CHALMERS

# Diagnosing Sharing Anxiety

*Examining willingness-to-share factors and stakeholder involvement in on-demand ridehailing and autonomous vehicle contexts*

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SIGMA DOLINS

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The discussion leader will be Dr. Giovanni Circella of University of California, Davis,
Director of the 3 Revolutions Future Mobility Program and the Honda Distinguished Scholar for New Mobility Studies.

The thesis is available at

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# ABSTRACT

Numerous studies indicate that the potential of autonomous vehicles (AVs) to reduce greenhouse gas emissions, reduce traffic congestion, and increase mobility access can only be fully realized through fleets of vehicles being used for shared rides, also known as dynamic ridepooling. This has the potential for transforming the public transport industry, as well as how transportation functions in urban and rural contexts.

In order for shared AVs (SAVs) to be a feasible service, users need to be willing to share a driverless space with strangers. However, most of the research in the field has focused on traffic impact studies or in technological acceptance, not social acceptance of the driverless space an AV represents. In contemporary dynamic ridepooling or on-demand transport, users are often motivated through lower fares to share their ride in a human-driven vehicle, yet pooled rides are not a given service by many companies.

Understanding how potential users feel about sharing a driverless space with strangers, is critical in order to develop strategies for increasing acceptance and adoption of a new mobility behavior, especially when planning for shared autonomous transport. What are the factors that would motivate users to make this choice? If given the option of a driverless vehicle, would users of these services be motivated by the same factors? That is what Study 1 of this licentiate thesis sought to answer.

Using qualitative research methods, the study comprised of four focus groups held in New South Wales, Australia, with active users of either the trialled on-demand transport service or commercial ridepooling. Through thematic analysis of the focus group conversations, confirmed factors of cost, comfort, convenience, safety, community culture, and trust in authority emerged. However, the results showed that when presented with driverless scenarios, the focus group participants' willingness-to-share dropped significantly, due to strong concerns about the unknown behaviour of their co-passengers. This revealed "sharing anxiety" in even extremely motivated users of dynamic ridepooling, and a potential barrier to the deployment of SAVs.

Thus Study 2 turned to transportation stakeholders in New South Wales, to understand their perspectives on how to mitigate this problem. Study 2 is a policy-focused investigation with experts from the state's transport authority, autonomous vehicle operators, public transport operators, and academics. Again, qualitative methods were used, this time one-on-one interviews. The results revealed a relative lack of awareness about the existence and impact of sharing anxiety, which in turn raises concerns about the preparedness of governments and transport operators to introduce SAV services.

The combined confirmation of sharing anxiety as a complex barrier, as well as the lack of awareness from transportation stakeholders, indicates a potential challenge to the widespread adoption of SAVs and shared autonomous public transport (SAPT), one that would require building strategies for increasing willingness-to-share at the community or societal level. This licentiate begins the foundational work towards the development of a descriptive and prescriptive framework, the *Societal Readiness Index for Shared Autonomy.*



**Keywords:** autonomous vehicles, ridehailing, ridepooling, on-demand transport, public transport, shared autonomous vehicles, shared autonomous public transport, qualitative methods, sharing anxiety.

## SAMMANFATTNING

Flertalet studier indikerar att möjligheten att autonoma fordon kan minska utsläpp av växthusgaser, köbildning i trafiken samt öka rörligheten och tillgängligheten endast är helt tillämpbart om det möjliggörs genom fordonsflottor som används för delade resor, även känt som dynamic ridepooling. Detta kan möjliggöra att förändra kollektivtrafikindustrin men även transportmedlets funktion i såväl stad som landsbygd.

För att delade autonoma fordon ska kunna bli en genomförbar tjänst krävs det att användarna ska vara villiga att dela ett självkörande fordon med främlingar. Däremot så har de flesta studier inom detta område lagt fokus på trafikpåverkan eller ur ett teknologiskt perspektiv, istället för att undersöka vad miljön i ett självkörande fordon representerar och hur socialt accepterat det är. I samtida dynamic ridepools och on-demand tjänster är användarna ofta motiverade av de lägre kostnaderna som medföljer delning av transporter med förare, däremot är det inte många företag som erbjuder transportpooler.

Att förstå hur potentiella användare känner inför att dela ett förarlöst fordon med okända medresenärer, är av största vikt för att kunna utveckla strategier för ökad acceptans och användande av nya transportformer, speciellt vid planering av delade autonoma transporter. Vilka faktorer skulle kunna motivera användare att välja den här typen av transporter? Skulle de motiveras av samma faktorer om de fick chansen att använda sådana tjänster? Det är de här frågorna studie 1 ämnade besvara. Studien genomfördes med hjälp av kvalitativ forskningsmetod och gjordes med 4 fokusgrupper i New South Wales, Australien med aktiva användare av tidigare implementerade on-demand transporttjänster eller kommersiell fordonsdelning. Genom tematisk analys av fokusgruppernas konversationer, framkom att de värderade faktorer som kostnad, komfort, smidighet, säkerhet, samhällskultur och tillit till auktoriteter. Det visade sig dock att när användarna ställdes inför scenarier med transport med autonoma fordon, sjönk viljan att dela fordon signifikant, på grund av stark oro gällande medpassagerarnas beteenden. Det här visade att "oro att dela fordon" hade stor påverkan även på extremt motiverade användare av dynamisk fordonsdelning och kan utgöra ett potentiellt hinder i genomförandet av autonoma fordon.

Således vände sig studie 2 till olika transportaktörer i NSW, för att förstå deras perspektiv kring hur man mildrar problematiken. Studie 2 som fokuserar på policy och regelverk inkluderar experter från delstatens transportmyndighet, operatörer av autonoma fordon, lokaltrafikoperatörer, och akademiker inom området. Liksom i studie 1 användes kvalitativa metoder i form av enskilda intervjuer. Resultaten visade på en brist på medvetenhet* om både förekomsten och inverkan av delningsångest**. Detta väcker i sin tur frågor kring hur förberedda myndigheter och transportoperatörer är när det gäller introduktion av SAV tjänster.

Kombinationen av delningsångest, och den komplexa barriär den utgör, tillsammans med bristen på medvetenhet om denna bland transportaktörer indikerar en potentiell utmaning för utbredd användning*** av SAV och delad kollektivtrafik (SAPT); något som kräver strategiskt arbete för att öka delningsviljan på lokal och samhällsnivå. Licentiatarbetet (eller Den här licentiatavhandlingen) är starten på det grundläggande arbete som behövs för att skapa det deskriptiva och normativa ramverket *Societal Readiness Index for Shared Autonomy.*

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- the core belief that anything I can do, I should try again because it could still be done better

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Basically, isn't life just one long shared ride?

# TABLE OF CONTENTS


**SAMMANFATTNING** II

**TABLE OF CONTENTS** V

**APPENDED PAPERS** VI

**LIST OF FIGURES** VII

**LIST OF TABLES** VIII

**CHAPTER ONE: KEY CONCEPTS** 1

1.1 On-Demand 1
1.2 Dynamic 1
1.3 Mobility Modes 1
1.4 Ridesharing vs. Ridepooling? 3

**CHAPTER TWO: INTRODUCTION** 5

2.1 Sharing, Autonomous Vehicles, and Public Transport Need to Evolve Together 5
2.2 The Knowledge Gap 7
2.3 Scope and Aim of Thesis 8
2.4 Thesis Structure 8

**CHAPTER THREE: RELATED WORK** 11

3.2 Previous Research in Ridehailing 12
3.3 Previous research in AVs 16
3.4 Previous research in SAVs 20

**CHAPTER FOUR: METHODOLOGY** 27

4.1 The Research Project 27
4.2 The Research Studies 29
*4.2.1 The choice of context* *29*
*4.2.2 The choice of approach* *30*
*4.2.3 Focus groups* *30*
*4.2.4 Interviews* *30*

**CHAPTER FIVE: SUMMARY OF PAPERS** 33

5.1 Paper I: Sharing Anxiety Is in the Driver's Seat: Analyzing User Acceptance of Dynamic Ridepooling and Its Implications for Shared Autonomous Mobility 33
*5.1.1 Method* *33*
*5.1.2 Results and Conclusion* *34*
5.2 Paper II: The 'Sharing Trap': A Case Study of Societal and Stakeholder Readiness for On-Demand and Autonomous Public Transport in New South Wales, Australia 35
*5.2.1 Method* *35*
*5.2.2 Results and Conclusion* *36*

**CHAPTER SIX: DISCUSSION AND IMPLICATIONS** 39

6.1 Sharing Anxiety 39
6.2 Significance and Implications of Sharing Anxiety 40
6.3 Indications of Another Knowledge Gap for Stakeholders 44
6.4 Towards a Societal Readiness Index 45
6.5 Reflections on Research Approach 47

**CHAPTER SEVEN: FUTURE WORK** 49

## APPENDED PAPERS

I. **Dolins**, S.; Strömberg, H.; Wong, Y.Z.; Karlsson, M. Sharing Anxiety Is in the Driver's Seat: Analyzing User Acceptance of Dynamic Ridepooling and Its Implications for Shared Autonomous Mobility. *Sustainability* 2021, *13*, 7828.

SD, HS, YW, and MK developed the research plan. SD and YW collected the data. SD, HS, and MK analyzed the data. SD wrote the paper with contributions from HS and MK.

II. **Dolins**, S.; Wong, Y.Z.; Nelson, J.D. The 'Sharing Trap': A Case Study of Societal and Stakeholder Readiness for On-Demand and Autonomous Public Transport in New South Wales, Australia. *Sustainability*, 13(17), 9574.

SD, YW, and JN developed the research plan. SD collected and analyzed the data. SD wrote the paper with contributions from YW and JN.

## LIST OF FIGURES

**Figure 1.** Diagram of features, such as on-demand and dynamic routing, and driverless vehicles, that when combined would create Shared Autonomous Public Transport. *Page 11*

**Figure 2.** Comparison of research focus and methods between ridehailing/ridepooling studies and AV studies. *Page 25*

**Figure 3.** An overview of the entire doctoral research project for the Societal Readiness Index for Shared Autonomy. *Page 28*

**Figure 4.** A Keoride vehicle picking up a passenger in New South Wales. Picture reprinted with permission from KeolisDowner. *Page 33*

**Figure 5.** The model of populations and sub-populations willingness-to-use mobility services. While not to scale, the figure shows how only some persons are willing to use ridehailing services, and a smaller subpopulation still is willing to share AVs. Dolins, Strömberg, Karlsson (2021). *Page 41*

**Figure 6.** Factors that could influence willingness-to-use SAPT or driverless public transport. The initial inspiration came from the IRIMS Framework, Karlsson, et al., 2020. *Page 46*

## LIST OF TABLES

**Table 1.** Types of shared, vehicle-based mobility services. *Page 2*

**Table 2.** Factor Categorization and Organization, inspired by the work Park, Chen & Akar (2018). *Page 12*

**Table 3.** Previous research on factors that might influence willingness-to-use ridehailing or ridepooling. *Page 14*

**Table 4.** Related AV acceptance studies and previously examined factors. *Page 18*

**Table 5.** Examined Factors for SAV Acceptance. *Page 22*

**Table 6.** List of interview participants and affiliation. Not for reprint. *Page 36*

**Table 7:** Relevant Factors that influence Willingness-to-Use Autonomous Public Transport. *Page 43*

# CHAPTER ONE: Key concepts

There are a series of mobility concepts that need to be defined in order to understand the setting for the work presented. These definitions are generic, and generally accepted.

## 1.1 On-Demand

The advent of ridehailing services introduced a new feature to the realm of mobility that had only existed previously in taxis: on-demand. Whereas traditional taxi rides used an unpredictable matching mechanisms, they were effectively putting riders into vehicles exactly when the riders wanted them. Ridehailing apps allowed customers to perform the uncertain and unpredictable task of hailing on the curb digitally, through data-connected phones. The concept of convenient, almost-instant order and delivery has now become a staple feature of many mobility modes, and even entered other industries (Shaheen, & Cohen, 2020).

"On-demand transport" and "demand-responsive transport" are often used to describe this feature (flexible, dynamic routing instead of schedule-and-station-based routing) in public transport products.

## 1.2 Dynamic

Traditionally, public transport followed fixed routes and scheduling. However, as the ability for real-time information exchange and communication grew, transport agencies experimented with "dynamic" or "flexible" routes and schedules. In the 80s and 90s, particularly with rural and community transport, this took the form of buses that only came when booked with the transport authority, or buses that would only stop in places or stations if a rider was already on board. As information technology advanced, vehicles could be ordered on-demand and take completely different routes, depending on when and where the users were located; now with mobile phones and location services, complex matching algorithms can create routes, match users to vehicles, and predict the impact a ride will have on further service (Tang, Duan & Zhao, 2019).

## 1.3 Mobility Modes

With the advent of new information and communication technologies (ICT), the variety of shared mobility has increased substantially. Older forms of shared transportation like carsharing schemes and carpooling or high-occupancy vehicle schemes have been made more convenient through real-time matching and availability. However, when taking about shared mobility, it is easy to confuse the different modes, especially across languages and cultures. For example, the Swedish word for car is "bil". Yet carpool and "bilpool" do not represent the same service in Sweden. Table 1 defines the different types of vehicle-based shared mobility. Other forms, such as free-floating kickscooters or bicycles, are omitted from this list.

*Table 1: Types of shared, vehicle-based mobility services.*

| Type of Mobility Modes | Definition | References |
|---|---|---|
| Carsharing | Membership-based.<br>Users have access to a number of vehicles spread throughout an area or zone or vehicles can be free-floating | Mounce & Nelson, 2019 |
| Carpooling | Involves a car owner, the driver, who brings other users into their vehicle because they share a common destination<br>End-to-end carpooling (i.e. carpooling for the entire journey) matches are constrained in 3 dimensions: origin, destination and time of travel, which requires a high density of trip offerings in order to consistently find suitable matches | Chan & Shaheen, 2012;<br>Wright, Nelson, & Cottrill, 2020 |
| Ridehailing | Used through a mobile phone application (app-based, on-demand rides) for a transportation network company (TNC)<br>Drivers take the user to the requested destination<br>Some TNCs use licensed taxi drivers, others contract out to ordinary citizens who own their own vehicle; dependent on the regulations of the country where they operate. | Burrows, 2015;<br>Rahel, 2016 |
| Ridepooling / Ridesplitting | A subset of ridehailing; an app-based service with a "pool" option<br>Offers a reduced trip price<br>Matches the first user's journey with a second user (in some services even a third user), to aggregate more persons into the same vehicle. | Sanguinetti et al., 2019;<br>Ke, et al. 2020;<br>Luo & Nie, 2019 |
| On-Demand Transport | Users arranged with a centralized dispatch office their pickups and drop-offs over telephone, usually several hours to days in advance (e.g. "dial-a-ride")<br>Also known as "communal transport", "micro-transit", "paratransit"<br>The service is available to the general public (i.e. it is not restricted to particular groups of user according to age or place of employment)<br>The service is provided by low capacity road vehicles such as small buses, vans or taxis<br>The service responds to changes in demand by either altering its route and/or its timetable<br>The fare is charged on a per passenger, and not a per vehicle or per km basis | US Department of Transportation National Transportation Study 1972;<br>Davison et. al, 2014;<br>Currie & Fournier, 2019 |

## 1.4 Ridesharing vs. Ridepooling?

Ridesharing used to be the popular colloquial term for describing ridehailing services, which created confusion when "pooled" options became available. The term "ridesharing" was used in different contexts and not consistently across previous studies or research that were used for the background in this thesis (Park et al. 2017; Sarriera et al. 2017; Wang et al. 2018; Moody, Middleton, & Zhao, 2019). Using "ridesharing" as a search criteria could sometimes return references focused on "carpooling", a behavior where a car driver already headed to a destination takes on an additional passenger (sometimes a familiar person, like a co-worker, and sometimes a stranger), facilitated by the use of a matching service (Chan & Shaheen, 2012). With other references, the subject would be focused on short-term car-sharing schemes, where a member of a service has access to a vehicle as part of a fleet of vehicles, uses it privately, and then returns it so that the next member can utilize the vehicle (Mounce & Nelson, 2019). Ridesharing connotates that the driver and passenger(s) share the same, or at least nearby final destinations, thereby reducing the number of cars and hence net road space required to complete the journey of at least two separate parties. Technically, this would be considered carpooling.

In reviewing previous and related work for this research, "dynamic rideshare" or "dynamic ride-share" was used to identify the sub-set of ridehailing services that expand on the typical on-demand matching of taxis or TNCs to potential riders, and in a tradeoff of convenience and price, place multiple riders in the same vehicle. Sanguinetti, Kurani, and Ferguson (2019) as well as Bansal, Liu, Daziano, and Samaranayake (2019) used the term "ridepooling" or "ride-pooling" to cover the same service and behavior type as other authors might call "dynamic ridesharing".

However, TNCs such as Uber or Lyft tend to abuse the use of "sharing" and its carpooling connotation, since the drivers are usually contracted workers who are completing transportation trips for users as customers, and not because of any shared end destination. In some cases, this misunderstanding can be beneficial for TNCs and contractor drivers, because certain markets (like in the United States) have existing carpooling interventions that support shared mobility, in the form of HOV lanes, better insurance coverage for the driver, or even taxation deductions (Wong, Hensher, Mulley, 2020; Neoh, Chipulu, & Marshall, 2017).

In 2018, SAE International deprecated the term "ridesharing" entirely, due to its widespread use to refer to a variety of distinct and different mobility contexts, causing confusion over its meaning and referral. To avoid confusion, in this licentiate, the term "dynamic ridepooling" is used to be explicit about the on-demand, co-riding nature of the mobility experience in question.

## 2.1 Sharing, Autonomous Vehicles, and Public Transport Need to Evolve Together

The potential of autonomous vehicles (AVs) has been, for a technological development still in its infancy, well-explored through numerous studies, models, and simulations. In 2017, researchers at UC Davis and the Institute for Transportation and Development Policy produced a report that more explicitly defined the components that comprised the "ideal" transportation scenario with AVs: future transportation systems must be electric, autonomous, and shared (Fulton, Jacob, & Meroux, 2017). With this combination, the report indicated that AVs might be able to substantially reduce greenhouse gas emissions, reduce traffic congestion, and increase mobility access. However, this report (and other studies) emphasized that this ideal transportation system can only be fully realized through fleets of electric and autonomous vehicles being used for shared rides, also known as dynamic ridepooling. In scenarios without the dynamic ridepooling behavior, or servitization, the impact of AVs ranges from minimal to negative.

For example, in a scenario of only autonomously driven vehicles, using conventional fuel sources and without trip sharing (sometimes referred to the "business-as-usual" scenario) there would not be a significant reduction in carbon emissions (Pernestål, Kristoffersson, & Mattsson, 2017; Jones & Leibowicz, 2019). Self-driving vehicles would likely lead to an increase in vehicle travel, and although the efficiency of AVs would potentially offset some of this, the overall increase in vehicle travel (including vehicles driving empty) would still contribute to an increase in carbon emissions (Clewlow & Mishra, 2017).

In another scenario combining electrified and autonomous features (referred to sometimes as a "2R Scenario"), models show that this could successfully reduce vehicle-related pollution and carbon emissions - although it is important to note that several studies show even these gains are only possible with the large scale decarbonization of electricity production (Liu et al., 2019).

Yet electrified and autonomous, if that is the extent of the scenario, might also be problematic. Modeling this scenario has revealed that AVs increase energy consumption, encourage urban sprawl, increase traffic congestion, worsen socioeconomic stratification at the personal level, and decrease public transit ridership (Wong, Hensher, & Mulley, 2020). If AVs were introduced tomorrow as an attainable, private consumer good without established norms and behaviors for sharing rides and journeys, citizens are likely to use AVs in a manner consistent with how they use privately-owned cars (Fraedrich, Heinrichs, Bahamonde-Birke, & Cyganski, 2019).

But when these technological developments - electrified and autonomous vehicles - are combined with a behavioral change, ridepooling, other researchers make a compelling case.

One of the most well-known simulation studies done was by the International Transport Forum, in 2015, which used Lisbon as a case study and demonstrated how the current vehicle population of the city spends 95% of the day idle; however, in the shared, electric, and autonomous vehicle scenario, the fleet is only idle 27% of the day (Martinez & Crist 2015), which is a vast increase in efficiency. In a study comparing private AV usage, autonomous taxis, and pooled, shared AVs (such as those in a public transit fleet), Levin et al. (2017) observed that during peak periods, shared AVs (SAVs) were the only scenario able to effectively contain empty vehicle travel and avoid surges in congestion. Electric, autonomous and shared vehicles

could lead to more efficient road use, creation of a higher car value, reduced parking pressure or need for parking spaces, and more efficient use of time when traveling (Fagnant & Kockelman, 2014; Urmson & Whittaker, 2008; Krueger et al., 2016). SAVS are also believed to be able to reduce the total number of vehicles required to meet the transport needs of a region or community, and estimated to reduce carbon emissions, reduce traffic accidents, increase the safety and diversity of interaction for vulnerable groups, increase mobility access for individuals, and decrease economic loss due to traffic congestion; the proposal of direct and positive externalities is made in a high number of studies (e.g. Dia & Javanshour 2017; Greenblatt & Shaheen, 2015). Thus, sharing, or embedding dynamic ridepooling as part of the AV offer, is considered imperative for a sustainable future transport system. However, while the feasibility of SAVs is dependent on users being willing to share a driverless space with strangers, most of the research in the field has focused on traffic impact studies or in technological acceptance of autonomous vehicles and has not focused on social acceptance of shared rides or sharing driverless spaces.

Increasing the social acceptance of shared mobility is not a new challenge. For decades, public agencies and local governments have tried to promote shared mobility in the form of carpooling or carsharing to increase automobile occupancy, reduce congestion, and conserve resources (Chan & Shaheen, 2012). These offers sometimes met with small success stories (a famous example being "slugging" carpooling culture in the Washington D.C. area, or the proliferation of ZipCar), but were previously limited by the high start-up costs of both vehicles and space, or the delay in communicating information between potential drivers and riders.

The advent of information and communication technologies (ICT) enabling real-time matching of drivers, riders, and vehicles broadens the convenience and scope of ridesharing (Shaheen & Cohen, 2017). In contemporary dynamic ridepooling or on-demand transport, users are often motivated through lower fares to share their ride in a human-driven vehicle. The on-demand (and thus hyper-convenient) nature of these services has become attractive to consumers and has introduced disruption to traditional timetable or route-based mobility modes, as well as to the taxi industry (Clewlow & Mishra, 2017).

However, while ridehailing trips on services like Uber outnumber traditional taxis 2:1, pooled rides still represent only 19% of all ridehailing trips (Anair, 2020). When modeling the choice between a driverless taxi and a driverless bus, a study by Lavieri and Bhat (2019) comparing willingness-to-share revealed that less than 39% of all respondents would be willing to share an AV with strangers, and then only for certain types of journeys (Lavieri & Bhat, 2019). This strong preference to ride alone has sparked the concern that it is taking people away from public transport services and contributing to traffic congestion in cities (Agarwal et al., 2019.)

This presents twin dilemmas. Firstly, cannibalizing from public transport is not sustainable, from an emissions, congestion, or social stratification standpoint. And secondly, if the majority of ridehailing users still prefer to ride alone – if shared mobility, in its various incarnations, is still a minority in the transportation ecosystem – how can we assume people will be ready and willing share AVs?

If significantly reducing public transport would have detrimental effects, perhaps rather than competing with transit, AVs and public transport should be designed to evolve together. Some studies predict that public transportation systems, particularly in rural areas, would benefit significantly from SAVs (Meyer et al., 2017); this is because these areas are extremely expensive for public transit agencies to offer services, often creating a situation where there is

a poor or limited public transport network and a high local dependency on private vehicles. Autonomous public transport, on the other hand, would reduce the public transport agency's costs, through lower personnel costs, and increase the mobility access and offer, since vehicles could operate for longer time periods or even on-demand (Gray, Farrington, & Kagermeier, 2008; Imhof, Frölicher & Arx, 2020). And ostensibly, operating costs could be lower in urban public transport settings as well, since the need for drivers would be removed.

Additionally, autonomous vehicles present an opportunity for the "individualizing of public transport", such as offering smaller vehicle sizes to suit geographic realities and narrower streets. It also means "the possibility of offering users different vehicle types and features, which presently only exists in a rather rudimentary form with first and second classes on public transport" (Lenz & Fraedrich, 2016, pp.186).

But in order to offer the same or better quality of service as public transport offers today, without causing additional traffic congestion, autonomous public transport requires a behavior component- sharing. Fortunately, public transport, by its nature, is a shared ride service and experience; the expectation that the rides and vehicles will be shared is already built into the service. If autonomous public transport was able to incorporate dynamic ridepooling and dynamic routing into its service offer, this could radically change the public transportation industry, as well as how transportation functions in urban and rural contexts (Clewlow & Mishra, 2017; Sörensen et al., 2021.)

## 2.2 The Knowledge Gap

Public transport ridership, what encourages the usage of public transport and what might decrease ridership, has been well-studied through the decades (Breuer et al., 2021; Hall et al., 2018; Abenoza et al., 2017; Fellesson & Friman, 2012). More recently, the advent of ridehailing services has introduced studies of this new, on-demand mobility mode (Nielsen et al., 2015; Beer et al., 2017; Jin et al., 2018; Bansal, Kockelman & Singh, 2016). There is also significant, plentiful research on the technological acceptance of autonomous vehicles (Yuen et al. 2020; Koul & Eydgahi, 2018. Choi & Ji, 2015; Lee et al., 2019; Hulse et al., 2018; Abraham et al., 2017; Litman, 2017; Greenblatt & Shaheen, 2015; Tenant et al., 2017; Zhao, 2017; Barbour et al., 2019).

Compared to the body of work investigating the potential of autonomous vehicles, the potential of autonomous public transport has received little attention (Dong et al., 2019, Salonen, 2018). Some studies showed that incorporating AVs as part of public transit systems could significantly reduce the total number of vehicles required to meet the transport needs of a community, anywhere from 31% to as much as 95% (Dia & Javanshour, 2017; Pakusch, Stevens & Bossauer, 2018). Such a change would be a radical rebalancing of urban flow and traffic, one that could be enormously beneficial to sustainable cities, but would require extensive preparation and planning. And because there are relatively few studies or examples of SAVs, assuming the consumer public will easily transition to shared AVs (even in a public transport context) would be an overly optimistic perspective (Barbour, 2019). Overall, there is little work that explicitly examines the merger of all three concepts: users' willingness-to-share their space and their journey with others, in a shared, autonomous public transport vehicle.

In order to capture the benefits of an autonomous fleet of vehicles, we need to be able to support and grow a society's capacity to organize, offer, and accept pooled rides. This can be done by investigating what could influence or generate acceptance for shared, autonomous public transport, beyond merely the technological acceptance of AVs. Therefore, to begin exploring

shared autonomous public transport, it is required to understand how potential users feel about sharing a driverless space and sharing it with strangers. This foundational knowledge will be critical for developing strategies to increasing acceptance and adoption of a new mobility system.

If shared autonomous public transport (SAPT) would be seen as the combination of:

- existing behaviors (public transit usage)
- technologies (on-demand and dynamic ridehailing)
- future technical development (autonomous vehicles)

Then, what motivates consumers to utilize existing services, and how could that be leveraged into acceptance of a future autonomous public transport system?

## 2.3 Scope and Aim of Thesis

The topic of this thesis is shared, autonomous public transport (SAPT). This is a concept that combines features of contemporary ridepooling services, using AVs, in a public transport system. As such, SAPT should be:

- on-demand, flexible routing
- using a variety of (driverless) vehicle types
- typically door-to-door pickup or very short walking distance
- short waiting times
- low pricing commensurate with public transit fares
- sharing / riding with other passengers

Shared autonomous public transportation does not yet exist. However, if and when it *does* come into being, it will be the result of two major technological advances which are currently available and have been previously studied: on-demand, ridepooling systems (ridehailing), and driverless vehicles (AVs). The aim of the work is to contribute to further knowledge about possible motivating factors and barriers to acceptance of shared rides in driverless vehicles, in order to transition towards shared autonomous public transport. This requires understanding both users' (those who are hoped to use shared AVs and not privately owned vehicles) and transport authorities' (those who are expected to provide autonomous public transport) motivations, barriers, and corresponding behaviors.

This aim led to the following research questions addressed in the licentiate thesis:

RQ 1: What factors impact travellers' willingness-to-use shared, autonomous public transport?

RQ 2: Are stakeholders aware of these factors? Are they planning accordingly?

## 2.4 Thesis Structure

This licentiate work is presented in the following manner. Chapter 1 covers definitions of different concepts and mobility types that give a useful foundation for understand shared and on-demand mobility. Chapter 2 gives brief background and introduction into autonomous vehicles, on-demand mobility, and the necessity for sharing behaviors in autonomous public transport. Chapter 3 covers related work, the context and co-evolution of two areas of transportation: ridehailing (or shared mobility) and autonomous vehicles. This makes the case

for how driverless technology could augment future public transport systems and highlights the need for research into social acceptance of shared, autonomous vehicles for public transport use- the knowledge gap this thesis tries to fill. Chapter 4 describes the research project. Chapter 5 summarizes the methodology and findings of Study 1 and Study 2 (described in Papers 1 and 2 respectively). In Study 1, focus groups were conducted in New South Wales, Australia, to determine factors that impact willingness-to-share and willingness-to-share-AVs. In Study 2, transportation stakeholders in New South Wales were interviewed to understand how they planned to increase sharing acceptance for autonomous services. Chapter 6 discusses the implications of this work, reflects on the impact of COVID-19 on the research process, and how these findings build a structure for future studies. And finally, Chapter 7 presents the outlook and plan for future work into willingness-to-share and drafting strategies for creating shared autonomous public transport.

## 3.1 Transport – A Socio-Technical System

In recent years, the framework of socio-technical systems has been used to map potential impacts or interactions of future technological transitions (Andersson, Skoglund, & Strand, 2018; Fraedrich, Beiker, & Lenz, 2015). It is easy to see that introducing autonomous vehicles is a coming future technological transition, one that numerous cities, governments, manufacturers, and urban stakeholders (as well as this licentiate) are trying to best anticipate and support (Golbabaei et al., 2021; Porter, et al., 2018; Gavanas, 2019).

Endemic to socio-technical theory is the assumption that technology alone does not change a system. Socio-technical system theory is founded on the idea that people interact with technology to complete a goal. However, the structure that governs and influences how people behave and use technology is different from the processes or systems that govern machines, and sometimes the interaction between the two creates unexpected results or situations. In 2011, a holistic approach to socio-technical systems began to emerge: that people, processes, goals, culture, technology, and physical infrastructure should be seen as interdependent and given joint consideration embedded within an external environment (Challenger & Clegg, 2011).

It is the numerous and complex interactions between societal groups and different actors, as well as the alignment of specific factors that create change — or otherwise stated as, "socio-technical transformation fundamentally changes the way how a system fulfills specific societal needs" (Fraedrich, Beiker, & Lenz, 2015, p.11).

Shared autonomous public transport (SAPT) is suggesting a radical shift to existing socio-technical systems; a transition to a new type of system, which will require both technological and behavioral adaptation. This licentiate does not focus on the technological development, but instead looks at research focused on the behaviors around both sharing rides and using autonomous vehicles. The figure below (Figure 1) attempts to encapsulate the nature of SAPT by examining the features of existing services it would need to incorporate.

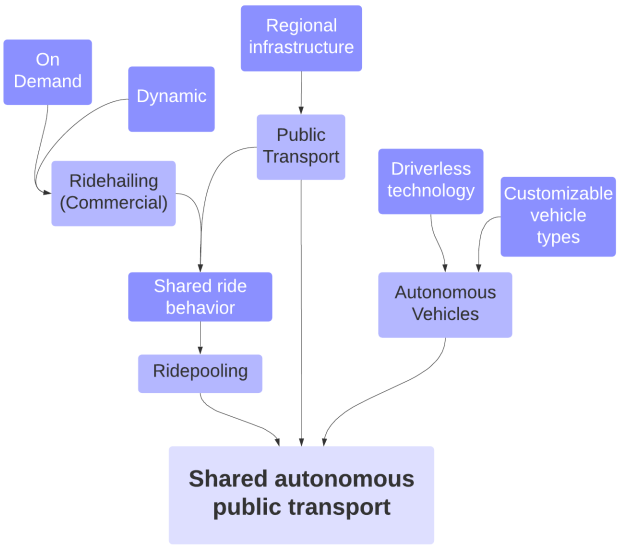


*Figure 1: Diagram of features, such as on-demand and dynamic routing, and driverless vehicles, that when combined would create Shared Autonomous Public Transport.*

The next sections provide a summary of some earlier studies into the topics of ridehailing, autonomous vehicles, and SAVs. I categorize the factors that were investigated in these studies in a format similar to the organizational structure used in Park, Chen, and Akar's study on factors that influence willingness-to-use carpooling schemes (Park, Chen & Akar, 2018).

*Table 2: Factor Categorization and Organization, inspired by the work Park, Chen & Akar (2018)*

| | | |
|---|---|---|
| **Internal Factors:** | factors that are intrinsic to an individual. | |
| | Demographics | *Gender, age, education, employment level, income, ethnicity, household size, social class, marital status, occupation* |
| | Judgements | *Personal innovativeness, perceived risk, perceived usefulness, attitude/motivations, trust, privacy* |
| **External Factors:** | factors that can affect an individual's decision-making, including aspects of service, vehicle design, or trip purpose. | |
| | Third-Party Interventions | *Cost, comfort, convenience, safety, environmental awareness* |
| | Situational Factors | *Time / time benefit, transportation anxiety, herd behavior, personal space, norms* |

## 3.2 Previous Research in Ridehailing

Ridesharing activities, such as carpooling, hitchhiking, "slugging", or other informal services, are not new. However, they were often constrained by the limits of information transfer in organizing rides (Currie & Fournier, 2020). Smartphones and on-demand ridehailing made this information exchange possible; when Uber launched in 2009, UberPool, its dynamic ridepooling product, was introduced in 2014.

Where on-demand ridehailing had disrupted the taxi industry, dynamic ridepooling (the matching of two or more sets of riders into the same vehicle for overlapping journeys) brought on-demand benefits to public transport through similar attractive mechanisms - ridepooling was cheaper than a private ride, just like public transport is cheaper than a taxi. This introduced a new topic for research: examining willingness-to-share and what was motivating people to either accept or reject this new subset of ridehailing.

Earlier research has tried to make estimates about dynamic ridepooling services such as UberPool, LyftLine, or DidiShare, their fleet sizes and their impact on public transport systems. Other work in the past few years has focused on on-demand ridehailing, including willingness-to-share in these commercial services; who is willing to use these services, what types of journeys are made with ridehailing, and which modes it begins to replace (Hou et al., 2020; Tirachini, 2020; Bilali et al., 2020; Alemi et al., 2019).

Previous research showed that highest acceptance of dynamic ridepooling or shared mobility was often found amongst users and residents who lived in dense neighbourhoods, with higher levels of education and technological familiarity (Dias et al., 2017; Neoh, Chipulu & Marshall,

2017; Lavieri & Bhat, 2019). The typical demographic profile suggests that younger users and single adults are more willing to share rides with strangers, while middle-aged users and parents are less willing (Krueger, Rashidi & Rose, 2016). However, elderly users, in particular ones who have experienced car accidents, were more willing to share (Bansal, Kockelman & Singh, 2016). Also racial/ethnic influences, which were only investigated in the United States, indicated that "fear of strangers" seems to be highest in Non-Hispanic Whites, leading to a decreased willingness to share (Sarriera et al., 2017).

The table below (Table 3) provides an overview of some of the ridehailing or ridepooling research and the factors that were examined in those studies.

*Table 3: Previous research on factors that might influence willingness-to-use ridehailing or ridepooling*

| Category | | Examined Factors | Authors |
|---|---|---|---|
| Internal Factors | Demographics | Gender | Bansal et al., 2016; Sarriera et al., 2017; Delhomme & Gheorghiu, 2016 ; Gerte, Konduri & Eluru, 2018; Lavieri & Bhat, 2019; Dias et al., 2017; Neoh, Chipulu & Marshall, 2017; Meurer, Stein & Wulf, 2014; Park, Chen & Akar, 2018; Moody, Middleton & Zhao, 2019; Bachmann et al., 2018; Nielsen et al., 2015; Liu & Yang, 2018. |
| | | Age | Bansal et al., 2016; Sarriera et al., 2017; Delhomme & Gheorghiu, 2016 ; Gerte, Konduri & Eluru, 2018; Lavieri & Bhat, 2019; Dias et al., 2017; Neoh, Chipulu & Marshall, 2017; Meurer, Stein & Wulf, 2014; Park, Chen & Akar, 2018; Moody, Middleton & Zhao, 2019; Bachmann et al., 2018; Nielsen et al., 2015; Liu & Yang, 2018. |
| | | Education | Gerte, Konduri, & Eluru, 2018 |
| | | Employment Level | Dias et al., 2017 |
| | | Income | Neoh, Chipulu & Marshall, 2017; Lavieri & Bhat, 2019; Nielsen et al., 2015. |
| | | Ethnicity | Sarriera et al., 2017; Gerte, Konduri, & Eluru, 2018; Lavieri & Bhat, 2019; Moody, Middleton & Zhao, 2019 |
| | | Social Class | Sarriera et al., 2017; Moody, Middleton & Zhao, 2019 |
| | | Household size | Gerte, Konduri & Eluru, 2018; Neoh, Chipulu & Marshall, 2017; Park, Chen & Akar 2018 |
| | | Marital Status | Neoh, Chipulu & Marshall, 2017; Park, Chen & Akar 2018 |
| | | Occupation | Neoh, Chipulu & Marshall, 2017 |
| | Judgements | Personal Innovativeness | Wang et al., 2018; Park, Chen & Akar 2018 |
| | | Perceived Risk | Wang, et al., 2018; Sanguinetti, Kurani & Ferguson 2019; Pakusch, Stevens & Bossauer, 2018 |
| | | Perceived Usefulness | Pakusch, Stevens & Bossauer, 2018; Wang, et al., 2018 |
| | | Attitude / Motivation | Sarriera et al., 2017; Moody, Middleton & Zhao, 2019; Werth et al. 2021 |
| | | Trust | Sarriera et al., 2017; Furuhata et al., 2013; Amirkiaee & Evangelopoulos, 2018; Bachmann et al., 2018; Liu & Yang, 2018 |
| | | Privacy | Sarriera et al., 2017; Furuhata et al., 2013; Amirkiaee & Evangelopoulos, 2018; Nielsen et al., 2015; Pakusch, Stevens & Bossauer, 2018; |

| External Factors | | | |
|---|---|---|---|
| | Third-Party Interventions | Cost | Pakusch, Stevens & Bossauer, 2018; Lavieri & Bhat, 2019; Furuhata et al., 2013; Amirkiaee & Evangelopoulos, 2018; Wang et al., 2018; Margolin, Misch & Stahr, 1978; Nielsen et al., 2015 |
| | | Comfort | Sarriera et al., 2017; Nielsen et al., 2015; Delhomme & Gheorghiu, 2016; Lavieri & Bhat, 2019; Pakusch, Stevens, & Bossauer, 2018 |
| | | Convenience | Sarriera et al., 2017; Delhomme & Gheorghiu, 2016; Sanguinetti, Kurani & Ferguson, 2019; Chan & Shaheen, 2012; Park, Chen & Akar, 2018; Wang et al., 2018; Margolin, Misch & Stahr, 1978; Nielsen et al., 2015; Sanguinetti, Kurani & Ferguson, 2019; Pakusch, Stevens & Bossauer, 2018 |
| | | Safety | Margolin, Misch & Stahr, 1978; Sanguinetti, Kurani & Ferguson, 2019; König & Grippenkoven, 2020; Nielsen et al., 2015; Chan & Shaheen, 2012; Pakusch, Stevens & Bossauer, 2018 |
| | | Environmental Awareness | Wang et al., 2018; Delhomme & Gheorghiu, 2016; Park, Chen & Akar, 2018; |
| | Situational Factors | Time / time benefit | Margolin, Misch & Stahr, 1978; Lavieri & Bhat, 2019; Pakusch, Stevens & Bossauer, 2018; Amirkiaee & Evangelopoulos, 2018; Delhomme & Gheorghiu, 2016 |
| | | Transportation Anxiety | Amirkiaee & Evangelopoulos, 2018 |
| | | Herd Behavior | Liu & Yang, 2018; Bachmann et al., 2018 |
| | | Personal Space | Nielsen et al., 2015; Chan & Shaheen, 2012; Sanguinetti, Kurani & Ferguson, 2019 |
| | | Norms | Bachmann et al., 2018; Liu & Yang, 2018 |

A major part of the earlier identified factors of relevance for users' willingness to use ridehailing and ridepooling are individual factors in terms of demographics and socio-economic factors (e.g., gender, age, income level, education, etc.). Other well-studied factors refer to how users perceive and assess the service provided in terms of costs, usefulness, convenience, safety. However, less explored or poorly understood factors appear to be regional and societal norms, personal space, or herd behavior (community culture). These may be even more relevant to explore than demographic factors as these are factors that can be influenced through policies or interventions, more so than age, gender, or ethnicity.

### 3.3 Previous research in AVs

Another category of related research is in the field of AVs; in the beginning of this field, studies had been mainly focused on user acceptance of the self-driving vehicle, a form of technological acceptance.

Age, gender, income level, time, and cost were some of the most studied factors. In a widespread multinational study for 2017, the authors concluded that men hold more favorable opinions towards automated vehicles than women, and that lower-income countries were more accepting of driverless vehicles than higher-income countries (Nordhoff et al., 2017). Another study concluded that AVs would be embraced by young people and urbanites, with more men having a positive outlook than women (Becker & Axhausen, 2017). Other studies examining factors such as convenience and perceived usefulness demonstrated that people intended to use AVs to go drive empty and deliver packages or pick up friends and family members (Harb et al., 2018). Some studies concluded that personality attributes or motivations, such as thrill seeking or supporting changes that benefited the environment, were significant in motivating willingness-to-use (Nordhoff et al., 2017; Haboucha et al., 2017).

In a literature review of surveys examining the acceptance of AVs, some studies showed that respondents were extremely concerned about the safety aspects of the AV, while other respondents were positive about the increased safety benefits of AVs (Becker & Axhausen, 2017). This indicates that perception of safety and willingness to embrace the technology may differ depending on culture or technological exposure. Table 4 provides an overview of previous studies on AVs, and which factors earlier research has examined in order to understand who is willing to use and accept AVs, and why.

*Table 4: Related AV acceptance studies and previously examined factors*

| Category | | Examined Factors | Authors |
|---|---|---|---|
| Internal Factors | Demographics | Gender | Bansal & Kockelman, 2017; Becker & Axhausen, 2017; Spurlock et al., 2019; Nordhoff et al., 2018; Hewitt et al., 2019; Cyganski, Fraedrich & Lenz, 2015 |
| | | Age | Bansal and Kockelman 2017; Spurlock et al. 2019; Nordhoff et al., 2018; Hewitt et al., 2019; Cyganski, Fraedrich & Lenz, 2015; Becker & Axhausen, 2017 |
| | | Education | Bansal & Kockelman, 2017; Cyganski, Fraedrich & Lenz, 2015; Becker & Axhausen, 2017 |
| | | Employment Level | Bansal & Kockelman, 2017; Cyganski, Fraedrich & Lenz, 2015; Cyganski, Fraedrich & Lenz, 2015 |
| | | Income | Bansal & Kockelman, 2017; Spurlock et al., 2019; Nordhoff et al., 2018.; Cyganski,; Fraedrich & Lenz, 2015; Becker & Axhausen, 2017 |
| | | Ethnicity | Nordhoff et al., 2018 |
| | | Social Class | Hewitt et al., 2019 |
| | | Household size | Cyganski, Fraedrich & Lenz, 2015; Becker & Axhausen, 2017 |
| | | Marital Status | Cyganski, Fraedrich & Lenz, 2015 |
| | | Occupation | Cyganski, Fraedrich & Lenz, 2015 |
| | Judgements | Personal Innovativeness | Haboucha, Ishaq & Shiftan, 2017; Lenz & Fraedrich, 2016; Becker & Axhausen, 2017 |
| | | Perceived Risk | Fraedrich et al., 2016; Hewitt et al., 2019; Becker & Axhausen, 2017 |
| | | Perceived Usefulness | Harb, et al., 2018; Hewitt et al., 2019; Fraedrich et al., 2016; Labriga & Bonnardel, 2020 |
| | | Experience with Technology | Becker & Axhausen, 2017 |
| | | Attitude / Motivation | Nordhoff et al., 2018; Haboucha, Ishaq & Shiftan, 2017; Cyganski, Fraedrich & Lenz, 2015; Fraedrich et al., 2016; Lenz & Fraedrich, 2016 |
| | | Trust | Hewitt et al., 2019; Fraedrich et al., 2016. |
| | | Privacy | Fagnant & Kockelman, 2015; Hewitt et al., 2019; Fraedrich et al., 2016; Becker & Axhausen, 2017 |

| | | | |
|---|---|---|---|
| External Factors | Third-Party Interventions | Cost | Fagnant & Kockelman, 2015; Fraedrich et al., 2016; Labriga & Bonnardel, 2020 |
| | | Comfort | - |
| | | Convenience | Harb, et al., 2018; Hewitt et al., 2019; Cyganski, Fraedrich & Lenz, 2015; Fraedrich et al., 2016; Labriga & Bonnardel, 2020 |
| | | Safety | Fagnant & Kockelman, 2015; Hewitt et al., 2019; Fraedrich et al., 2016. |
| | | Environmental Awareness | Nordhoff et al., 2018; Haboucha, Ishaq & Shiftan, 2017 |
| | Situational Factors | Time / time benefit | Spurlock et al., 2019; Harb et al., 2018; Hewitt et al., 2019; Cyganski, Fraedrich & Lenz, 2015 ; Labriga & Bonnardel, 2020 |
| | | Transportation Anxiety | Hewitt et al., 2019 |
| | | Herd Behavior | Hewitt et al., 2019 |
| | | Personal Space | - |
| | | Norms | Hewitt et al., 2019 |

It is worth noting that I did not place any articles under the factory category of "comfort" or "personal space". This is because these concepts did not often emerge in these articles, at least not in the same context as they did for ridehailing or ridepooling. For example, concerns about personal space were presented as concerns about privacy (both physical and digital), and concerns about comfort were presented as concerns about safety.

### 3.4 Previous research in SAVs

A newer subset of AV research has been emerging in the context of sharing rides in on-demand mobility contexts (e.g., Narayanan, et al., 2020; Paddeu, et al., 2020). These include studies that simulated fleet sizes of SAVs for certain cities or regions. One result showed that incorporating SAVs could significantly reduce the total number of vehicles required to meet the transport needs of a community (Dia & Javanshour, 2017). Other simulations showed a potential reduction of the total vehicles needed in a community, by as much as 31-95% (Pakusch, Stevens & Bossauer, 2018).

An interesting study in 2017 compared attitudes between Israelis and North Americans; in this survey, five variables were found to be significant: technological interest, environmental concern, personal enjoyment of driving, attitude towards public transport, and attitudes towards AVs (Haboucha et al., 2017). It was also determined that Israeli individuals were more willing to accept AVs than North Americans, indicating potential cultural differences for explanations. And while costs were determined as an important variable in the choice to use SAVs, 25% of respondents would refuse to use SAVs entirely, even if it was completely free, which speaks to a deep-rooted hesitation (Haboucha et al. 2017).

Many of these studies investigated similar factors as in AV acceptance research or ridehailing research (see Table 5), except for marital status, occupation (employment status or level was asked, as it impacted commute times) and personal space. Concerns about space did exist for users but was often discussed in the context of privacy and safety.

*Table 5: Examined Factors for SAV Acceptance*

| Category | | Examined Factors | Authors |
|---|---|---|---|
| Internal Factors | Demographics | Gender | Madigan et al., 2017; Merat, Madigan, & Nordhoff, 2017; Lavieri & Bhat, 2019; Qua Kockelman, 2019; Barbour et al., 2019; Gurumurthy & Kockelman, 2019 |
| | | Age | Madigan et al., 2017; Merat, Madigan, & Nordhoff, 2017; Lavieri & Bhat, 2019; Quarles & Kockelman, 2019; Barbour et al., 2019; Gurumurthy & Kockelman, 2019 |
| | | Education | Quarles & Kockelman, 2019; Barbour et al., 2019 |
| | | Employment Level | Barbour et al., 2019; Krueger, Rashidi & Rose, 2016 |
| | | Income | Lavieri & Bhat, 2019; Quarles & Kockelman, 2019; Gurumurthy & Kockelman, 2019 |
| | | Ethnicity | Lavieri & Bhat, 2019; Barbour et al., 2019 |
| | | Social Class | Krueger, Rashidi & Rose, 2016; Madigan et al., 2017; Merat, Madigan & Nordhoff, 2017 |
| | | Household size | Barbour et al., 2019 |
| | | Marital Status | - |
| | | Occupation | - |
| | Judgements | Personal Innovativeness | Krueger, Rashidi & Rose, 2016; Merat, Madigan & Nordhoff, 2017 |
| | | Perceived Risk | Gurumurthy, Kockelman & Simoni 2019; Gurumurthy & Kockelman, 2019; MERGE Project, 2018 |
| | | Perceived Usefulness | Diels, et al., 2017 Merat, Madigan & Nordhoff, 2017; Stoiber et al., 2019; Gurumurthy, Kockelman & Simoni 2019; Dia & Javanshour, 2017; MERGE Project, 2018 |
| | | Experience with Technology | Diels, et al., 2017 |
| | | Attitude/Motivation | Merat, Madigan & Nordhoff, 2017; MERGE Project, 2018 |
| | | Trust | Gurumurthy & Kockelman, 2019 |
| | | Privacy | Madigan et al., 2017; Merat, Madigan & Nordhoff, 2017; Barbour et al., 2019; Gurumurthy, Kockelman & Simoni, 2019 |

| | | | |
|---|---|---|---|
| External Factors | Third-Party Interventions | Cost | Krueger, Rashidi & Rose, 2016; Pakusch, Stevens & Bossauer, 2018; Lavieri & Quarles & Kockelman, 2019; Stoiber et al., 2019; Barbour et al., 2019; Gurumurthy, Kockelman & Simoni, 2019, MERGE Project, 2018 |
| | | Comfort | Diels, et al., 2017; Madigan et al., 2017; Pakusch, Stevens & Bossauer, 2018; Lavieri & Bhat, 2019; Stoiber et al., 2019; MERGE Project, 2018 |
| | | Convenience | Krueger, Rashidi & Rose, 2016; Madigan et al., 2017; Pakusch, Stevens & Bossauer, 2018; Lavieri & Bhat, 2019; Stoiber et al., 2019; Gurumurthy, Kockelman & Simoni, 2019 |
| | | Safety | Diels, et al., 2017; Madigan et al., 2017; Merat, Madigan & Nordhoff, 2017; Pakusch, Stevens & Bossauer, 2018; Gurumurthy & Kockelman, 2019 |
| | | Environmental Awareness | Krueger, Rashidi & Rose, 2016 |
| | Situational Factors | Time / time benefit | Krueger, Rashidi & Rose, 2016; Merat, Madigan & Nordhoff, 2017; Pakusch, Stevens & Bossauer, 2018; Lavieri & Bhat, 2019; Stoiber et al., 2019; al., 2019; Dia & Javanshour, 2017 |
| | | Transportation Anxiety | Barbour et al., 2019; Dia & Javanshour, 2017; MERGE Project, 2018 |
| | | Herd Behavior | Stoiber et al., 2019 |
| | | Personal Space | - |
| | | Norms | Stoiber et al., 2019; MERGE Project, 2018 |

In those studies where the focus has been ride-sharing in AVs, like in other work, attempts were made at creating demographic profiles of likely users and early adopters of SAVs. In Barbour et al., 2017, men and those with graduate education were less likely to be concerned about safety; in contrast, people with smaller or infrequent commutes were more likely to be concerned with safety. It is not yet understood what features or protocols would enhance safety in current shared mobility services, and how those would need to be further developed for SAVs (Zhang, 2019). Persons who came from households larger than three persons (likely families), or who already owned more than four vehicles, were concerned with the privacy aspects of SAVs (Barbour et al., 2017). One particularly interesting finding from that study showed that respondents who identified as African-American as well as respondents who lived within one mile of a grocery store, were less likely to be concerned with the reliability of an SAV service. The typical "early adopter" of SAV profile was someone younger, highly educated, living in a household with low vehicle ownership (Barbour et al., 2017). Taken together, these aspects are important because the results from these various studies illustrate that different aspects of SAVs hold different meaning and value to different groups of users.

It could be easy to criticize earlier research as focusing too much on early adopter demographics and not on perceptions of service in SAVs, but due to the emerging nature of this new form of mobility and the scarcity of high-functioning, shared AV pilots or vehicles for people to use, it is difficult to find appropriate user groups with which to investigate their feelings, reactions, or perceptions in response to a real vehicle or artefact. One exception was the MERGE (2018) project, which showed that potential customers want to know that the new AV technology is safe, but that they are perhaps even more concerned with the safety and service design of a shared AV and what kind of processes are in place to protect passengers from not just vehicle failures, but other riders.

### 3.5 Summary and implications for licentiate

Earlier studies have identified factors that are very likely to influence willingness-to-use SAPT, since they affect how users perceive the qualities of service- factors such as cost, comfort, and convenience (e.g., Quarles & Kockelman, 2018; Meurer et al., 2014; Neoh, Chipulu, & Marshall, 2017; Sarriera et al., 2017; Park et al., 2018).

Other studies also included attitudinal factors of acceptance, such as personal innovativeness (how interested an individual was in trying new technology), or concern about the environment and climate change (Moody et al., 2019; Amirkiaee & Evangelopoulos, 2018; Werth et al., 2021).

Technological acceptance of AVs has been the topic of quite a few investigations, such as trust in the driving and steering technology, or in simulations of fleet sizes (Krueger et al., 2016; Bansal & Kockelman, 2017; Lavieri & Bhat, 2019; Sanguinetti, Kurani, Ferguson, 2019). Yet, it felt that this body of previous work lacked studies focusing on the sharing behaviour and context for AVs.

Other factors had been discussed less frequently in previous work, such as herd behaviour (Liu & Yang, 2018); personality types (Lavieri & Bhat, 2019); regional economics, and trust (Bachmann et al., 2018; Furuhata et al., 2013). These factors, and others like them (such as community or cultural influence) are relevant to explore- perhaps more so than demographic factors -because these are factors that can be influenced through policies or interventions.

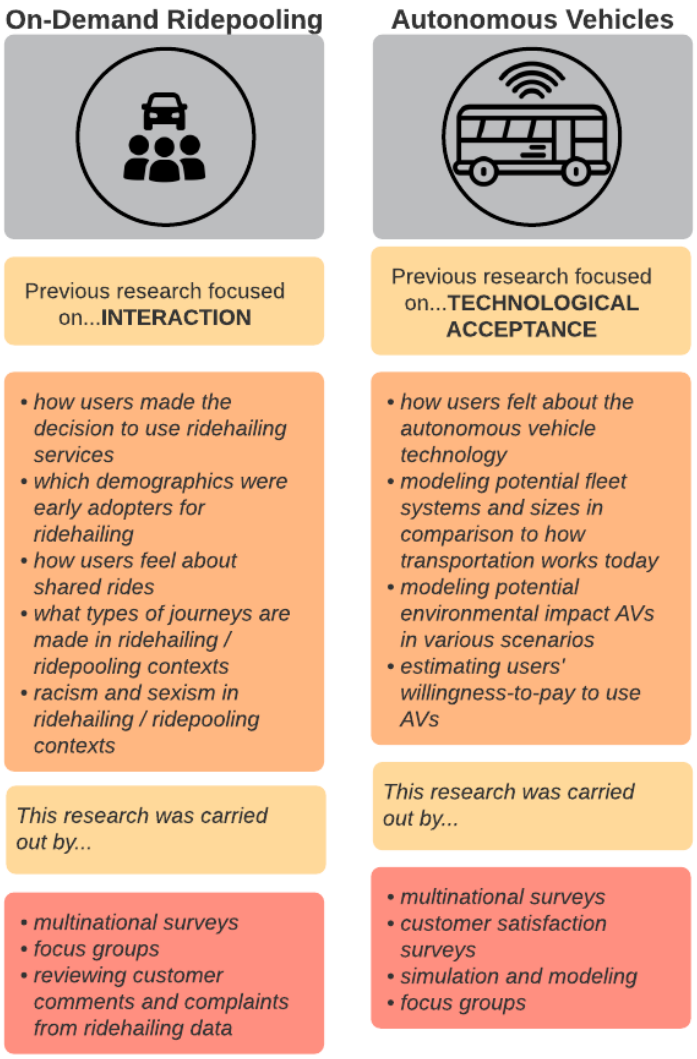


*Figure 2: Comparison of research focus and methods between ridehailing/ridepooling studies and AV studies*

Some of the studies reviewed, although they are multinational surveys or cultural comparisons, suggested that there is a need to expand the dataset with additional geographic diversity and variables to track the evolution of perceptions on shared automated vehicles, both temporally and spatially (Barbour et al., 2019). This indicates that there could be a cultural or community-based dimension to the acceptance of shared, autonomous mobility, and that learnings from a study done in one region of the world cannot necessarily be applied to another without localization and contextual consideration.

Another aspect that was not captured fully in the previous research is the influence of time. In the previous studies, much of the work focused on survey methods, such as online questionnaires. Moreover, these were usually large surveys, deployed once, meaning they failed to capture the influence of time. There were few, if any, longitudinal studies on the topic of willingness-to-share and willingness-to-share AVs. How would exposure to more ridehailing and potentially AV pilots change people's perceptions of SAV mobility and their willingness-to-share?

In the following studies, I attempted to do two things: perform focus groups, to understand what factors I would then include in future longitudinal studies; and perform interviews, to understand how transportation stakeholders view user attitudes towards dynamic ridepooling and SAVs and what their plans are for growing acceptance of SAPT.

## 4.1 The Research Project

The work presented in this licentiate thesis is part of a larger, industrial project, which aims to examine which behaviors and services could be prerequisites for society using autonomous technology to its utmost potential. This project will analyze international use cases and use socio-technical theory to create a framework for evaluation and recommendations for increasing willingness-to-use shared, on-demand, autonomous public transport: the *Societal Readiness Index for Shared Autonomy*. This work is done as a collaboration between RISE, Chalmers University of Technology, and Keolis, a multinational transport operator. The United States, Australia, Sweden and France were identified by Keolis as significant regions with high potential for the adoption of autonomous public transport, and thus set the boundaries and scope of the research to these countries.

This Index will effectively be a composite of indicators from the individual, neighborhood/regional, and state/national levels. These indicators can be factors that influence individual mode choice, or measurements of a community's diversity, or the political and regulatory framework of a statewide transport operator. The value in such an index is a customizable tool that can identify which factors contribute to users' decision-making process when it comes to accepting and selecting shared, autonomous public transport; this will help cities and operators determine where on-demand, autonomous transportation may be first deployed, and if areas are deemed unsuitable in the near-term, what measures can be taken to increase their ability to accept new mobility services. Furthermore, the development of an index to be used in different regions and markets requires an understanding of differences between these areas.

The figure below (Figure 3) depicts where the work in this licentiate and the completed studies described serve in the structure of the entire project and its goals.

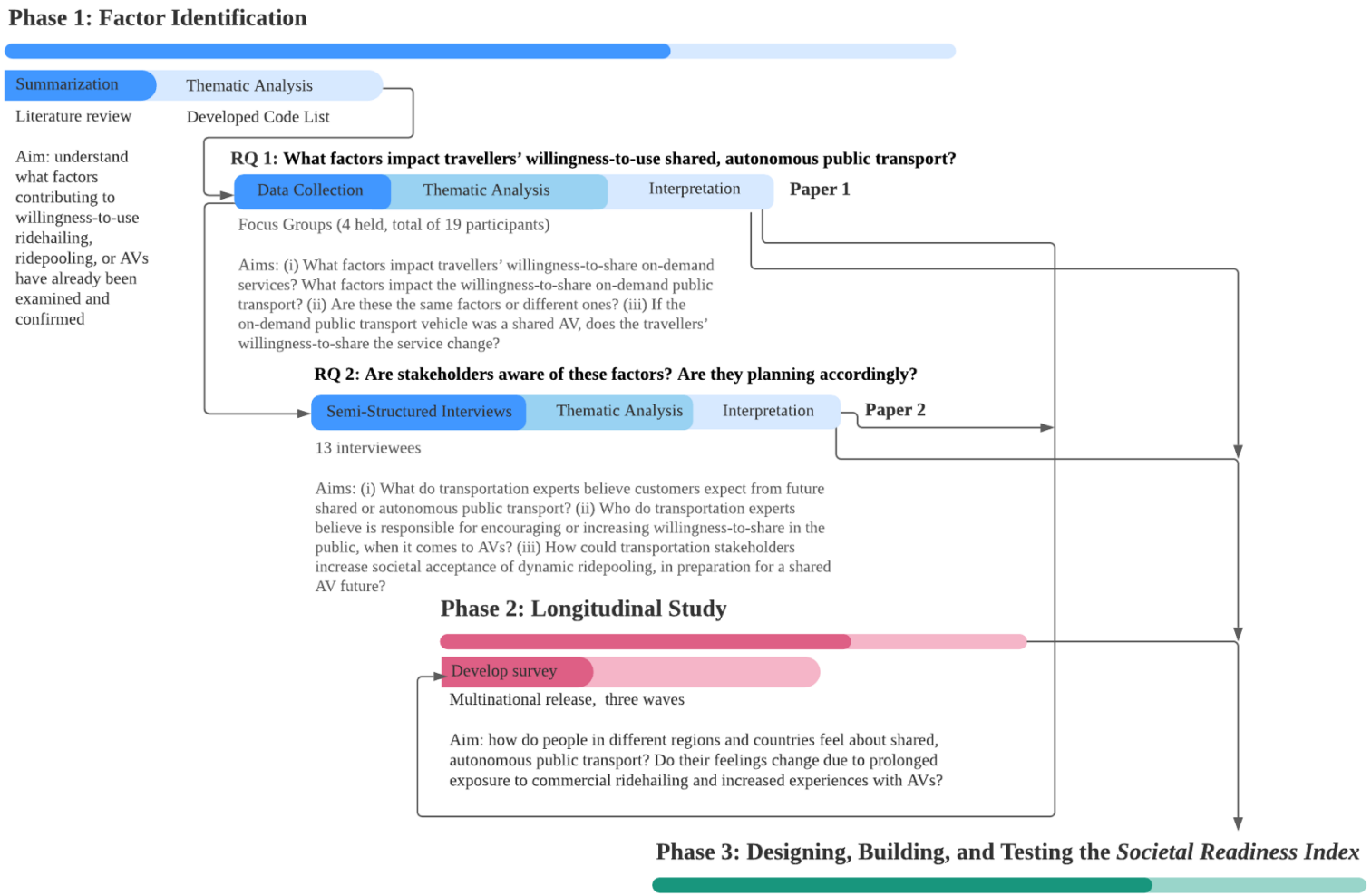


Figure 3: An overview of the entire doctoral research project for the Societal Readiness Index for Shared Autonomy.

The project plan therefore includes three main research phases. The first phase focuses on identifying factors through a literature study and complementary explorative studies (the licentiate work being one part of this phase). The second phase is a longitudinal study, where a survey will be distributed, minimum twice (but hopefully three times) over a period of 15 months to a sample of respondents in France, Sweden, and Australia. The factors that will be investigated in this longitudinal study will be the factors identified in phase one. The third and final phase involves selecting factors from the longitudinal study and creating scales and prescriptions in order to develop, and then apply, the Societal Readiness Index in new markets.

## 4.2 The Research Studies

Situated within research for the *Societal Readiness Index for Shared Autonomy,* this licentiate is focused on work completed as part of the first phase and on one case study, in Australia and more specifically New South Wales. Two studies were carried out concurrently. These studies were:

- focus groups with users, both of contemporary mobility services and for future mobility options, and
- interviews with stakeholders and decision-makers, such as AV manufacturers, the regional transportation authority, and transport operators.

The hope was that the focus groups would give input on factors for the survey investigation to be carried out in phase two of the research project, and that the interviews would reveal best practices or policy pathways for consideration in addressing willingness-to-share autonomous public transport.

### 4.2.1 The choice of context

In New South Wales, the state is perhaps the most progressive in all of Australia when it comes to investigating both autonomous mobility and on-demand transport. The regional transport agency, Transport for New South Wales (TfNSW), released a document called Future Transport 2056, creating guidelines and plans for how they intended to direct mobility services and efforts in the coming decades, with significant emphasis on digital and smart city infrastructure. This meant New South Wales had an unusual level of documentation and planning available for new mobility services; they had even established the Smart Innovation Centre, a team within TfNSW dedicated to planning and preparing for emerging mobility.

At the time of the study, there were 17 active on-demand transport pilots and three autonomous vehicle pilots taking place. These funded trials were unusual compared to other cities or states, not only within Australia, but in a global context; furthermore, TfNSW was emphasizing a market-driven approach and aggressively changing regulations and policies to make it easier for commercial actors to enter and operate within New South Wales.

In Sydney, New South Wales, Keolis introduced an on-demand public transport pilot called “Keoride”. At the time of the studies, it operated in two regions of Sydney, and represented the public transport alternative to commercial ridehailing and ridepooling services such as Uber or UberPool. It also had active and heavily publicized autonomous vehicle pilots available to the public. This made it an attractive choice for comparing groups of customers with contemporary mobility experiences, and also to investigate their thoughts and feelings about autonomous vehicles.

### 4.2.2 The choice of approach

The literature review of investigations into willingness-to-use ridehailing, and willingness-to-use autonomous vehicles, identified some consistent factors that are important for users in order to adopt new services (e.g., cost, convenience, comfort). However, these findings (reported in Chapter 3) were judged not sufficient to cover a new mobility mode that combines on-demand ridepooling with autonomous vehicles. Willingness-to-share ridehailing services is not considered sufficiently similar to shared autonomous public transport that the lessons learned from this previous work is totally applicable. Therefore complementary explorative qualitative studies were needed to focus on the particular behaviors and motivations of shared, driverless mobility.

Qualitative methods are useful for doing exploratory research, such as trying to analyze choices or motivations; these insights can often develop ideas for further research. Since the focus of the first phase of the research project is understanding attitudes towards a potential technology development and service offer, it is a nascent industry that requires significant exploratory research. Specifically, it is critical to understand transport-related attitudes as the success of driverless vehicles depends on individuals' willingness to change their travel mode (Nordfhoff et al., 2018).

There is also a need to investigate the relationship between perceptions of safety and personal space in the segment of the population that intends to use autonomous vehicles. And finally, a range of factors separate from private ownership and perceptions of personal space and safety may emerge when applied to shared AVs, since users' willingness-to-share, combined with technological acceptance, must be considered.

Focus groups and personal interviews are examples of standard qualitative methods for eliciting feelings and open-ended responses from stakeholders. It is recognised that each of these methods has advantages or disadvantages.

### 4.2.3 Focus groups

Four focus groups were run with transport service users in order to address RQ 1.

Focus groups are an acknowledged qualitative research technique which can reveal insights that are otherwise difficult to obtain from other methods, such as a questionnaire or survey. In focus groups, participants share and receive feedback on their experiences, opinions, thoughts, and feelings without constraint. This is an essential component of the data-gathering technique when we are looking to investigate feelings and opinions on a service which does not currently exist. According to the social scientists Krueger and Casey, focus groups provide "a more natural environment than that of (the) individual interview because participants are influencing and influenced by others—just as they are in real life" (Krueger & Casey, 2009, p. 11); they can, thus, yield data that is not possible with other approaches, including one-to-one interviews where interviewees have less input in the form of other participants' thoughts and reactions.

### 4.2.4 Interviews

Interviews were run with altogether 13 stakeholders and decision-makers, such as AV manufacturers, the regional transportation authority, and transport operators in order to address RQ 2. Interviewing transportation experts was seen as crucial, since "orientations of experts are seen as essential for shaping social practices in a field of action" (Döringer, 2021).

Part of the interviews were face-to-face. Face-to-face interviews are considered ”the gold standard” of the interview process (Deakin & Wakefield, 2014). They have several key strengths; flexibility, spontaneous personal and observable interaction, and more control over the interview environment than would be possible during remote methods of interviewing (Heath, 2018). Mergel et al. (2019) were explicit that face-to-face interviews makes it possible for the interviewer and interviewee to exchange physio-social cues and to experiment the same environment at the same time, elements that are difficult to replicate or completely lost in an online or telephone interview. There is evidence that in-person or on-site interaction increases the likelihood that the interviewer finds more details that inform the research question (Furtado et al., 2017). However, there are also disadvantages with face-to-face interviews, such as the high cost per participant, geographical and time constraints associated with travelling.

Several of the interviews had to be completed over the phone or via Skype, due to time and travel constraints of some of the interviewees. Social scientists have noted that face-to-face interviews have “synchronous communication in both time and place”, whereas telephone and internet-enabled conversations are only synchronous in time (Opdenakker, 2006). Thus, while technology enables more flexibility in the interview process, it is possible that physio-social cues were missed due to the remote nature of the interaction.

### 4.2.5 Coding and analysis

Interviews and focus interviews provide qualitative data; each interaction can be audio recorded and recordings then transcribed and analyzed with a tool like Atlas.ti. Unlike survey methodologies, where the choices are limited or predetermined by the survey design, in interviews and focus groups the range of “responses” or observations can vary widely. The analysis involves repeatedly coding, reviewing and refining the process (Strauss & Corbin, 1998). Quotes or sections of the text is “coded”, or given keywords describing the concept it engenders. These codes can be either inductive or deductive. Strauss and Corbin (1990, p.12) encourage researchers to code "conceptually similar events/actions/interactions", grouping these repeated instances under the same theme. Codes are developed from the text itself; these are called emergent codes (Blair, 2015). Deductive codes are generated using a ”top down” approach, such as starting with explanations and seeing if they fit the available data. Inductive codes are necessary to account for observed occurrences or patterns that were not in the initial analytic frame. Inductive codes are based on a ”bottom up” approach; beginning with the data and building up.

The analysis of the data collected in the focus groups and interviews followed a top down and a bottom up approach. A deductive, “top down” approach was taken to generate an initial list of codes during a brainstorming workshop in Sweden. This initial list guided my analysis during the first views of the transcripts, however, during the analysis, additional codes were generated (inductive approach) as new themes and concepts emerged from the data.

The two papers summarized here can be found in the Appendix.

## 5.1 Paper I: Sharing Anxiety Is in the Driver's Seat: Analyzing User Acceptance of Dynamic Ridepooling and Its Implications for Shared Autonomous Mobility

Study 1, described in Paper I, aimed to identify factors that impact willingness-to-share dynamic ridepooling in commercial and public transport contexts as well as driverless vehicles. To begin to understand what factors motivate or demotivate willingness to share, I formulated the following research questions:

- What factors (if any), beyond socio-economic factors, impact travellers' willingness-to-share on-demand services?
- What factors impact the willingness-to-share on-demand public transport?
- Are these the same factors or different ones?
- If the on-demand public transport vehicle was a shared AV, does the travellers' willingness-to-share the service change?

### 5.1.1 Method

New South Wales had been selected as the case study for Australian markets; within New South Wales, several AV as well as on-demand transport pilots were taking place. The decision was made to try to hold focus groups in those neighborhoods, in order to capture local residents' perspectives and feelings, as well as their individual transport needs and experiences.

Three of the focus groups were in Sydney, the largest city of New South Wales; the fourth group was in Newcastle, a former industrial hub and university town north of Sydney. More specifically the focus groups took place in four locations: Northern Beaches, Inner West, Macquarie Park, and Newcastle.

The participants for the focus groups were recruited into two categories:

- Experienced users of on-demand transit: current users of an on-demand public transit service known as Keoride
- Potential users: persons who lived or worked in areas where on-demand ridehailing, and/or AV pilots were available and publicize

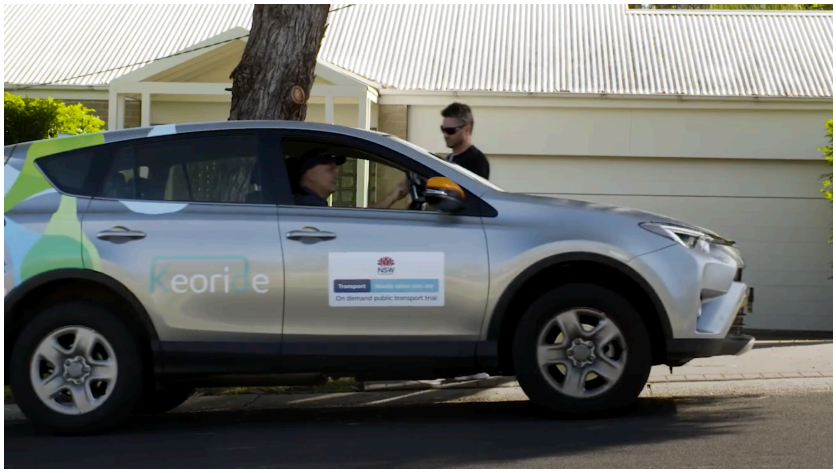


*Figure 4: A Keoride vehicle picking up a passenger in New South Wales. Picture reprinted with permission from KeolisDowner.*

The Northern Beaches and Macquarie Park groups represented experienced users, and the Newcastle and Inner West groups represented potential users. Experienced participants were recruited through the assistance of public transit operator KeolisDowner, and potential users of on-demand mobility participants were recruited through the online task managing service Airtasker.

The focus groups followed a predefined script. The discussion sought to understand the experience of using on-demand mobility; how unrelated persons from a particular community react to on-demand mobility services, and how they feel about sharing "their space." This focused on two important sharing aspects: aspects of physical space, and aspects of prioritization in journey order and time.

Each focus group session was approximately 90 minutes, audio recorded, transcribed, and coded. This initial list of codes included the commonly researched factors identified from previous work such as time, flexibility, convenience, or the environment

### 5.1.2 Results and Conclusion

Some already recognised factors were reiterated in the focus groups: the importance of travel time, flexibility, price sensitivity, and convenience all emerged as meaningful to participants when considering using dynamic ridepooling services or on-demand transport services.

Most of the respondents from all four groups shared the view that public transportation and dynamic ridepooling services either instilled a sense of community, or relied on an existing sense of community; they all agreed that that the nature of the interactions were relationship-based.

Both groups expressed that on-demand ridepooling services, whether they were provided by public transport or commercial, were more comfortable and "luxurious" compared to public transit buses or trains. There was a strong connection in the focus groups between driver and vehicle, one that extended to their perception of public transport as well. Some users attributed a large part of their satisfaction with the on-demand transport service to its drivers. The participants displayed emotional attachment to the drivers as an authority figure in the vehicle in case of emergency as well as a social representative of the community or service. Satisfaction

and loyalty to existing service seemed inspired by the belief that the drivers, vehicles, as well as other riders offered a consistent and shared experience. The elements created a kind of community or herd behavior, as well as engendering greater trust in authority.

The most important finding was that of a demotivating factor, particularly in the context of driverless vehicles, which was termed "sharing anxiety" which was the result of the relationship between several concerns: journey time and quality; concerns about safety; concerns about personal space within the shared vehicle (sharing a public space with strangers); and trust in authority, such as a service operator or transit agency (the transit agency being a government authority). When the presence of a driver or authority figure is removed, the riders felt unsafe for reasons that appeared to have less to do with navigation of the vehicle. Essentially, riders were concerned about autonomous driving technology, but their anxiety increased sharply at the suggestion of shared autonomous transportation, due to their belief about the potential threat that strangers introduced. Community-level differences affected how people gauged safety: users from homogeneous areas displayed lower levels of concern that did users from diverse neighborhoods. How strongly sharing anxiety would manifest, was particular to each individual's experiences with public transport or commercial ridehailing.

Establishing the existence of sharing anxiety is a significant finding, as it is a socio-cultural problem that cannot necessarily be addressed by a technological "feature fix". The results also differentiated the work from previous surveys and focus groups, where research had focused heavily on technological acceptance of AVs, and potentially missed the concerns riders had about other strangers in a shared AV.

### 5.2 Paper II: The 'Sharing Trap': A Case Study of Societal and Stakeholder Readiness for On-Demand and Autonomous Public Transport in New South Wales, Australia

The second study, described in Paper II, was an investigation into how stakeholders plan to increase willingness-to-share for both contemporary dynamic ridepooling and future SAV services, more specifically to investigate the awareness of sharing anxiety in users, and how they viewed their role and abilities in overcoming this problem. In relation to this study the following research questions were formulated:

- What do transportation experts believe customers expect from future shared or autonomous public transport?
- Who do transportation experts believe is responsible for encouraging or increasing willingness-to-share in the public, when it comes to AVs?
- How could transportation stakeholders increase societal acceptance of dynamic ridepooling, in preparation for a shared AV future?

#### 5.2.1 Method

Thirteen interviews were conducted with representatives for the transport operators or the transport authority in New South Wales who were working with autonomous vehicle issues (see Table 6). Although 13 interviewees a relatively small sample size, the background of the participants covered a wide range of perspectives throughout New South Wales; many of them were already working together to develop autonomous and on-demand mobility projects in their professional capacities. It was therefore hoped that they would present a strong picture of the current environment of transportation development in New South Wales.

*Table 6: List of interview participants and affiliation. Not for reprint.*

| Number of Interviewees | Affiliation |
|---|---|
| **1** | University of Sydney ITLS |
| **2** | Buslines Group |
| **1** | Busways |
| **2** | EasyMile |
| **3** | KeolisDowner |
| **2** | P2P Commission |
| **2** | Transport for New South Wales |

The interviewees were recruited using chain referral sampling, a strategy also known as 'snowball sampling', beginning with persons at TfNSW and University of Sydney Business School.

The interviews were conducted in person and by telephone. A semi-structured interview format was selected in order to have the freedom to ask probing, open-ended questions (cf. Newcomer, Hatry & Wholey, 2015). Each interview lasted anywhere from 35-60 minutes, depending on the mood and answers of the interviewee.

The interviews were recorded, then transcribed and coded using Atlas.ti qualitative analysis software. The codes used were the same initial list for the focus groups. Then, during analysis of the interview transcripts, I would create new codes to match any themes that emerged.

### 5.2.2 Results and Conclusion

On the topic of customer expectations for shared, autonomous public transport, the interviewees believed riders expected reasonable pricing, reassurance from a trusted authority (which would educate future users and make the booking process and the journey very transparent), safety, reliability, comfort, and convenience.

However, there was a widespread array of views on which particular stakeholder group was most responsible (or had the most resources and potential) for shaping public attitudes and increasing the acceptance of shared, on-demand and eventually autonomous mobility; for example, AV manufacturers placed this role on transport agencies, who also assigned this role to service providers. Interviewees from TfNSW felt there was still ambiguity about where shared mobility could fit into the entire public transport offer, and that even if the political will existed to provide it, improving the image of public transport and shared transport presented a significant communication and educational challenge. They foresaw a larger struggle in educating the public to use on-demand transport, since "on-demand" did not fit with the public's perception of public transport.

The most pessimistic view came from the academic interviewee, who argued that the unusual circumstances of co-occupying a limited shared space with a previously unknown passenger is a much bigger disincentive than embracing new technologies towards a shared autonomous future, and that only steeply reduced prices would ever convince the public to participate. However, besides the academic, most interviewees were surprised by the suggestion of potential "sharing anxiety" in potential users of future transport; they viewed this as a problem that would naturally resolve itself with increased technological acceptance of new, driverless vehicles.

Study 1 showed that there is a strong level of concern, fear, or anxiety on the part of potential passengers when it comes to dynamic ridepooling in an autonomous, driverless vehicle, a

concern centred around the authority vacuum and the potential behaviour of other passengers in a shared, driverless vehicle. Despite how prevalent this concern was, however, it seemed relatively unknown as a barrier for autonomous vehicle acceptance to the experts I interviewed.

Thus, the potential behaviour of other passengers in a shared driverless vehicle did not seem to be a concern for the stakeholders themselves. The result demonstrates a knowledge gap in the stakeholders about future user needs, therefore presenting a barrier to acceptance of future mobility services. This indicates that attention is needed from stakeholders throughout the transportation industry - authorities, operators, manufacturers and developers - to address sharing anxiety, and to test or design policies and programs that could make the transition to driverless public transport smoother.

Through the focus groups, I discovered how willingness-to-use SAVs decreased significantly in users who are otherwise motivated to share rides. The discussions found, compared to previous work (Krueger et al., 2016; Bansal & Kockelman, 2017; Lavieri & Bhat, 2019; Sanguinetti, Kurani & Ferguson, 2019), that much more beyond technological value is placed in the artefact of a driver, and that a "driverless" vehicle evokes something we called "sharing anxiety"; the heightened concern about safety and responsibility in a vehicle that is shared with strangers and with no human driver on board.

## 6.1 Sharing Anxiety

Sharing anxiety appears to be the result of a complex relationship between several concerns:

- *Journey time and quality*

Participants were concerned about the impact that adding co-riders to their trip would have on their own arrival estimates or overall journey length, as well as the quality of the trip itself. Concerns about time and comfort have been found in other work on both ridehailing and ridepooling, but it was unclear if this concern about time or comfort was related to the service itself or to the presence of other people.

- *Concerns about safety / concerns about personal space within the shared vehicle*

Another dominant worry was over their concerns about personal safety and personal safe. Without the presence of a driver, participants were worried who would "intervene", physically, if a co-rider crossed personal boundaries, in contexts as innocuous as having a lot of luggage in the cab of the vehicle, to as significant as physical harassment. This tied into the next aspect of sharing anxiety, centred around the drivers.

- *Trust in authority / lack of authority*

The drivers, being "employed" by both the riders and the company operating the service, were seen as authority figures who both had the responsibility and ability to intervene in case of a physical problem in the vehicle. One example a participant raised was that of a severe allergic reaction in another rider. Who would be responsible for offering medical aid? How would safety processes like this be handled?

How significant a barrier sharing anxiety presented to an individual's decision-making was particular to each person's previous experiences. Users from the potential group, with most of their experiences being through on-demand ridehailing services, were extremely pessimistic about future interactions with co-riders in shared rides. Users from the experienced group, who had used the on-demand transport product Keoride, were not nearly as pessimistic about co-riders as the other focus groups. I believe this may be from the sense of community and homogeneity they derived from the people they witnessed in their commute; a phenomenon known as "familiar strangers".

The "familiar stranger" is a social phenomenon first introduced to academia by the psychologist Stanley Milgram (Blass, 1992); a person is a "familiar stranger" to us if we regularly observe,

but do not interact with them in any way. As one study put it, "the claim is that the relationship we have with these Familiar Strangers is indeed a real relationship in which both parties agree to mutually ignore each other, without any implications of hostility. A good example is a person that one sees on the subway every morning. If that person fails to appear, we notice" (Paulos, & Goodman, 2004).

These familiar strangers may explain the difference in comfort and satisfaction between the two groups of users. The experienced participants described a sense of kinship or innate understanding about who was riding the service along with them - for example other students, other commuters, or people of a similar ethnicity and economic level (as indicated by e.g., clothing). The potential users from the most diverse neighbourhood, Newtown, were extremely distrustful (sometimes to the point of paranoia) about the potential behaviour and motivations of both other riders and the transport authorities themselves[1]. However, even the experienced participants, who were by far the most comfortable with sharing rides with strangers, were still deeply concerned with who would represent the authority in the vehicle, in the case of emergencies that had nothing to do with driving. Except for two men who admitted that they had never felt unsafe in public transport (possibly due to above-average height and stature), all participants had some degree of sharing anxiety.

### 6.2 Significance and Implications of Sharing Anxiety

Why is the presence of sharing anxiety significant for shared, autonomous public transport? Although on-demand ridehailing has normalized certain technical aspects of arranging transportation, even within contemporary ridepooling services, the idea of sharing with strangers in an unsupervised and intimate space is discomfiting even for experienced users of ridepooling. Some of the stakeholders were aware of the preference for riding alone versus ridepooling, but most viewed it as a minor problem that could be solved with attractive price management, and most underestimated the safety concerns that are the foundation of sharing anxiety. A few other studies (Merfeld et al., 2019; Kacperski, Vogel & Kutzner, 2020) about stakeholder perceptions for shared autonomous mobility have taken place, notably a Delphi study which showed that experts consistently ranked technological drivers and factors as the most important, and social factors (such as ethics and sustainability) as the least important (Merfeld et al., 2019).

This "blind spot" towards sharing anxiety within transportation stakeholders is problematic. Sharing anxiety occurs even in experienced and motivated users of ridepooling or on-demand transport, a group that would otherwise be identified as logical early adopters (cf. Rogers, 2003) of SAVs. It was the "drop off" effect of users' decreasing willingness, when faced with new factors, that inspired me to try to demonstrate the scope of the problem. In Figure 5, I attempted to model which populations (and subpopulations) were willing-to-use certain mobility services.

[1] Since Newtown's diverse nature made it less likely to be matched with riders of similar ethnicity or economic status, this could indicate a lack of the "familiar stranger" phenomenon at work and thus, be contributing to the increased discomfort and dissatisfaction of these participants.

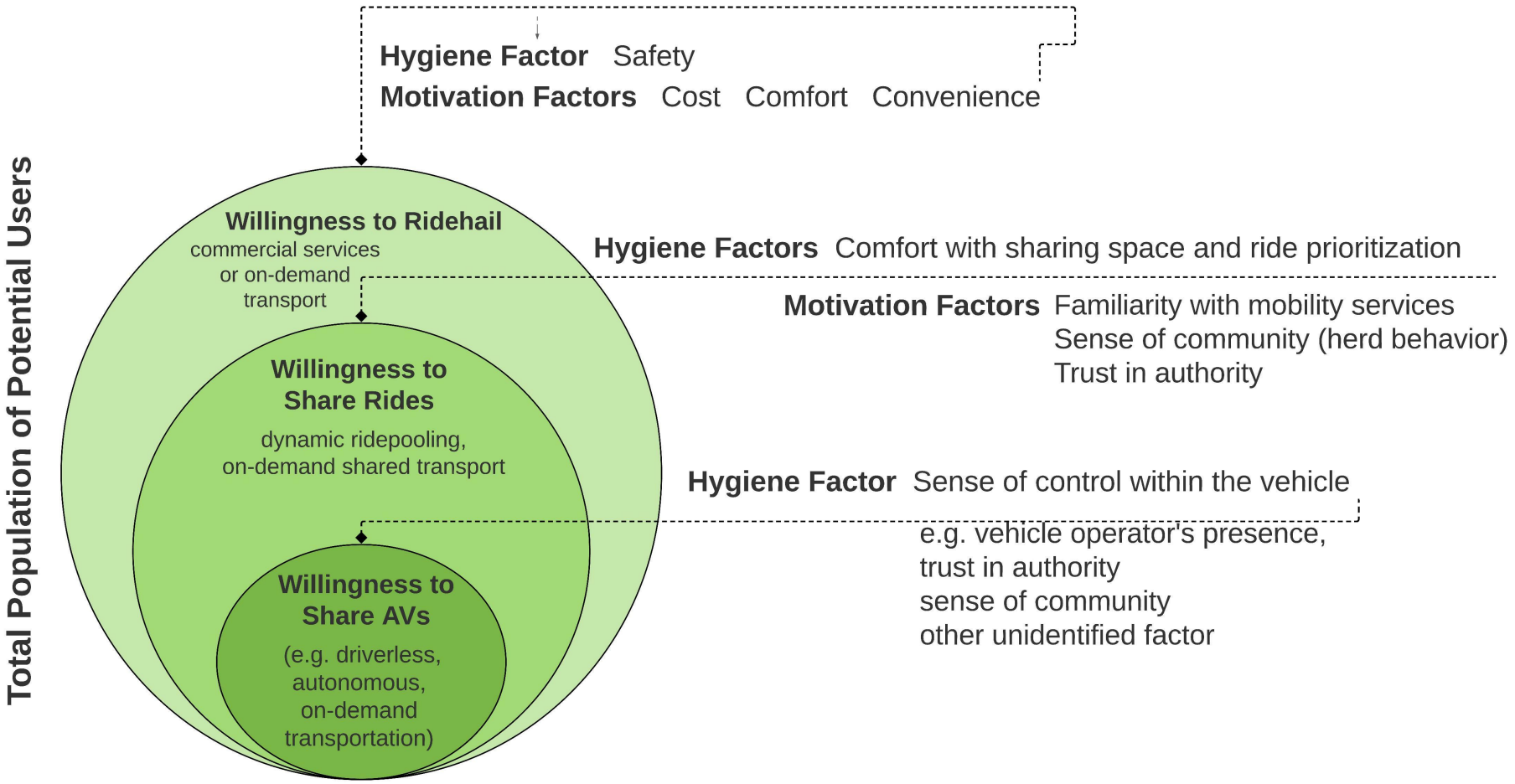


*Figure 5: The model of populations and sub-populations willingness-to-use mobility services. While not to scale, the figure shows how only some persons are willing to use ridehailing services, and a smaller subpopulation still is willing to share AVs. Dolins, Strömberg, Karlsson (2021).*

Inspired by hygiene theory (Herzberg, 2005), which frames the decisions to use objects or services as gates or moments governed by motivating and demotivating factors, I attempted to apply this to the decision to use on-demand ridehailing, dynamic ridepooling, and shared autonomous transport.

At the largest or widest level, I begin with the population of users who are willing to use ridehailing services. As ridehailing has grown in popularity, one can assume that the majority of technologically-proficient people are aware of it and will use it on occasion. This group is motivated by established factors such as cost, comfort, and convenience, and require the service to seem safe.

Within this group, there is a smaller sub-population that is willing to use shared rides, or dynamic ridepooling services: the users of contemporary dynamic ridepooling. They accept that they will share space and ride prioritization, and they are willing to accept this due to several factors: they are motivated by a cheaper price, they have some time flexibility, and they trust the authority of the service provider, or they trust the type of riders who they assume they will share with. This is a sub-population because for some, the benefit of a cheaper price does not outweigh the negative of a longer journey or having to share the vehicle space with a stranger. Participants in the focus groups said when they encountered bad experiences in their shared rides (poor service from a driver or misbehaviour from another rider), they shifted their mode choice to riding alone, driving or on public transport.

And lastly, within the sub-group that is willing to use shared rides, there is a yet-smaller set of the population that is willing to use SAVs. This is a group who believes the service to be technologically safe, or that they could control the vehicle sufficiently should the need arise. The motivating factors for what differentiate this final subgroup from the contemporary dynamic ridepooling group have yet to be completely determined. I have listed ‘trust in the service provider or transport authority’ and ‘sense of community’ as potential motivating factors. However, identifying what sets this section of the population apart from the second-tier group, willing to share rides but not share driverless vehicles, is the core question of this research project. Within the focus group, there were only two persons (out of nearly two dozen) who were relatively unburdened with sharing anxiety.

Yet, one of the positive pieces of evidence from Study 1 (and Paper I) was that the experienced participants had extremely high satisfaction with the on-demand public transport service, and had less acute or intense discussions displaying sharing anxiety, compared to the potential participants from the ridehailing groups. This indicates that the introduction of on-demand transport services, *with* drivers, had a positive impact in normalizing several aspects of shared transportation. It defined a culture of ridesharing and expectation of behavior for riders, with the driver as the “enforcer”. Introducing this expectation of behavior should be considered a kind of “bridging service” or “bridging technology”- a prerequisite for creating and promoting safe, shared, autonomous public transport by narrowing the gap between contemporary mobility and the future.

Therefore, the answer to RQ 1: What factors impact travellers’ willingness-to-use shared, autonomous public transport? can be summarized in the following table (Table 7):

*Table 7: Relevant Factors that influence Willingness-to-Use Autonomous Public Transport*

| | | | |
|---|---|---|---|
| **Internal Factors:** | factors that are intrinsic to an individual. | | |
| | Demographics | *Gender, age, education, employment level, income, ethnicity, household size, social class, marital status, occupation* | Confirmed in Previous Research |
| | Judgements | *Personal innovativeness, perceived risk, perceived usefulness, attitude/motivations, trust, privacy* | Confirmed in Previous Research |
| | | *Trust in authority, familiarity with mobility services / previous experiences with mobility* | Revealed in Licentiate Studies |
| **External Factors:** | factors that can affect an individual's decision-making, including aspects of service, vehicle design, or trip purpose. | | |
| | Third-Party Interventions | *Cost, comfort, convenience, safety, environmental awareness* | Confirmed in Previous Research, Revealed in Licentiate Studies |
| | Situational Factors | *Time / time benefit, transportation anxiety, herd behavior, personal space, norms* | Confirmed in Previous Research, Revealed in Licecntiate Studies |

Sharing anxiety presents itself as a barrier that is a mix of both internal and external factors: primarily concerns over time, safety, community culture, and trust in authority. Thus, although the individual concepts have been confirmed in earlier work, these studies gave a new dimension to the complexity of interplay between factors. Understanding what third-party interventions could be leveraged to alleviate sharing anxiety is a goal for future research.

## 6.3 Indications of Another Knowledge Gap for Stakeholders

Study 2 (and Paper II) was mainly focused on interviewing transportation stakeholders across three broad categories: the transport agency, public transport operators, and AV manufacturers.

These groups were aware of commonly studied factors such as cost, comfort, convenience, and ease-of-use, but despite the customer-focused nature of their core businesses, most of interviewees were unaware of the existence of sharing anxiety. When the topic was raised during their interviews, their responses tended to be somewhat dismissive about the potential problem it presented; they had generally optimistic perspective that the new technology would be readily embraced once it could be proven safe to the public and were confident that any concerns could be met with other or newer technological innovations. This over-reliance on technological solutions to social problems is a phenomena that has been documented in other studies (Lim & Taeihagh, 2019; Kummitha & Crutzen, 2019; Merfeld et al., 2019; Kacperski, Vogel & Kutzner, 2020).

Since AV manufacturers are in the business of creating and selling vehicles, it is logical that they might not see that their product created a shared environment that triggered concern in users, a concern unrelated to the technology of navigation.[2] However, it was surprising that both public transport operators and the transit agency (the latter of which is usually tasked with customer safety and advocacy) were so quick to dismiss sharing anxiety as a significant barrier that could hinder AV adoption.

An example of potential oversight: the transport agency in this case study had established a ridehailing commission to track and address reports of unsafe behavior, misconduct, or accidents in a database. These reports are generated from contemporary mobility services- a setting with a driver. However, within this database, there was no designation for incidents that might have taken place in a shared ride. Without that information, it is difficult or impossible to understand whether or not the fears of "misbehavior" that presented in the focus groups was justified. Moreover, the suggestion to add another designation for incidents taking place during a shared ride seemed unnecessary, or even quaint, to the interviewees.

Every transportation agency will take different approaches to planning for autonomous vehicles and autonomous public transport; in these case studies, the transportation agency had taken a very market-first approach to regulation and policy. This led to two perspectives: some stakeholders believed that users' experience with services like UberPool had already done much to educate people on how to share rides comfortably, and they were confident it would continue to do so, therefore extra intervention was not needed. Other stakeholders believed users may experience some discomfort at first but adapt within their first half dozen rides. In both cases, the belief is that the transport agency was not required to be involved in supporting acceptance of shared mobility.

This is an interesting example of cognitive dissonance because the transport regulators themselves did not see a connection between acceptance of dynamic ridepooling as a behavior, and acceptance of public transport. However, the two transport modes share a commonality, in that there is an expectation that users do not own the vehicle and expect other persons to share the journey with them. Strategies that increase acceptance of public transport could perhaps be used to increase acceptance of dynamic ridepooling, and vice versa.

[2] Not see, or be unwilling to state in an interview that could surface later.

Although the operators are the ones staffing and maintaining public transport vehicles, the transport agency is both the regulator of public transport systems in a region, and the face or symbol of authority for passengers. Driverless vehicles do exist in other transport modes- subway trains, automated trams, or railway trains that are so long most passengers never see the driver at the helm. However, this experience is not believed to be enough to build on for future driverless modes, because the size of space relative to a train or shuttle is so wildly different. (Several times the focus group participants mentioned that the larger space format of subways, trains and trams gave them a feeling of manoeuvrability and safety.) In a context where the space is smaller, and the driver is absent, it is the responsibility of the transport agency to address the authority vacuum that an AV represents, and to provide a substitute entity, structure or process that mitigates it.

Therefore the answer to RQ 2: Are stakeholders aware of these factors? Are they planning accordingly? is not entirely straightforward.

Most stakeholders were aware of the influence of obvious and logical factors, particularly socioeconomic factors or the influence of cost, convenience, and comfort. However, very few stakeholders were aware of the existence of sharing anxiety. Most of the stakeholders were reliant, even overly optimistic, that any social concerns on the part of the public towards SAVs would be solved either through widespread exposure to the technology, or through some other, future technological solution. Thus, they were not planning concrete strategies or policies to increase willingness-to-share rides, instead relying on market forces to drive the behavior adoption in the consumer public.

### 6.4 Towards a Societal Readiness Index

Together, the studies' findings highlight the problem my doctoral research is intended to address: sharing anxiety as a barrier to the adoption of autonomous public transport, and the scale of the problem is poorly understood by stakeholders and industry experts.

Addressing sharing anxiety should be considered critical for the proliferation of sustainable and increasingly digitized, on-demand public transport; otherwise, cities, operators, and manufacturers are making expensive assumptions about how quickly and easily these mobility options will be embraced by the consumer public. There are not yet many proven tactics to mitigate it (how can there be effective solutions for a poorly understood problem?) and further investigation is needed in order to create a transition plan for operators, authorities, manufacturers, and transportation planners.

The Societal Readiness Index is intended to measure factors that can impact willingness-to-share rides, in particular the context of autonomous public transport. Factors that have been confirmed in previous studies, re-confirmed or revealed through my studies, or that my studies have not revealed but still indicate value, will be included into the Index.

Below, in Figure 6, I have categorized factors that could influence users' willingness-to-use SAPT: factors confirmed from earlier studies, revealed in this licentiate's findings, or factors that merit future consideration and investigation for use with the Index.

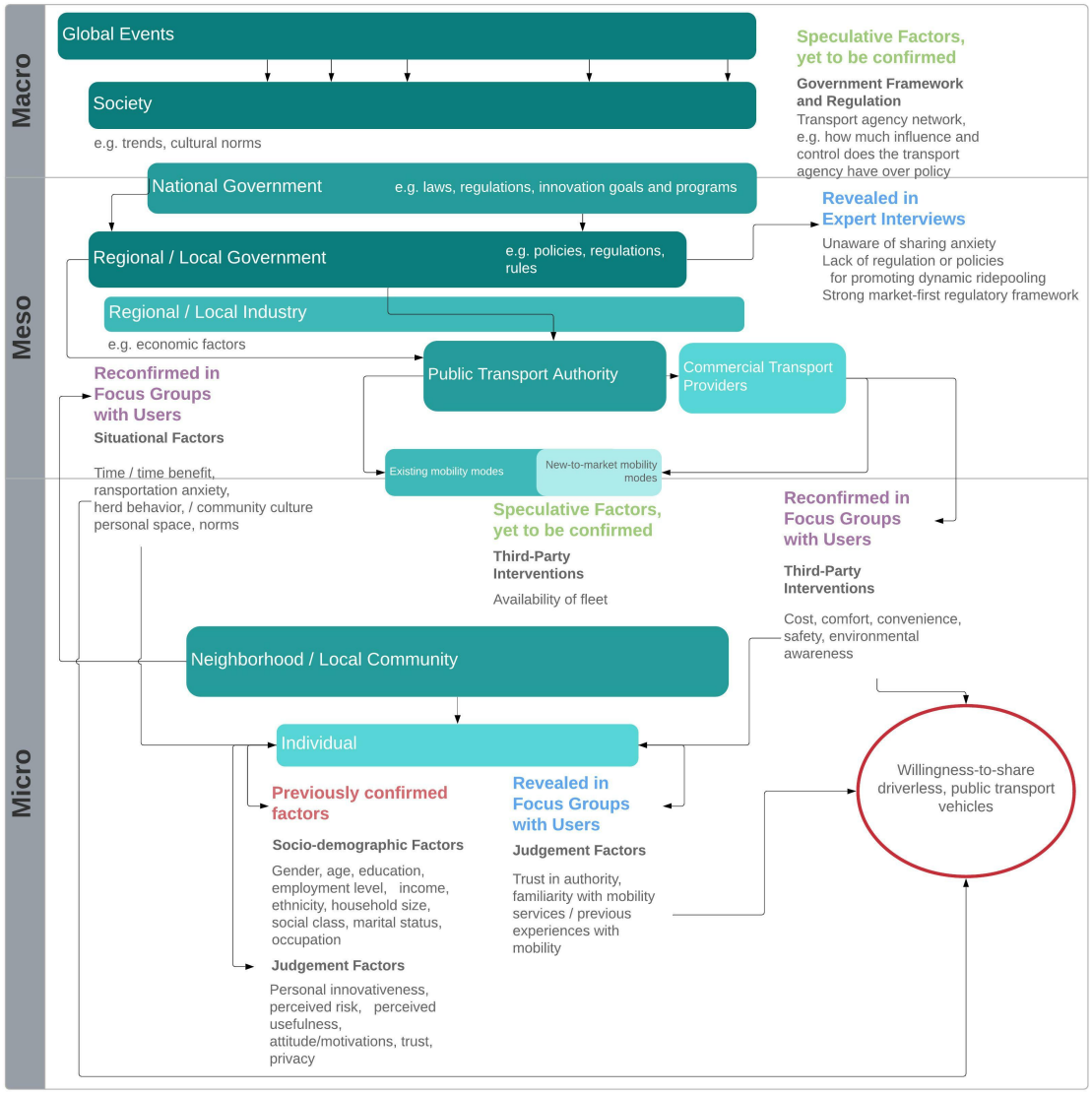


*Figure 6: Factors that could influence willingness-to-use SAPT or driverless public transport. The initial inspiration came from the IRIMS Framework, Karlsson, et al., 2020.*

Based on these factors and these findings, we can conclude that the case study for this licentiate, New South Wales, would not score high on the Index, and would require significant interventions; these interventions will be designed later as the Index is developed in future research.

## 6.5 Reflections on Research Approach

With the benefit of hindsight, it is beneficial to review the research approach I took and consider what might have been done differently.

With the focus groups with users, perhaps the biggest critique of Paper I was that there was significant difficulty in recruitment of participants. Using a commercial service like TaskRabbit and Airtasker first, instead of trying to promote it through other means, would have saved a significant amount of time and possibly allowed for several more groups to be held in both categories. Though the categories were split between users who had been exposed to on-demand transport and commercial ridehailing, one original intention had also been to recruit users who lived in the same neigborhood as an active AV pilot. Unfortunately the Newcastle pilot was delayed during the study visit, However, the flow of questions and format proved quite successful, and I have already begun replicating it for the Swedish use case.

Regarding the interviews with stakeholders, the sample size of 13 interviews was smaller than I would have liked. Had I insisted on more remote or Skype interviews, it would have increased the validity of the investigation. However even with a small sample size, the background of the participants covered a wide range of perspectives throughout New South Wales; many of them were already working together to develop autonomous and on-demand mobility projects in their professional capacities. It was therefore hoped that they would present a strong picture of the current environment of transportation development in New South Wales.

Additionally, the findings from the second study felt less impactful because of the unfortunate realization that most transportation experts were (at the time of interview) underestimating the impact of sharing anxiety and overestimating the attractiveness of new technology. This meant that the policy initiatives and recommendations I hoped to gather were not present. This doesn't mean they were non-existent, but with more time, it would have been insightful to run workshops with several participants concurrently.

And, of course, there is the impact of COVID, and how it will change not just the short-term goals of this research, but future mobility planning.

Sharing anxiety will of course be heightened in an era of highly contagious disease. The "unseen" factor a stranger represented in the findings had been due to the potential for misbehaviour, but now it is also represented by the threat of infection. However, combating a physical threat can be done through technical intervention, such as disinfecting sprays, or data collection of trips matched with health data, and these interventions can be replicated across all use cases.

Creating behavioural interventions for social concerns is less straightforward and context dependent. After the findings from the Australian use case, the research interest is now to confirm if sharing anxiety is present in similar contexts in other countries and cultures, and what strategies (if any) can be used to address it. Are Swedes and French also hesitant to share rides with strangers, for the same reasons as Australians? Do they also put a lot of emotional investment in the driver? How prevalent is sharing anxiety in users in other countries, and how common is it that stakeholders are underestimating its impact? Do French or Swedish

stakeholders, each with their unique ecosystem of transport experts and agencies, have different approaches to planning for shared autonomous transport?

While the research thus far only investigated elements of service offers and related policy recommendations, in view of current or future public health crises, there is new urgency for consideration of interior vehicle layout and how that contributes to restoring trust and confidence in the safety of public spaces, and issues surrounding personal data for contact tracing. Where perceptions of trust in public authority may have been at one level before COVID, different governmental responses to handling the pandemic may have completely altered how people view governmental agencies, requiring new methods to motivate or stimulate desired mobility behaviours. Therefore, the longitudinal study across two or more nations is still being developed, in time to see if biosecurity concerns become a permanent aspect of sharing anxiety.

The pandemic has served as a stern reminder of three things: that we must constantly challenge ourselves to plan for contingencies; that it's imperative that public systems must be similarly resilient; and that in private as well as shared spaces, it is important to wash your hands.

This work assumes an international and multicultural perspective, and was carried out with the intention to perform qualitative data collection with potential users of shared autonomous public transport services in three countries:

- Australia, where the public transport authority of New South Wales has demonstrated high levels of innovation of both on-demand public transit and AV pilots and deployments;
- France, a global leader in developing some of the first AV shuttles on the market, with numerous deployments of on-demand public transit services and the location of some of the most challenging AV pilots; and
- Sweden, with a strong history of both institutional and public support for public transit, vehicle innovation, but a lack of commercial dynamic ridepooling services.

This is an industrial research project, focused on producing knowledge valuable for implementation, co-funded by Vinnova, the Swedish Innovation Agency, and Keolis, a multinational public transport operator. The three countries selected as use cases represent significant markets for Keolis; each country has different mobility ecosystems and offers, unique cultures and therefore different public opinions towards public transport and autonomous vehicles. An international comparison between the three should give insight into potential measures for increasing the acceptance of shared, autonomous mobility in a variety of contexts and regions.

What's been confirmed by these two research activities thus far is:

- Sharing anxiety presents a significant barrier to the adoption of shared, autonomous public transport
- Transportation stakeholders in Australia underestimate the challenge of sharing anxiety
- Transportation stakeholders in Australia do not have a strong or cohesive plan for addressing it

With these findings, I plan to replicate my investigation in two other use cases, Sweden and France. The next phase of the research (as indicated in Figure 3, reprinted below) is to engage in a multinational longitudinal study. This survey hopes to recruit approximately 1,000 persons in each country and to follow their attitudes and views on SAPT over approximately 18 months, capturing how the effect of pandemic realities, transportation offers and time might change opinions, and hopefully understanding which factors are most susceptible to intervention.

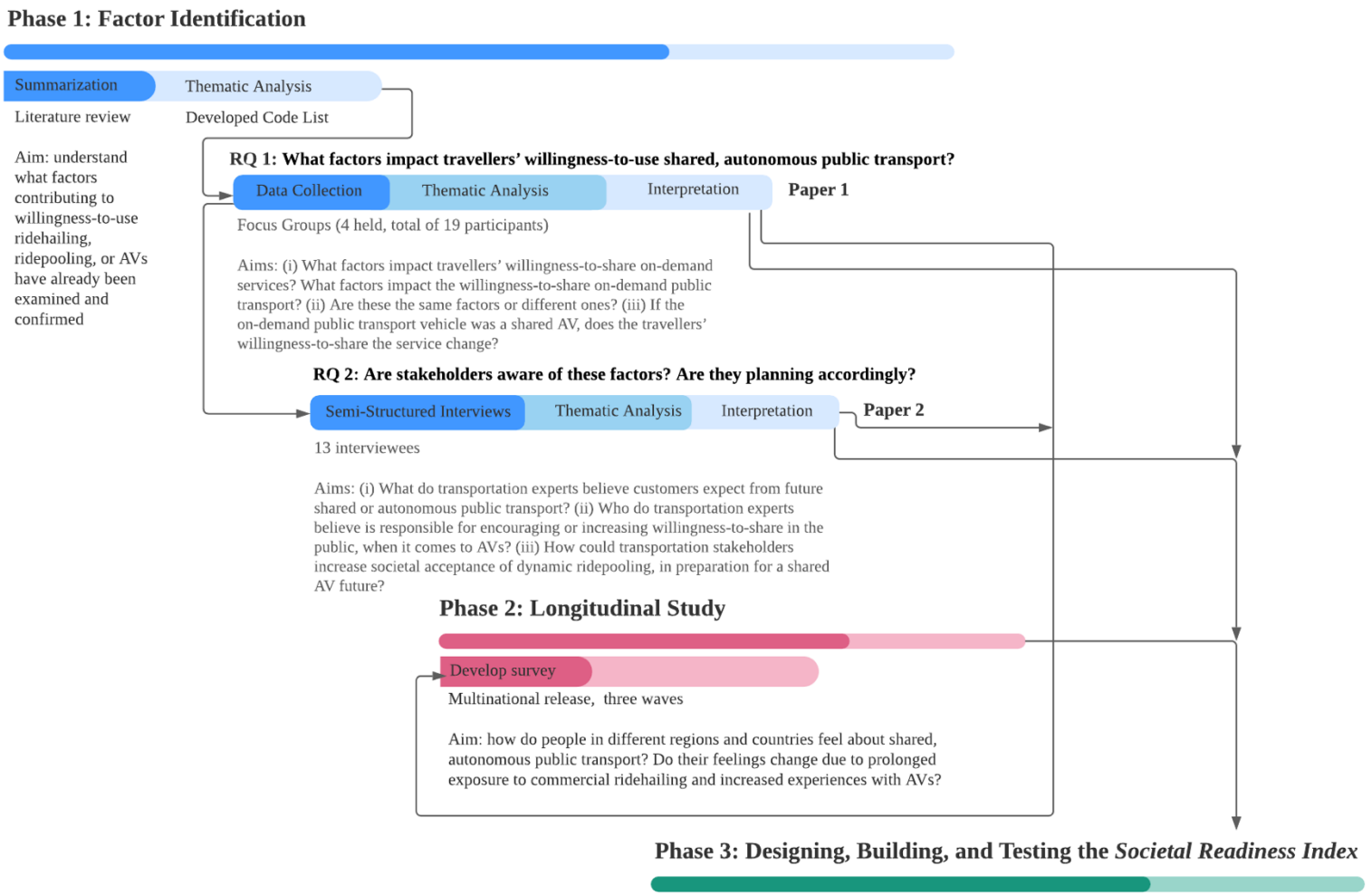


Figure 3: An overview of the entire doctoral research project for the Societal Readiness Index for Shared Autonomy.

Together, the data I collect will be used in the third phase, to create a descriptive and proscriptive evaluation tool called the Societal Readiness Index for Shared Autonomy, socio-technical systems theory-based framework for understanding existing conditions in a region, and to help operators and regional planners to quickly make assessments and recommendations for increasing sharing acceptance in their communities.

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# APPENDED PAPERS