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Shifting, Not Shrinking? Exploring Labor Roles in Traditional and Automated Taxi Services

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Leah Kaplan, Zoe Szajnfarber, and John Paul Helveston
Department of Engineering Management and Systems Engineering, The George Washington University

Abstract

Systems engineering has often concerned itself with how operator and customer roles change when systems change. In the context of automated vehicles (AVs), it has been assumed that operators will be removed from the system, but new insights reveal that the role of operators (typically thought of as drivers) has been transformed, not eliminated. In this study, we identify how taxi companies, Transportation Network Companies (TNCs, e.g., Uber and Lyft), and AV companies use varying organizational architectures to achieve required functions, and we explore how these architectures might change with the emergence of automated taxi services. Drawing on field observations, detailed ethnographic studies, archival documents, and semi-structured interviews with AV technical and operational experts, we identify and detail required functions for these services. Preliminary results reveal that the structures of commercial AV taxi services more closely parallel traditional taxi organizations rather than current TNCs based on their capital cost and human labor requirements. Future research will explore short and long-term development pathways for AV systems and their associated structural and functional requirements. While the structures of these AV companies will continue to develop alongside the automation technologies, early explorations of AV organizations can promote dialogue about regulations that might direct emerging AV services toward more desirable service and labor outcomes.

Keywords
Automated vehicles, TNCs, Taxis, Robotaxis, Labor

1. Introduction
Transportation Network Companies (TNCs) like Uber and Lyft have raised billions of dollars by promising a future of automated taxi fleets (robotaxis) that would eliminate the cost of a driver and pave a path to profitability [1]. Prior simulation studies investigating the potential impacts of automated vehicles (AVs) have similarly adopted this assumption of "zeroing out" the labor costs for robotaxi services, focusing solely of the capital costs of AVs [2]. Introducing automation, however, often results in a transformation of human labor rather than a complete substitution [3]. Government officials are calling for assessments of the future of transportation work in light of automation and its implications for worker skill requirements and workers' rights [4]. Understanding these labor changes can also provide insights into how AV services might be delivered and regulated. To investigate how vehicle automation is changing the nature of labor requirements for robotaxi services, this study draws on field observations, detailed ethnographic studies, archival documents, and semi-structured interviews with AV technical and operational experts (N = 13). Through this early exploration of robotaxi labor requirements, this study aims to promote dialogue about regulations that might direct emerging AV services toward more desirable service and labor outcomes.

2. Related Research
Prior research has sought to provide high-level estimates of job losses and gains due to vehicle automation based on large surveys that identify and categorize job requirements [5]. Such studies classify occupations as likely to be eliminated or impacted by automation (or not) based on whether the job involves driving as a primary or secondary activity. Yet increasingly researchers are finding that automation impacts occupations in complex, non-binary ways. To capture the potential transformation—rather than substitution—of human labor, Dekker and Woods [3] argue that researchers should take a qualitative approach that can better capture the mutual shaping of automation technologies and human work systems. A recent study from the U.S. Department of Transportation found that transit operator jobs might shift to focusing more on customer assistance and other non-driving duties once buses reach higher levels of automation [6]. In the trucking sector, Viscelli [7] identified a series of potential AV trucking deployment scenarios, each with unique impacts to drivers' roles and associated compensation. These potential scenarios were largely shaped by potential policy decisions, highlighting external factors beyond technology development that could have equally

significant impacts on labor outcomes. While these studies provide valuable insights into alternative pathways for transportation labor impacts, they remain limited to the trucking and transit sectors. The door-to-door passenger transportation service sector (hereafter referred to generally as "taxi services") which accounts for over 830,000 jobs in the U.S., remains yet unexplored [8]. Taxi services play an important role in current transportation systems, providing additional transportation options, and filling temporal and geographic gaps in transit systems [9]. Vehicle automation in these services may not only affect the role of the driver, but also the roles and responsibilities of riders and who can use the service. In this study, we extend prior work seeking to qualitatively evaluate the impacts of vehicle automation on labor into the underexplored domain of taxi services.

3. Methodology

We employ a qualitative, direct research approach to examine the organizational structures and processes involved in delivering different forms of taxi services. In direct research approaches, researchers collect process data in real organizational contexts and utilize structured "sensemaking strategies" to identify patterns within the data [10]. Qualitative approaches are particularly valuable for identifying key system components and their relationships, especially in emerging systems [11] and process data collected via direct research approaches can lend themselves to multiple levels of analysis [10]. In this study, we analyze taxi systems both in terms of process evolution over the course of a single ride and evolution of the types of services over time.

We began our study with direct observation of commercial robotaxi services, taking rides in a publicly-available service that uses SAE Level 4 vehicles during the Summer of 2022 (N = 11 rides). The rides varied in time of day and geographic location (within the bounded service area), and two included a human safety driver onboard while the remainder did not. Researchers took notes on the vehicle features, drop-off and pick-up zones, public interactions with the vehicles, and personal interactions with customer-facing employees of the service. These preliminary observations provided a first touch-point of comparison between automated and existing taxi services. The majority of commercial robotaxi services are not available to the general public or require riders to agree to strict non-disclosure agreements. To further identify processes underlying robotaxi services and how they vary between AV companies, we utilized semi-structured interviews with AV technical and operational experts. We conducted twelve semi-structured interviews with thirteen unique interviewees (one interview included two interviewees), each of between 30 minutes and 1 hour in September 2022-January 2023. Three interviews were conducted in-person, with the remainder conducted over Zoom. The same researcher conducted all of the interviews. Initial interviewees were recruited via purposive sampling with additional interviewees identified via snowball sampling (i.e., prior interviewees suggesting future interviewees). The interviewees included AV regulatory and operational experts covering a range of involvement with AV government-run pilot projects, commercial operations, and AV research. One participant had expertise in AV operations in Europe but the remaining interviewees focused on a U.S. context, covering the operations of six different AV companies. Interviews were conducted until theoretical saturation was achieved (i.e., new interviewees did not mention any new functions, labor roles, or system features). All interviews, with the exception of one for which consent to record was not given, were recorded and transcribed via auto-transcription software within 24 hours. All transcripts were edited by the researcher who conducted the interviews within 48 hours. We triangulated information from these interviews with archival data provided by the interviewees and identified by the researchers, including safety cases published by AV companies that further detail their operations, vehicle designs, and existing AV regulations [12].

We open-coded all of the interview transcripts, reading through each transcript multiple times in order to identify emergent themes [13]. Two key themes that emerged were the establishment of new labor roles and variations between the business models of different companies. Using a visual mapping strategy [10], we delineated some of the functions in robotaxi services and began to draw parallels between automated and traditional services. Rather than directly observe taxi and TNC systems to identify more detailed process steps, we drew on two in-depth ethnographic studies that detail the functions involved in traditional taxi and TNC services and describe changes in the structures of these organizations over time. Dubal [14] interviewed taxi workers (N = 45) and Uber drivers (N = 15) in San Francisco, and collected hours of participant observations at organizational, regulatory, and advocacy meetings between 2010-2015. Cameron [8] conducted participant observations as a TNC driver (N = 160 hours), participant observations as a rider (N = 112 rides) and conducted semi-structured interviews (N = 136 interviews) from 2016-2019. We performed a second round of theme-based coding on our interviews and the two ethnographies to identify detailed labor tasks. Finally, we grouped these detailed tasks into higher-order functions and identified who (or what) performs that function in each taxi system.

4. Results

From requesting a vehicle to eventually exiting the vehicle at the desired destination, we consider the various steps in using a taxi service in terms of their higher-level functions and map them to who (or what) performs each function in different types of existing and potential future taxi service systems (Table 1). We bound our analysis to include only those functions directly involved in providing the taxi service for a rider, excluding labor involved in app programming and the development and training of AV systems (though, as with other AI-related domains, training in particular has critical labor implications, especially for low-wage workers). In the following sections, we describe how each function has changed over the evolution of the taxi industry, including new types of human labor that have been created as part of emerging AV services. We also hypothesize about additional changes that may occur with further development of AV technologies.

Table 1: Mapping high-level functions to labor type for different types of taxi operations

Function	Function description	Early Taxi Company	Current Taxi Company	Current TNCs	Current AV services
Vehicle general service	Vehicle cleaning, refueling, start-up procedures	Driver			Service technician
In-vehicle passenger support	Assisting riders with disabilities, providing entertainment, managing conflict between riders	Driver			N/A
Customer service	Answering riders' questions	Driver		Driver + App	Tele-assistant + App
Driving	Operation of the vehicle	Driver			Vehicle
Incident response	Assisting riders, speaking with first responders (e.g., in case of accident)	Driver			Field support agent
Fare collection	Collecting payment for ride	Driver		App	
Dispatch	Matching vehicle to riders, allocating vehicles in service area	Dispatcher	Computerized dispatch technology	App	
Remote monitoring	Real-time monitoring of the vehicle, safety reminders, providing remote assistance as needed	N/A			Tele-assistant
Vehicle maintenance	Repairs to vehicle (and sensors), oil changes, tire rotations	Mechanic			

4.1. Vehicle Maintenance

Two types of functions help ensure that vehicles in the taxi fleet can operate properly: vehicle general service and vehicle maintenance. Vehicle general service includes refueling the vehicles and cleaning their interiors and exteriors. AVs currently require additional general service tasks including software startup procedures and regular downloads of the data they ingest (Interviews 1-4, 6-7, 10-12). Drivers perform these general service responsibilities in the taxi and TNC systems, but AV companies have shifted these responsibilities to a distinct role, which we define as a *Service Technician.* This role is filled through either contract partnerships [15] or by a full-time employee. Some companies are also looking to automate these general maintenance functions in the future, as one interviewee described:

> *You know, there are companies who can throw a relatively inexpensive AV kit on vehicles to perform a lot of these fleet operations, right. So, you know, do we have an AV kit on these vehicles that will drive them autonomously when it's their turn to charge, drive them up to the charging station, charge them, and then take them back to their parking spot and move the next one in or autonomously take them through the carwash every night or, you know, what are some of these routine fleet functions that we can improve upon?* (Interview 3)

Though automating these routine service functions may be possible, companies will need to weigh the added costs of layering in additional automated functions against paying a human laborer to perform these tasks. Less easily automated are more technical vehicle maintenance tasks that are traditionally performed by a mechanic. Mechanics remain an integral labor role in an AV future. Current AV companies have at least one dedicated AV mechanic on staff to perform not only typical vehicle repairs but also specialized maintenance on the AV sensors and computing equipment (Interviews 1, 3-6, 10-12). Moreover, some AV companies are proactively partnering with local community colleges to create AV-oriented mechanic training programs (Interview 5). As their fleets grow in size, AV companies may also need to upskill existing mechanics in order to service all of their vehicles.

4.2. System Operation (Dispatch and fare collection)
Technology changes have already largely automated system operation processes for matching riders to vehicles and collecting fare payments. In the past, taxi dispatchers used telephones and radios to determine the locations of vehicles and manually assign ride requests to drivers. The advent of computerized dispatch technology eased this task and increased efficiency by automatically assigning taxis to requests based on set operating rules (e.g., assign ride to the closest taxi based on GPS location) [9]. Since their inception, TNCs have relied on automatic dispatching—or rather matching—systems to perform the dispatch function. The functionality of the algorithms underlying these matching systems is more complex and opaque than those of computerized dispatch systems. TNCs' algorithms must negotiate between incentivizing independent contractor drivers, attracting riders, and generating profit for the company. Similar to TNCs, AV companies are using app-based systems to allow users to request rides in their vehicles. Since AV companies do not need to incentivize human drivers to accept rides, their automatic dispatch algorithms can return to simpler assignment rules. Though most of the dispatch function is performed by an algorithm, some AV companies still employ human dispatchers (Interviews 6, 10). These dispatchers facilitate resource allocation within the companies' current operational design domains (ODDs). One former dispatcher explained the importance of this allocation process for achieving service quality goals:

> *...the dispatchers would have to make sure there's an adequate number of cars out on the road, but then they're also situated in, kind of spread out, in the service territory to where you're meeting that, you know, ten to fifteen minute ETA [expected time of arrival] expectation that customers have.* (Interview 10)

Resource allocation may become increasingly critical as AV companies expand their ODDs and fleet sizes, suggesting the need to maintain a human dispatch role in the short-term as these companies scale up. As AV operations stabilize over time, however, the need for this human support role could dwindle and it may ultimately be eliminated.

Fare collection falls in the domain of the driver in taxi services. Taxi drivers must start and stop the taximeter and generally accept both cash and credit card payments. In TNC systems, fare collection occurs automatically via the app interface, though drivers must still indicate when the ride has started and finished via the app [8]. Initially, TNCs' purely app-based approach to payment precluded use of cash to pay for rides and posed a significant equity barrier to low-income individuals who lack access to credit and banking services. Recently, some TNCs have developed systems in which riders can add a cash balance to their app at select retailers to overcome this barrier to use [16]. At present, few AV companies have regulatory approval to charge for their rides. Those with approval collect payment via their app-interfaces, similar to TNCs, maintaining no need for a human laborer to perform this function. To the authors' knowledge, no AV company has yet established retailer partnerships that would allow for cash payments. In order to ensure equitable deployment of AVs, however, AV companies will need to develop innovative strategies for accepting cash payments, as occurred in TNC systems.

4.3. The In-Vehicle Experience and On-trip Support
The most obvious change to the in-vehicle experience resulting from vehicle automation is the change to the driving function. A level 4 or 5 AV, as defined by SAE International, is one in which the driving function is performed entirely by a vehicle's computer and sensor systems [17].Yet driving is not the only function involved in a rider's in-vehicle experience that a current taxi or TNC driver provides. Drivers provide various types of in-vehicle passenger support including assisting individuals with disabilities, providing entertainment, and managing conflict between riders during shared rides [8]. AV companies have developed specially-designed vehicles to perform some of these functions. Custom features in different robotaxi vehicles include tablet-based entertainment systems with which riders can play music, and more accessibility-focused features such as automatic ramp deployment and wheelchair securement systems (Interview 8). Companies are also exploring different shared vehicle designs in which passengers are physically separated from one-another to preclude conflict between riders. Even with some of these ongoing developments, one interviewee highlighted, "*There's very little technology out there that actually substitutes for the people helping people part of it*" (Interview 8). In particular, the broad range of intellectual and physical disabilities could make developing inclusive AV designs difficult and potentially cost-prohibitive. Providers of AV services may need to consider cost tradeoffs between layering in additional vehicle features and maintaining a human in the vehicle to serve as a "vehicle attendant," which recent studies have found could be a critical feature for early AV adoption [18]. Yet not all prospective AV user segments might view a human attendant as a desirable feature. One analysis of a recent AV pilot program found that some female riders actually preferred the human-*less* nature of AVs due to prior experiences with assaults from taxi or TNC drivers [19].

4.3.1. New Roles for Vehicle Support in AV Systems

Though vehicle automation eliminates the driver role, two new roles have emerged in AV systems to support riders. We define these roles as *Tele-assistant* and *Field Support Agent*. In some of the current AV designs, passengers can connect with a human Tele-assistant by pressing a help button located inside the vehicle. This button connects to a human in a remote location who is able to monitor and interact with the vehicle in a limited capacity. Tele-assistants provide a customer service function, including answering rider questions about the AV technology (Interviews 10-12). As riders become more familiar with AV systems, this function will likely decrease in importance and could be transferred to a question section in the app interface, as is generally available in TNC apps. Some cities also require that AV companies have a first responder hotline with a Tele-assistant available to answer first responders' questions at all times (Interview 5).

A second, more critical function of the Tele-assistant role is the remote monitoring function which involves real-time monitoring of the vehicle, issuing safety reminders, and providing remote assistance as needed. One interviewee described an experience during which a Tele-assistant virtually "came onboard" to issue a safety reminder:

> *I was riding in a [AV company's vehicle] a couple of months back…and one of the ladies did not, or she failed to put on her seatbelt. So when we started off on our ride she was so excited that she forgot to fasten her seatbelt. So one of the [Tele-assistants] kind of came onboard, and just, you know, gently reminded her that she needed to be belted in before the ride would resume.* (Interview 10)

Drivers are technically responsible for issuing these types of safety reminders to riders in taxi and TNC systems. Some TNCs have recently started to introduce elements of tele-assistance into their systems to increase rider safety. These safety-oriented features vary by country but in the U.S. some TNCs use riders' phone GPS locations to monitor for route deviations and have partnered with established security firms to provide human support via phone or chat if riders encounter any safety problems [20]. As demonstrated by TNCs, AV companies may be able to outsource some elements of the Tele-assistant role to professional security firms in the future. What may prove more difficult to outsource, for both technical and regulatory reasons, is the remote assistance element of the remote monitoring function. One interviewee explained the remote assistance function performed by Tele-assistants:

> *Remote assistance is when the car gets into a situation where it's say maybe less familiar, or wants to double check something, a human behind a terminal can take a look at what the car is seeing, and sort of answer some questions for it to let it continue to operate...[the] expectation is to have these calls answered within like, a couple seconds. So basically, instantly, the scene comes up on the terminal in front of the [Tele-assistant]. These are central roles. They have access to all the cameras that are functioning in the car plus an overlay of LIDAR data. They have really strong situational awareness, and they'll help confirm the scene for the car, basically, and then the car is still driving itself, it continues on through the situation.* (Interview 11)

Given the complexities of roadway driving and the inevitability of edge-case scenarios, this function is unlikely to ever be fully eliminated, though the vehicle to Tele-assistant ratio may increase as AV technology improves, decreasing the labor requirements and associated costs.

A second new role in AV systems is the *Field Support Agent (FSA)* role. These individuals—many of whom were former safety drivers—are responsible for providing in-person incident response (Interviews 1, 3-5, 10-11). These incidents range from small problems that inhibit the vehicle's progress, such as a flat tire, to more severe issues like a car accident. The role of FSAs will also continue to evolve alongside AV technology. Technology improvements may decrease the frequency of incidents and may impact how the agents are able to respond to incidents. If future AV designs remove steering wheels altogether, companies will need to develop alternative strategies and response plans for how FSAs can move AVs after an incident and assist riders. Given the safety-critical nature of the FSA role, companies will also need to determine efficient vehicle to FSA ratios that balance labor costs and fast response times.

6. Conclusions

This results of this study suggest that although vehicle automation may eliminate drivers, AV firms will still require human labor for numerous other roles, many of which are likely to persist in some capacity even as AV technology improves. We make no claims about the predicted number of driver jobs eliminated or created, though we recognize that the scale of job losses and gains has critical implications for local and national economies, and the individual experiences of workers. In further expansion of this work, we aim to hone in on this individual experience, delineating what types of individuals currently fill AV industry jobs, including their backgrounds and qualifications. Taxi and TNC driver roles are often filled by immigrants and racial minorities for whom full-time wage work is unavailable [14], raising questions regarding whether those individuals could realistically pivot into roles in the AV industry.

This paper does not distinguish between different potential firm structures for AV companies, though such differences could significantly impact employee classifications. Taxi firms, for instance, evolved from organizations that owned their vehicle fleets and formally employed drivers to organizations that leased vehicles to drivers who functioned as independent contractors [14]. AV companies are currently exploring a variety of business models and firm structures, with some planning to maintain their own vehicle fleets and others aiming to lease AVs to TNC platforms. We may also see business models in which AV suppliers, TNC platforms, and human independent contractor drivers all interact in a transportation market. These evolving business models could impact how human laborers are classified (i.e., as employees or independent contractors) and how other forms of risk such as legal liability are distributed in the system. We plan to explore these potential dynamics in our future work.

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