the frequency of each model over time.

To inform the remaining findings and implications sections of the paper, we tagged benefits, disadvantages, and recommendations mentioned in the interviews and sorted them by MOD PPP model. We then applied the benefits and disadvantages as a lens through which to analyze potential explanations for the observed trends.

3. Findings: typology of MOD PPPs

Based on our analysis, we classified MOD PPPs along three key dimensions: asset contribution (assets contributed by each partner to enable service), service provision (service provided to the public through the partnership), and vehicle type (the vehicles used to provide the service). We defined two asset contribution models: Agency-Operated MOD, in which the private partner provides only the ride-matching and routing algorithm, and Agency-Subsidized Private MOD, in which the private partner also provides the vehicles and/or the drivers. We identified four service models: 1) First-Mile/Last-Mile (FMLM), 2) Low-Density, 3) Off-Peak, and 4) Paratransit. Finally, we observed three vehicle types: vans, taxis, and personal vehicles owned by TNC drivers. Each dimension offers a lens through which to analyze how to meet service goals while minimizing competition with fixed-route public transit. The asset contribution model impacts the public agency's level of data access and control over the service and, in turn, its ability to monitor whether the MOD PPP competes with fixed-route transit or meets equity and environmental goals. Not surprisingly, the service model affects the risk that a MOD PPP will compete with fixed-route transit. Vehicle size affects potential vehicle occupancy and impacts on congestion, VMT, and emissions. Fig. 1 depicts the observed relationship between these three dimensions among MOD PPPs in the U.S.

Fig. 2 below maps the locations of 62 MOD PPPs by U.S. public transit agencies, transportation authorities, and cities. The map distinguishes MOD PPPs by asset contribution model and service model.

3.1. Asset contribution models

The MOD asset contribution models vary by which partner provides necessary assets for the MOD service: on-demand ride-matching and routing software, drivers, and vehicles. In each model, the public partner pays the private partner and the private partner designs the on-demand ride-matching and routing software. In Agency-Operated MOD, the public partner uses this software to offer services with its own employed or contracted drivers. With Agency-Subsidized Private MOD, the private partner is responsible for employing or contracting with the drivers. While all observed Agency-Operated MOD partnerships use microtransit vans to provide service, Agency-Subsidized Private MOD may use microtransit vans, taxis, or personal vehicles owned by TNC drivers. For Agency-Subsidized TNCs or MOD Taxis, the private partner owns the vehicles or arranges for drivers to use their personal vehicles. Generally, the public partner owns the vans used for Agency-Operated MOD and the private partner owns them for Agency-Subsidized Private Microtransit, though either partner or both partners can contribute these vehicles.

Table 2 illustrates these contributions. The arrow indicates that the public agency's control over the service and access to trip data is lowest under the Agency-Subsidized TNC model, increases under Agency-Subsidized MOD Taxi and Microtransit models, and is greatest under Agency- Operated MOD. This hierarchy reflects differences between the type of data that the private sector partners typically provide public agencies. Uber and Lyft often give the public partner aggregated measures such as: average trip fare and trip length, a heat map of trip volume by geographic area, and the percent of trips under designated estimated times of arrival (ETAs). The microtransit company Via generally offers trip-level data down to the nearest intersection of pick-ups/drop-offs. Companies that provide only the ride-matching and routing software for Agency-Operated MOD supply the public partners with all trip-level data.

Table 1
Expert interviews.

Type and number of organizations	Number of interviewees	Function in organization
4 MOD companies	5	Vice President. Managers: Transportation Partnerships, Transportation Policy, Accessibility Policy, Business Development.
21 Public transportation agencies, defined as agencies required to report to the National Transit Database	27	Innovation: Director, Program Manager. Planning: Director, Vice President, Manager, Principal Planner, Transportation Planner. Operations: Deputy Chief Officer, Director. Demand Response: Vice President, Manager, Supervisor. Contract Services: Director, Administrator. Marketing: Chief Officer, Director, Strategic Manager. Information Technology: Senior Director.
2 Transportation authorities	2	Planning: Manager. Operations: Program Services Manager.
1 Regional Planning Agency	4	Planning: Deputy Director, Senior Regional Planner. Operations: Senior Program Specialist.
3 Cities	3	Innovation: Senior Officer. Transportation: Engineering Manager, Assistant Planner.

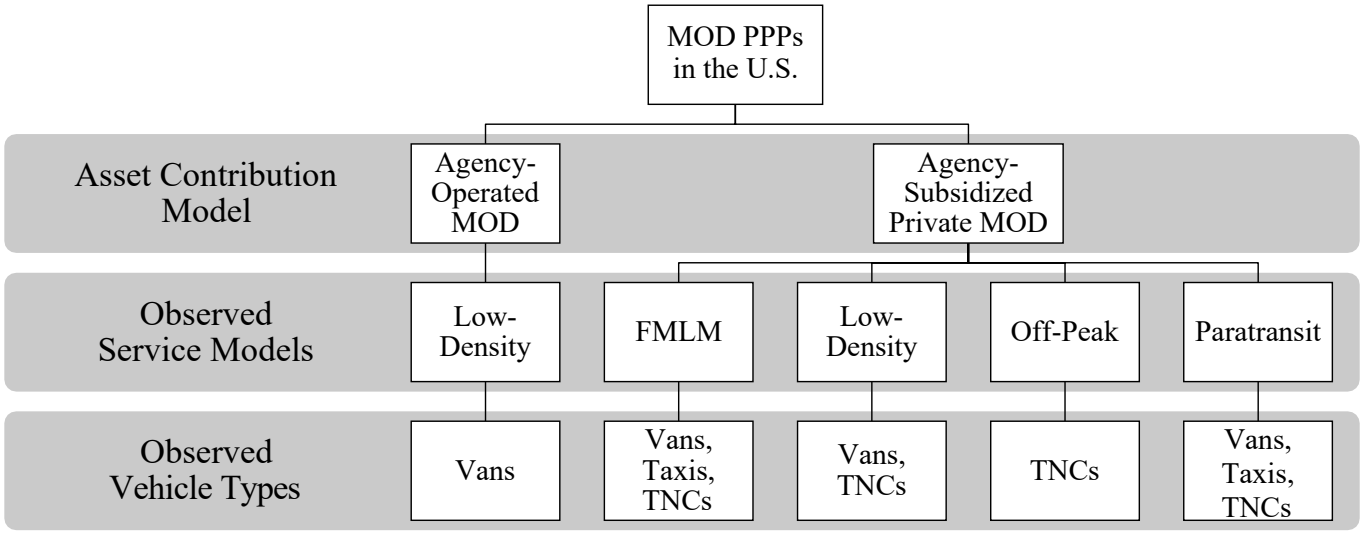

Fig. 1. MOD PPP typology.

3.2. Service models

The service models are distinguished by socio-demographic, geo-spatial, and temporal restrictions on trip provision. Table 3 presents how these restrictions differ by service model. The highlighted cells in the table indicate which restriction defines each model. For instance, FMLM partnerships are defined by their geo-spatial restrictions because they only subsidize trips that start and end at a public transit stop or station, thereby supporting public transit transfers. Low-Density and Paratransit partnerships do not require transfers to transit and instead serve trips from their origin to destination (point-to-point service), while Off-Peak partnerships can either: a) employ point-to-point service or b) set FMLM restrictions, if the agency operates reduced fixed-route service in off-peak hours. Low-Density partnerships restrict subsidized service to trips taken within specified zones, generally located in areas with densities too low to support frequent fixed-route bus service. Similarly, Off-Peak partnerships only subsidize trips taken during times in which demand is too low to support frequent fixed-route bus service. Off-Peak partnerships differ from FMLM or Low-Density partnerships provide service during standard fixed-route service hours or only during peak because they specifically fill gaps caused by scaling back fixed-route service during off-peak hours, whereas FMLM and Low-Density part-hours. Finally, Paratransit partnerships only subsidize trips made by individuals with disabilities or above a designated age.

While the first three service models do not restrict subsidies to those within a specified demographic, they can incorporate demographic restrictions to meet agency goals. For example, a FMLM partnership could restrict service to those with a transit station parking pass, thereby reducing parking demand at stations by only subsidizing those who would otherwise drive and park. An Off-Peak partnership could restrict service to low-income night-shift workers, thereby targeting subsidies to help individuals secure and keep otherwise-hard-to-access jobs.

Any of the four service models can either fill gaps by providing service where no comparable service existed previously or replace a previously existing, less efficient service. FMLM, Low-Density, and Off-Peak partnerships can replace low-ridership fixed bus routes. Low-Density partnerships can also replace general public dial-a-ride services,

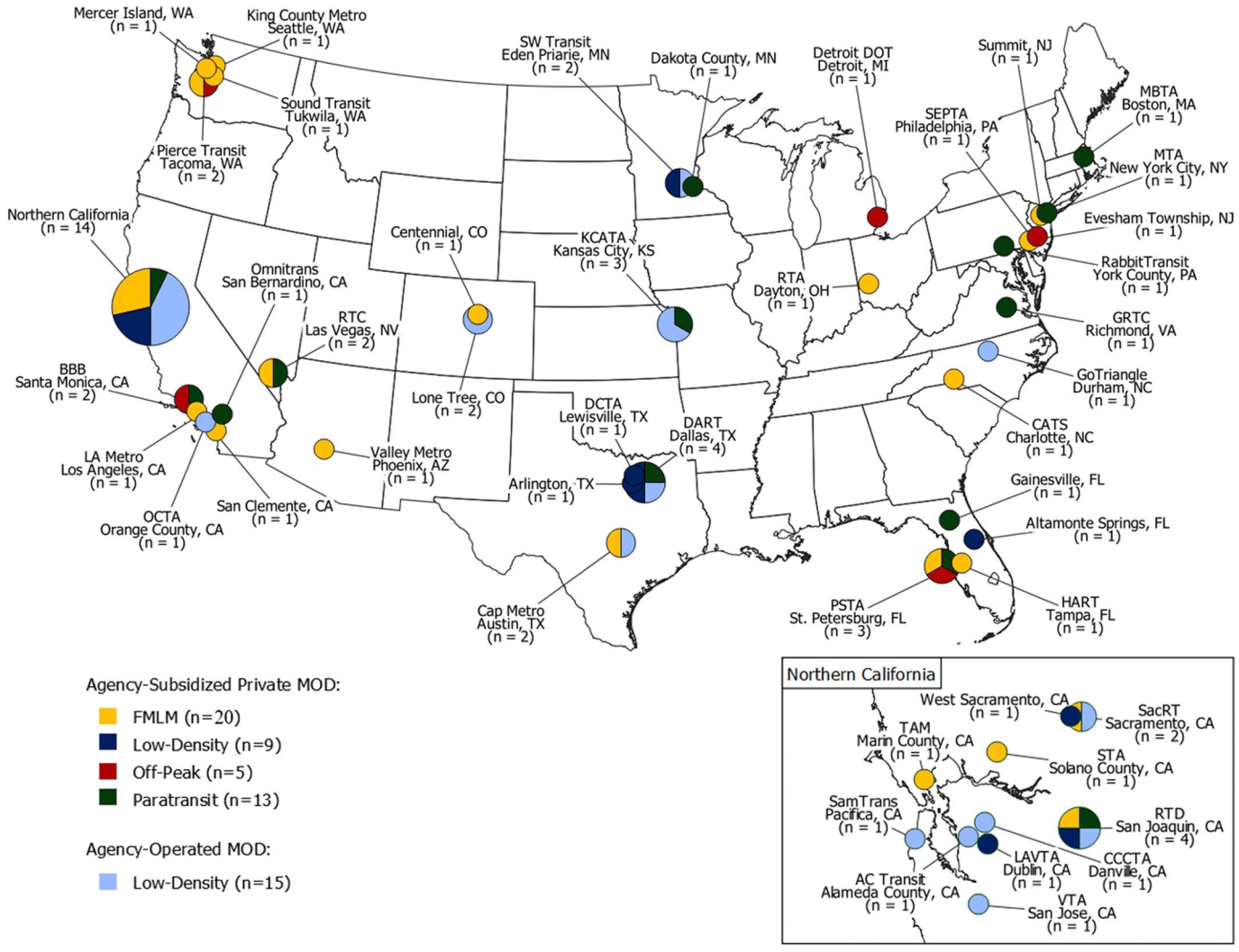

Fig. 2. Map of MOD PPPs in the U.S. through April 2019.

and Paratransit partnerships can replace and/or supplement prior paratransit services.

As an example of two different partnership models in the same city, Dallas Area Rapid Transit (DART) started GoLink, an Agency-Operated MOD partnership with DemandTrans, in June 2017 and a separate Agency-Subsidized Private MOD partnership with Uber in March 2019. GoLink provides Low-Density point-to-point service in 13 zones for $1.50 per trip on weekdays from 5 am to 9 pm. DART encourages FMLM trips by offering free GoLink service with any DART pass. In the same zones and times, passengers can use the GoPass app to access $3 UberPOOL rides anywhere within a given zone (Low-Density, point-to-point service). As with GoLink, DART encourages FMLM trips by offering $1 UberPOOL trips to or from eligible DART stations. DART presents the UberPOOL option as a faster but more expensive option for passengers than GoLink (Dallas Area Rapid Transit, 2019).

Table 2
Asset contribution models by public and private contributions.

			Software	Drivers	Vehicles
Agency's level of control, access to data, & required resources	Agency-Operated MOD	Van			
	Agency-Subsidized Private MOD	Van			
		Taxi			
		TNC			

Provided by:
- Private Partner
- Public Partner
- Either or Both the Private / Public Partner

Table 3
Service models by restrictions on passengers' eligibility for subsidized trips.

	Geo-Spatial **Only serve trips that:**	**Temporal** **Only serve trips made during:**	**Socio-Demographic** *(e.g., Income, Ability, Age, Frequency of Transit Use)* **Only serve trips made by:**
First-Mile/ Last-Mile	Start/End at Fixed-Route Public Transit Stop or Station	Public Transit Service Hours (or Peak Hours)	Anyone, But Could Restrict Eligibility *(e.g., only serve commuters or those who own transit station parking passes)*
Low-Density (Geo-Spatial Gap-Filling or Replacement)	Start/End Outside Fixed-Route Service Area *(e.g., within buffer zone of replaced bus route)*	Public Transit Service Hours	Anyone, But Could Restrict Eligibility
Off-Peak (Temporal Gap-Filling or Replacement)	Are Within Public Transit Service Area	Off-Peak Hours *(e.g., night, possibly midday)*	Anyone, But Could Restrict Eligibility *(e.g., only serve low-income night-shift workers)*
Paratransit	Are Within Public Transit Service Area	Public Transit Service Hours	Persons with Disabilities; Senior Citizens

4. Findings: benefits and disadvantages of each MOD PPP model

In this section, we consolidate the benefits and disadvantages of each asset contribution model and service model, as identified in the expert interviews and a review of publicly available documentation of existing MOD PPPs. Each public transportation agency acronym used here and in following sections is identified by location in Fig. 2, above.

Table 4 explores each asset contribution model and its potential benefits and disadvantages. In general, greater control and access to data under the Agency-Operated MOD model enables public agencies to better understand the MOD service and promote the public good, such as increasing equity and public transit ridership. Two reasons deter some public agencies from selecting Agency-Operated MOD as an asset contribution model, including: 1) the financial and physical resources required by the agency to operate the service are greatest under the Agency-Operated MOD model and 2) demand is insufficient to justify the large microtransit vans typically used in Agency-Operated MOD.

In Table 5, we provide an overview of the four MOD service models and their potential benefits and disadvantages. From the perspective of minimizing competition with fixed-route services, the Paratransit and Off-Peak models offer advantages because paratransit is a separate service, while Off-Peak partnerships, by definition, typically operate outside fixed-route service hours. Protecting fixed-route services under the FMLM and Low-Density models requires additional precautions, as discussed in the implications section.

5. Findings: partnership trends

After categorizing the models, we analyzed existing MOD PPPs according to the typology to identify trends in the partnership models used. In the few cases where partnerships lacked service time restrictions, thereby providing Off-Peak service in addition to FMLM or Low- Density service (e.g., Dublin, CA), we classified them as FMLM or Low- Density, respectively, because the decision to provide all-day service was for convenience rather than to explicitly fill off-peak gaps. The expert interviews provide possible explanations for the observed trends,

Table 4
Description, benefits, and disadvantages of each asset contribution model.

Name and description	Potential benefits	Potential disadvantages
Agency-Operated MOD: Private MOD company provides only on-demand ride-matching and routing software, while the agency uses its own drivers or drivers from its existing contract.	• Public agency has complete control over the service and retains access to all data (e.g., AC Transit, King County Transit) • Employing agency drivers can earn union support (e.g., KCATA) • Microtransit vans enable greater vehicle occupancy, potentially reducing VMT more than taxis or TNCs	• Requires more resources • Can be difficult to aggregate enough riders to offset costs (e.g., VTA) • Microtransit service may pull riders from more sustainable modes such as: bus, rail, bicycle, or walking
Agency-Subsidized Private MOD: • Agency-Subsidized Private Microtransit: Private partner hires their own drivers or contracts with a third party for driver services only. • Agency-Subsidized Private MOD Taxis: Private partner contracts with taxi companies for their vehicles and drivers. • Agency-Subsidized TNCs: Private partner contracts with independent drivers who use their personal vehicles.	• Public transportation agency does not need to own vehicles or hire drivers for the MOD service	• Subsidizing a service that employs private MOD company drivers sometimes leads to union resistance (e.g., DART) • Public partner may have limited access to trip data (e.g., PSTA) • Subsidizing trips on smaller vehicles could increase VMT

Table 5
Description, benefits, and disadvantages of MOD service models.

Name and description	Potential benefits	Potential disadvantages
First-mile/last-mile: Public partner subsidizes MOD trips to or from public transit stops or stations. MOD company geofences the designated transit stops or stations to ensure the discount only applies to eligible trips.	Protects transit by only subsidizing rides to/ from public transit stations (e.g., PSTA) Can modify discount to reduce parking demand at transit stations (e.g., Summit, NJ) May increase proportion of FMLM rides that are shared Restricting discount to peak hours attracts commuters who require reliable FMLM service (e.g., RTD) When geared toward commuters, employers may help cover service cost (e.g., STA)	Can compete with other non-SOV FMLM options, such as riding the bus, biking, or walking Transfers and multiple payments may deter potential passengers
Low-density: Public partner subsidizes MOD trips anywhere within a designated zone. These partnerships target low-density areas that cannot support fixed route bus service.	Better service than infrequent, low-ridership bus routes, at a lower cost than a dial-a-ride service (e.g., RTD, SW Transit) Zone structure can make it easier for riders to understand which trips are eligible for a discount (e.g., LAVTA)	
Off-peak: Public partner discounts MOD trips during off-peak hours.	Direct, on-demand trips at a lower cost to agency than low-ridership late-night transit service Discourage drunk driving (e.g., Evesham Township, NJ) Better serve night-shift workers (e.g., PSTA)	
Paratransit: Public or private partner uses MOD technology to supplement or replace the public transportation agency's existing paratransit service.	Provides on-demand paratransit trips rather than requiring riders to schedule trips a day or more in advance Lower per-trip costs for public agency and passengers (e.g., MBTA)	

related data and have the resources to provide vehicles and drivers for a MOD service.

3) Between 2015 and 2018, Agency-Operated MOD and Agency-Subsidized Private Microtransit appear to be increasing, while the number of new partnerships in the other two categories have remained fairly constant. The expert interviews suggest that this trend is due to concerns about the difficulty of securing data from TNCs, the potential for greater vehicle occupancy and VMT reduction from the use of microtransit vans, and the sense that these models compete less with fixed-route services. MOD companies that operate microtransit vans and offer MOD software for public agency use are also gaining experience in adapting their services to fit public agency needs, increasing partnership opportunities.

4) MOD Asset Contribution Model Terminations: Eight of 38 Agency-Subsidized Private TNC partnerships, 5 of 13 Agency-Operated MOD partnerships, and 1 of 3 Agency-Subsidized Private Taxi partnerships have been terminated. The agency-subsidized MOD taxi service ended due to excessive costs. Agency-Operated MOD services ended due to:

- Overly-restricted service areas that led to insufficient ridership (2 pilots)
- Unadaptable ride-matching and routing algorithm (2 pilots), and
- Concerns about competition with fixed-route services (1 pilot).

The latter two pilots were replaced, respectively, with 1) another Agency-Operated MOD service with an improved routing algorithm and 2) an Agency-Subsidized TNC pilot for FMLM service.

Reasons for terminating the Agency-Subsidized TNC pilots included:

- Concerns about competition with fixed-route services (1 FMLM pilot and 2 Low-Density pilots);
- Overall difficulty working with TNCs, including cost, labor union concerns, lack of data access, and difficulty of providing an equitable paratransit alternative (2 FMLM pilots and 1 Low-Density pilot);

Table 6
Number of Public Transit Agency MOD PPPs in the U.S. through April 2019.

	Agency-Operated MOD	Agency-Subsidized Private MOD			
	Microtransit Vans	**Microtransit Vans**	**Taxi**	**TNC (Personal Vehicles)**	**Total:**
FMLM		**2**	**1**	**11**[a]	14
2016			Tampa*	St. Petersburg (FL), Philadelphia*, Sacramento*	
2017				Dayton, San Joaquin (CA), Phoenix*	
2018		Seattle		Charlotte, Tacoma, Austin, Las Vegas	
2019†		Seattle		Los Angeles	
Low-Density	**13**[b]	**0**[c]		**6**[d]	19
2015	Eden Prairie (MN)				
2016	San Jose*, Kansas City*, Alameda County (CA)			Dallas*, Lewisville (TX)	
2017	Austin*, Dallas			Dublin (CA), San Joaquin (CA)	
2018	Sacramento, Durham, Contra Costa (CA)*, San Joaquin (CA), Orange County			Eden Prairie (MN)*	
2019†	Kansas City, Pacifica (CA)			Dallas	
Off-Peak				**4**[e]	4
2016				St. Petersburg (FL)	
2017				*Santa Monica*	
2018				Tacoma, *Detroit*	
Paratransit		**1**	**2**	**8**[f]	11
2016				Boston	
2017		San Joaquin (CA)	NYC, Kansas City	York County (PA), Richmond (VA), Dallas	
2018				Las Vegas, San Bernardino (CA), Santa Monica, St. Petersburg (FL)	
Total:	13	3	3	29	**48**

Note: The italicized Off-Peak partnerships employ FMLM restrictions, as opposed to point-to-point service. Please note that this table excludes PPPs with transportation authorities and cities, focusing on public transportation agencies only.
†Through April 2019.
*MOD PPP has ended.
[a]Also includes four MOD partnerships with cities and two with transportation authorities: 1) Centennial, CO (2016*); 2) Summit, NJ (2016); 3) San Clemente, CA (2016); 4) Mercer Island, WA (2018*); 5) Solano Transportation Authority, CA (2017); and 6) Transportation Authority of Marin, CA (2017).
[b]Includes Lone Tree, CO (2017* and 2019).
[c]Includes: 1) Arlington, TX (2017) and 2) West Sacramento, CA (2018).
[d]Also includes: 1) Altamonte Springs, Lake Mary, Longwood, Maitland, and Sanford in Florida (2016*) and 2) Monrovia, CA (2018).
[e]Also includes Evesham Township, NJ (2015).
[f]Also includes: 1) Gainesville, FL (2015) and 2) Dakota County, MN (2019).

- Decision to evaluate other options before potentially scaling up the service (2 Low-Density pilots).

Two agencies replaced Agency-Subsidized TNC pilots with Agency-Operated MOD services. One of these subsequently re-introduced an Agency-Subsidized TNC service in the same zones as its Agency-Operated MOD service but restricted the discount to ridesplitting trips only.

5) The most common service model is Low-Density, closely followed by FMLM. Low-Density is also the easiest model to implement, as it involves a general zone-based structure for subsidized ride eligibility, while FMLM is a popular choice because it increases the chance that riders will use the subsidized service to access public transit.
6) The number of new MOD PPPs for FMLM and Off-Peak service has been relatively steady since 2016, while new MOD PPPs for Paratransit service peaked in 2017, and new MOD PPPs for Low-Density service seem to be increasing.
7) MOD Service Model Terminations: Categorizing the terminated pilots by service model shows that 6 of 21 FMLM pilots and 8 of 25 Low-Density pilots have ended, compared to none of the Off-Peak or Paratransit pilots. The relative longevity of MOD Paratransit pilots is likely due in part to the greater cost savings and service improvements these partnerships typically provide (e.g., MBTA).

6. Implications

Partnerships with MOD companies present public transit agencies with opportunities to improve the efficiency and quality of service, particularly for elderly, disabled, low-income, and rural populations. At the same time, such partnerships can compete with existing public transit service when not implemented carefully. We analyzed 62 existing MOD PPPs in the U.S. and conducted 34 interviews with public and private partners. This work informed the identification of a typology of MOD PPPs, benefits and disadvantages of each partnership model, and comparative trends in the occurrence of each model.

Our analysis suggests several considerations for choosing service

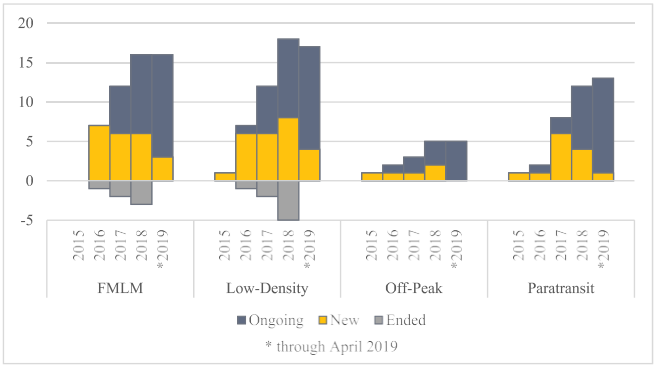

Fig. 3. Number of new and ongoing asset contribution models from 2015 to April 2019.

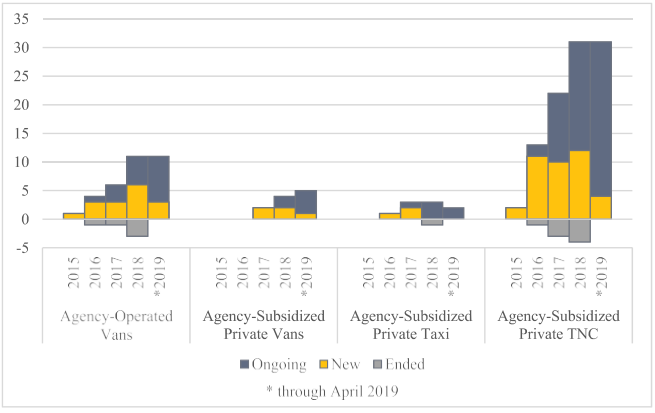

Fig. 4. Number of new and ongoing service models from 2015 to April 2019.

models and asset contribution models for a MOD PPP. Key recommendations focus on protecting fixed-route public transit and meeting equity and environmental goals. The recommendations are neither universal nor backed by empirical support but are instead based on evidence from the interviews and review of publicly available documentation on existing MOD PPPs. Agencies that have adopted or considered the strategies are cited.

When choosing a service model, agencies should consider that, while Off-Peak and Paratransit MOD PPPs do not compete with fixed-route services, FMLM and Low-Density models may require strategies to support rather than undermine existing public transportation. Although the FMLM model encourages transfers to fixed-route services by requiring trips to start/end at public transit stops, some agencies take additional measures to reduce the likelihood of passengers using the MOD service to access locations near the public transit stop rather than transferring. These strategies include: a) setting required start/end stops on high-performance routes in places without major trip attractors (e.g., PSTA) and b) creating catchment zones that divide trip generators and attractors and assigning one or two designated transfer stops to each zone (e.g., HART, PSTA). One way to protect fixed-route services under the Low-Density model is to restrict service to areas outside the geofenced fixed-route service area (e.g., RTD). Less aggressive measures include: a) using microtransit vans to allow greater vehicle occupancy (e.g., 15 partnerships); b) subsidizing only ridesplitting or pooled trips (e.g., DART, LAVTA); and c) offering higher subsidies for shared rides (e.g., MBTA), large groups (e.g., SacRT), and transfers to/from fixed-route services (e.g., DART, GoTriangle). Offering higher subsidies for disadvantaged populations also helps meet equity goals (e.g., DART, KCATA, LA Metro, RTD, SacRT). For both FMLM and Low-Density partnerships, our interviewees identified the ideal use cases as locations dense enough to support shared rides but with disparate origins and destinations that are difficult to serve with fixed-route public transit.

Regarding the selection of asset contribution models, our analysis suggests that, if agencies have sufficient resources, the Agency-Operated model generally allows greater data access and control over the service than Agency-Subsidized Private MOD. In some cases, the public agency has sufficient resources for Agency-Operated MOD but too few microtransit vans to meet peak demand. A few public agencies have started to address this problem by employing a mix of asset contribution models to meet peak demand, while preserving as much data access and control over the MOD service as possible (e.g., SW Transit). These agencies employ Agency-Operated MOD to provide a majority of the service and supplement with Agency-Subsidized Private MOD for “overflow” service in peak periods. The challenge raised by this strategy is that private MOD operators typically also have long wait times in peak periods. In other cases, agency resources and/or demand for the service are simply insufficient to enable Agency-Operated MOD. The expert interviews suggest that better data sharing strategies, including laws that protect an individual's location data from public information requests, could help public agencies to ensure Agency-Subsidized Private MOD supports equity and environmental goals. Other strategies to increase the public agency's data access under Agency-Subsidized Private MOD include: a) centrally dispatching trips (e.g., RabbitTransit) and b) enabling passengers to pay for the MOD service using funds from their public transit accounts (e.g., DART). These approaches allow the public agency to track when and where trips occur and, in the second strategy, whether passengers transfer to fixed-route public transit ser- vice.

Other takeaways from the expert interviews relate to identifying gaps or inefficiencies in public transit service, determining goals and data needs, contracting with MOD companies, and marketing. Potential opportunities for MOD PPPs to fill gaps in public transit service include: low-ridership bus routes; dial-a-ride/paratransit services with high costs per passenger; dispersed employment centers; public transit stations with high parking demand; late-night transportation for workers; non-emergency medical transportation; and temporary needs, such as events or construction. With respect to goals and data needs, MOD performance metrics are most similar to those for dial-a-ride service (e.g., average wait time between request and pick-up). In terms of cost per passenger and passengers per hour, most MOD PPPs perform better than traditional dial-a-ride or paratransit services but worse than fixed-route services (e.g., OCTA, SW Transit). Agencies can also facilitate user surveys by requiring potential passengers to register with the agency before receiving a discount code (e.g., DART). When developing a contract with selected partner(s), agencies should consider ensuring the contract allows adjusting service easily, such as expanding service areas (as suggested by VTA) or restricting subsidy eligibility. Several agencies also noted the importance of considering ease of marketability when designing service, including how eligible trips are defined (e.g., LAVTA) and selecting service zones with well-known boundaries (e.g., GoTriangle).

The trends analysis combined with the identified benefits and disadvantages suggests that, as MOD PPPs become more sophisticated, the common asset contribution models will likely continue to shift toward Agency-Operated MOD and Agency-Subsidized Private Microtransit because these models enable higher vehicle occupancy and potentially lower VMT. Among service models, FMLM will likely become more common as MOD companies become better able to restrict subsidized trips to those that start and end at public transit stops. Paratransit MOD PPPs will also likely become more popular due to the large potential cost savings, decrease in wait times, and lack of competition with fixed-route services. Low-density MOD PPPs will likely continue to replace general public dial-a-ride service for the same reasons.

Opportunities for future research include empirically analyzing the benefits, disadvantages, and recommendations that we identified

qualitatively. Future efforts could also involve matching each service model to an ideal density range, as well as further analyzing MOD PPPs' equity and VMT impacts. Examining induced demand for MOD PPP service is crucial to this work, as providing service with shorter wait times and more direct trips will draw new riders, potentially increasing VMT and agency costs. Agent-based and activity-based modeling could suggest the most appropriate policy combinations for MOD PPPs to achieve a range of societal goals, including equitable travel/wait times and costs for low-income, minority, and rural populations. Similar techniques could highlight a phased policy approach for public transportation agencies to prepare for the next generation of MOD PPPs as automated vehicle (AV) technology and shared AV fleets are deployed.

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