Institute of Transport Economics
Norwegian Centre for Transport Research

Autonomous vehicles and transport system organization

Shifting boundaries, mandates and responsibilities

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Summary

Autonomous vehicles (AVs) are likely to transform urban mobility. By focusing on transport systemic dynamics, organizational structures, and user practices, we present a conceptual framework that has four AV scenarios and eight non-mutually exclusive pathways for potential AV introduction. The complexity and multiplicity of future system configurations underscores that we cannot take for granted how new technologies will be provided, used and regulated. Current mobility business models, legal frameworks, land-use practices, and enforcement policies must be updated. Recognizing the political nature of AV integration, system stakeholders must work actively to ensure access to AV mobility without exacerbating social inequities, climate emissions, excessive land-use, and economic inefficiency.

Kort sammendrag

Automatiserte kjøretøy (AVer) vil endre transport-systemet, særlig i byene. Flere vil få økt mobilitet og derigjennom økt tilgjengelighet. I denne studien tar vi utgangspunkt i endrings-prosesser, organisasjons-strukturer og brukerpraksis, og presenterer et konseptuelt rammeverk med fire scenarioer og åtte utviklingsstier som ikke er gjensidig ekskluderende for hvordan AVer kan introduseres. Kompleksiteten i dette underbygger påstanden om at vi ikke kan ta utfallet, hvordan teknologien tas i bruk, som gitt. Dagens mobilitet er styrt av etablerte lover, forret-ningsmodeller og arealbruk som må utvikles for å ta høyde for mulighetene AVer gir. Dette reiser en lang rekke politiske spørsmål. Hvem som tilbyr og organiserer tjenestene påvirker hvilke styrings-instrumenter som kan brukes. Uavhengig av organisasjon vil automatisert transport påvirke forholdet mellom personlige, private og offentlige transporttilbud.

Preface

Autonomous vehicles (AVs) are likely to be a part of the future. This may both be in the form of a radically different future mobility system, or as part of a future where today's system and institutions largely remain in place. This report looks at scenarios and development pathways for how that future might materialize, focusing on highlighting the impact of organisation on outcome.

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Oslo, December 2024
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ENGLISH **Summary**

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Autonomous vehicles (AVs) are likely to transform urban mobility. By focusing on transport systemic dynamics, organizational structures, and user practices, we present a conceptual framework that has four AV scenarios and eight non-mutually exclusive pathways for potential AV introduction. The complexity and multiplicity of future system configurations underscores that we cannot take for granted how new technologies will be provided, used and regulated. Current mobility business models, legal frameworks, land-use practices, and enforcement policies must be updated. Recognizing the political nature of AV integration, system stakeholders must work actively to ensure access to AV mobility without exacerbating social inequities, climate emissions, excessive land-use, and economic inefficiency.

Introduction

The integration of autonomous vehicles (AVs) into transport systems represents a pivotal shift in both private and professional mobility. While early discussions around AVs focused on their technical feasibility, today's advancements highlight their broader implications for the organization and operation of transport services. This report addresses the uncertainties and opportunities presented by AVs, aiming to help public sector actors navigate this transformative period. By analysing potential pathways to AV adoption, it explores the organizational structures and systemic changes necessary for their successful integration.

The future of AVs cannot be taken for granted. Whatever outcomes emerge will be the result of deliberate choices made today. It is up to policymakers and public authorities to ensure that AVs contribute to accessible mobility for all, while avoiding outcomes that exacerbate inequality, waste urban space, degrade natural environments, strain public finances, or increase carbon emissions.

Building on insights from existing studies, such as the Oslo Study, this report shifts the focus from predictive modelling of user behaviour to a qualitative examination of roles, responsibilities, and organizational dynamics within the transport system. It introduces a conceptual framework centred on three dimensions of AV use – distance to access, timing of service delivery, and type of occupancy – to help policymakers evaluate various scenarios for AV integration in urban and peri-urban areas.

Additionally, the report examines the legal and regulatory frameworks that will shape AV adoption. For instance, the Norwegian Vocational Transport Act, which defines boundaries between public and private transport services, may require updates to accommodate AV technologies. Similarly, the unique role of county governments in regulating taxis and purchasing public transport services highlights their potential to influence how AVs are integrated into the transport system. By focusing on these organizational and legal aspects, the report provides a foundation for public authorities to consider how AVs can align with broader mobility goals while addressing local and regional needs.

Research Approach

The research approach adopted in this report is conceptual, grounded in innovation studies, economic reasoning and supported by insights from political science. The central aim is to investigate the underlying dimensions of AV use and the role of political decision-making in shaping market outcomes, including service levels, societal utility, and the necessity of regulatory interventions. This report lays out pathways for AV introduction and explores the reorganization of transport services and their implications for the broader mobility landscape.

A key theoretical underpinning of the report is the multi-level perspective (MLP) framework, modified to reflect the complexity of urban mobility as a multi-regime system. Within this framework, AVs are positioned as an innovation that could disrupt the current socio-technical regimes of automobility and public transport. The study examines how these regimes might evolve under pressure from landscape-level trends such as digitalization and climate change.

We also discuss AVs in the context of Mobility as a Service (MaaS) by drawing on prior studies to highlight how different organizational structures could influence AV integration. Whether AVs are introduced by private companies, public transport authorities (PTAs), or through public-private partnerships, the organizational and regulatory context will be critical in determining their role within the mobility system.

We identify three core practices – storage, maintenance, and operation – that are central to motor vehicle use and explore how these could be reconfigured in an AV future. These form the basis for four scenarios of transport system organization: business-as-usual, commercial AV systems, public AV systems, and private-commercial AV systems. To further articulate the transition pathways to these scenarios, we use three dimensions of AV use – timing (fixed vs. on-demand), geography (station-based vs. door-to-door), and occupancy (exclusive vs. shared) – to define eight potential pathways. These pathways and scenarios are conceptual tools that are not mutually exclusive but represent corner solutions, providing policymakers with a structured framework to evaluate the organizational implications of AV adoption.

Scenarios for transport system organization with AVs

The three practices that form the basis for forming our scenarios are:

- **Storage**: While vehicle storage is often associated with ownership, it applies to other segments such as leasing, subscriptions, car sharing, and rentals. AVs have the potential to reduce the need for private storage by enabling vehicles to operate more continuously, but commercial or public storage will remain necessary.
- **Maintenance**: Currently, maintenance responsibilities are largely tied to ownership and leasing, with providers covering these tasks in other segments. With AVs, maintenance will mainly fall to service providers, reducing consumer involvement.

- **Operation**: AVs will fundamentally shift operational responsibilities from consumers to providers. In segments such as ridesourcing and taxis, this shift aligns with existing practices, but for private ownership, and leasing, it marks a significant departure.

We categorize transport segments into three groups: private car use (ownership, leasing, and subscriptions), access-based car use (e.g., car sharing, ridesourcing, taxis), and public transport. Each segment is analyzed to show how responsibilities for the three sub-practices might evolve with AVs. The analysis highlights that private car use would undergo the most significant changes, with users relinquishing operational responsibilities to the service providers. For access-based and public transport segments, the shift primarily reinforces existing practices, with providers (either public or private) managing storage, maintenance, and operation. Four scenarios are developed to articulate differences in roles and responsibilities given these practices and segments:

1. **Business-as-Usual (BAU)**: Private ownership remains dominant, with consumers relinquishing their operational role; current structures for storage and maintenance are maintained.
2. **Public-Private Service (PPS)**: Personal vehicles are largely phased out in favor of a system dominated by commercial transport services. Providers assume nearly all responsibilities for storage, maintenance, and operation, with public transport maintaining its current structure.
3. **Public Transit Scenario**: All transport services, including AVs, are integrated into a unified public transport system under the oversight of public transport authorities. This scenario envisions the most significant shift toward a public-centric model.
4. **Private Commercial Scenario**: Both personal vehicles and public transport are replaced by private commercial operators. This scenario emphasizes efficiency but risks creating inequities in service provision, particularly in less profitable areas.

Pathways to Scenarios

Using three key dimensions of AV use – geography, timing, and occupancy – we identify eight potential pathways for AV introduction. Each pathway represents a unique combination of these dimensions, offering conceptual a tool to articulate system change:

1. **Geography**: ranges from fixed stations or stops, typical of public transport, to dynamic, door-to-door services as seen in taxis and personal vehicles, and a middle ground, involving pick-up/drop-off (PUDO) points.
2. **Timing**: AV services could operate on a spectrum from fixed schedules, mirroring traditional public transport, to fully on-demand services akin to ridesourcing platforms.
3. **Occupancy**: spans exclusive use, where passengers control who they share the vehicle with, to shared use, where strangers co-occupy vehicles. A middle option involves selective sharing, catering to specific groups or memberships.

The eight pathways emerge from different combinations of these dimensions. Each pathway highlights trade-offs between user convenience, system efficiency, and environmental impact. They offer insights into how transport systems might evolve based on regulatory choices, market responses, and societal preferences. The pathways also underscore the importance of aligning AV integration with broader urban planning and sustainability goals. The following table shows the eight pathways for AV introduction (colours represent expected outcomes as problematic, mixed or promising):

Pathways	TIME	DISTANCE	OCCUPANCY
P1	Dynamic	D2D	Exclusive
P2	Dynamic	D2D	Shared
P3	Dynamic	S2S	Exclusive
P4	Dynamic	S2S	Shared
P5	Fixed	D2D	Exclusive
P6	Fixed	D2D	Shared
P7	Fixed	S2S	Exclusive
P8	Fixed	S2S	Shared

Discussion

Shared AV systems offer the potential to dramatically reduce parking demand by maximizing vehicle utilization, but exclusive-use models could increase congestion due to idling and non-use. Policymakers must rethink parking norms, shifting from minimum requirements to innovative regulations that encourage sustainable mobility and land use. Enforcement mechanisms, like time limitations and fines, must adapt to prevent AV-related inefficiencies, such as vehicles circumventing restrictions by idling or relocating. Additionally, strategically consolidating parking into hubs, leveraging underground facilities, and integrating parking with public transport hubs can optimize land use and ensure accessibility while reducing congestion.

Ensuring minimum levels of service for mobility across diverse geographic contexts presents complex challenges. PTA) face competing mandates to both provide high-quality alternatives to private car use in urban areas and maintain minimum service levels in rural regions for non-car owners and vulnerable groups. High-frequency and well-connected public transport systems are essential to meet urban mobility goals and attract car users. However, rural and low-density areas require coverage-oriented solutions, such as specialized routes, taxi services, or exclusive contracts with providers. The rise of AVs presents opportunities to rethink service delivery in these areas, potentially offering more efficient and inclusive options while addressing the challenges of balancing equity and efficiency across geographic contexts.

Autonomous vehicles will change the economics of mobility for all transport segments, both public and private. From economic reasoning we expect that irrespective of which transition pathway is followed, there will be a decrease in generalised cost, the economic term for the sum of disutility associated with transport, including out of pocket expenses, travel time and inconvenience. Exactly how much will vary from trip to trip, and among different organizational models, and depend on a series of factors that are presently unknown. Still, we argue that some outcomes are more likely than others.

Firstly, the impact on the PT system is likely to come through two mechanisms. 1) lower reliance on drivers, which is currently a major cost constraint on service; a restructuring of the costs associated with vehicle operation are likely to reduce overall costs, and 2) new services added to the system, which are likely to increase costs. This raises a series of questions relating to distribution, accessibility and desired levels of service. Secondly, and following the first mechanism, the current socio-technical regime is likely to be challenged. Today's distribution of responsibilities between tiers of government and public and private actors needs to be reconsidered. However, exactly how is not obvious. Thirdly, and following the second mechanism, if the PT system is to expand, this raises a series of questions relating to the role of public versus private mobility. Again, the exact outcome is not clear. What is clear is that a comercial, open-access-based systems will be very different from an organisation built around an expanded PTA, with tendering or licensing as policy instruments. Lessons can be drawn from the recent introduction of Mobility-as-a-Service (MaaS) and e-scooters. Fourthly, the vehicle segments that are likely to consolidate or disappear in the face of competition from AVs are the current on-demand modes for car-sized vehicles; taxis, ridesharing, and car sharing. These roles could all be served by on-demand access to AVs.

Key areas for future study include understanding customer responses, such as trust, willingness to pay, and preferences for services, with metrics developed to assess these along dimensions like distance, timing, and occupancy. The financial implications of AV deployment also demand attention, including the costs to governments, consumers, and the private sector, and the required public investment to ensure equitable and sustainable systems. Additionally, the compatibility of AV technology with various transport modes must be explored to identify viable niches that can be nurtured for transitions toward optimized regimes. The changing symbolic meaning of car ownership in an AV future also warrants examination, as shifting perceptions of the car as a cultural and material artefact could influence adoption patterns and user behaviour. Finally, public and political reactions to significant mobility changes require investigation to anticipate resistance and ensure that interventions are realistic, effective and socially acceptable.

Automatiserte kjøretøy - organisatoriske implikasjoner

Endring i forholdet mellom offentlig og privat

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Automatiserte kjøretøy (AVer) vil endre transportsystemet, særlig i byene. Flere vil få økt mobilitet og derigjennom økt tilgjengelighet. I denne studien tar vi utgangspunkt i endringsprosesser, organisasjonsstrukturer og brukerpraksis, og presenterer et konseptuelt rammeverk med fire scenarioer og åtte utviklingsstier som ikke er gjensidig ekskluderende for hvordan AVer kan introduseres. Kompleksiteten i dette underbygger påstanden om at vi ikke kan ta utfallet, hvordan teknologien tas i bruk, som gitt. Dagens mobilitet er styrt av etablerte lover, forretningsmodeller og arealbruk som må utvikles for å ta høyde for mulighetene AVer gir. Dette reiser en lang rekke politiske spørsmål. Hvem som tilbyr og organiserer tjenestene påvirker hvilke styringsinstrumenter som kan brukes. Uavhengig av organisasjon vil automatisert transport påvirke forholdet mellom personlige, private og offentlige transporttilbud.

Introduksjon

Automatisert transport (AVer) vil endre transportsystemene radikalt, det gjelder både for offentlig og privat transport. Forskning på AVer er dominert av et fokus på tekniske forhold. Samtidig som teknologien for AVer i stor grad faller på plass, øker behovet for å forstå implikasjonene teknologien har for framtidig organisering og drift av transportsystemet. Denne ser systematisk på noen av usikkerhetene og mulighetene som AVer medfører. Formålet er å hjelpe offentlige aktører i å identifisere kritiske beslutningspunkt. Politiske beslutninger som må tas, som vil endre forholdet mellom private og offentlige aktører i framtiden.

Framtiden til AVer er ikke gitt. Utfallene, hvordan nytten og ulempene av automatisert transport fordeles er et resultat av politiske og administrative valg. Det ligger et stort ansvar hos beslutningstakere og myndigheter for å sikre at teknologien kommer til nytte på en måte som bidrar til bedre tjenester og ikke til økt ulikhet, arealbeslag, energibruk, offentlige utgifter eller økte utslipp.

Vi bygger videre på eksisterende studier, som Oslo-studien, og presenterer en kvalitativ og konseptuell undersøkelse av hvordan roller, ansvar og organisatoriske forhold innenfor transportsystemet påvirkes av AV-teknologi. Vi tar utgangspunkt i egenskaper ved et framtidig transporttilbud, som forholdet knyttet til om tilbudet skal være dør-til-dør, eller stopp til stopp, etterspørselsstyrt eller følge ruter, og om beslutningen om samkjøring skal tas av de som reiser eller de som planlegger reisen. Målet med dette er å lage scenarioer som hjelper i å se utfallene av beslutninger om hvordan automatisert transport tilbys. Vi fokuserer på by- og bynære områder, men trekker i noen grad også fram konsekvenser i distriktsområder.

I tillegg undersøker rapporten de juridiske og regulatoriske rammene som blir utfordret av teknologien. For eksempel vil yrkestransportloven, som i dag definerer grensene mellom offentlige og private transporttjenester, måtte oppdateres.

Metodisk tilnærming

Denne rapporten er konseptuell og bygger på rammeverk fra innovasjonsstudier, økonomiske resonnementer og innsikt fra statsvitenskap. Hovedmålet er å undersøke de grunnleggende dimensjonene ved bruk av automatiserte kjøretøy og hvordan politiske beslutninger påvirker markedsutfall, inkludert tjenestenivå, samfunnsnytte og behovet for regulatoriske tiltak. Rapporten skisserer mulige tilnærminger for innføring av AVer og utforsker hvordan transport-tjenester kan reorganiseres, samt hvilke konsekvenser dette har mer generelt.

Grunnforståelsen for analysen bygger på flernivårammeverket (MLP). Vi har tilpasset dette rammeverket for å gjenspeile kompleksiteten i bymobilitet. Vi ser på mobilitet i et «flerregime-system», altså at det er flere sosiotekniske regimer som eksisterer parallelt. Innenfor dette rammeverket blir AVer sett på som en innovasjon som vil påvirke dagens sosiotekniske regimer, særlig knyttet til bilbruk og kollektivtransport. Studien undersøker hvordan disse endres under press fra større trender som digitalisering og klimaendringer.

Rapporten trekker veksler på introduksjonen av kombinert mobilitet, eller Mobility as a Service (MaaS). Dette gjelder særlig hvordan innfasingen av denne teknologien ble formet av ulike organisasjonsstrukturer. Denne tilnærmingen viser at AVer kan introduseres på flere ulike måter, de kan introduseres av private selskaper, offentlige administrasjonsselskap/mobilitetsselskap, eller gjennom offentlig-private samarbeid. I alle tilfeller vil den organisatoriske og regulatoriske konteksten være avgjørende for hvilken rolle AVer vil spille i kommende mobilitetssystemet.

Vi identifiserer tre kjernepraksiser – oppbevaring, vedlikehold og drift – som er sentrale for dagens transporttilbud, og utforsker hvordan disse påvirkes i en fremtid med AVer. Dette danner grunnlaget for fire scenarier for organisering av transportsystemet: videreføring av dagens system (business-as-usual), kommersielle AV-systemer, offentlige AV-systemer og private-kommersielle AV-systemer.

For å beskrive hvordan overgangen til disse scenariene kan finne sted, benytter vi tre dimensjoner av AV-bruk – **tidsdimensjonen** (fastsatt eller behovsbasert), den **geografiske dimensjonen** (stasjonsbasert eller dør-til-dør), og **delthet** (eksklusiv eller delt). Dette gir åtte mulige kombinasjoner. Vi bruker disse kombinasjonene og scenariene som konseptuelle verktøy, de er «hjørneløsninger». Som tilnærminger er de ikke gjensidig utelukkende, men representerer ytterpunkter som gir beslutningstakere en strukturert ramme for å vurdere de organisatoriske konsekvensene av å ta i bruk AVer. Et godt framtidig mobilitetstilbud vil måtte trekke inn momenter fra de ulike kombinasjonene og scenarioene, men utfallet med hensyn til fordeling, trafikk konsekvens og tilskuddsbehov, styres av i hvilken grad de ulike praksisene følges. Det vil finnes eksklusive og delte transporttilbud, men det betyr noe om hovedløsningen er eksklusiv eller delt.

De tre praksisene som danner grunnlaget for våre scenarier er:

- **Lagring:** Hvem har ansvaret for å oppbevare kjøretøyet når det ikke er i bruk. Selv om dette ansvaret ofte forbindes med eierskap, gjelder det også for andre segmenter som leasing, abonnement, bildeling og bilutleie. Automatiserte kjøretøy reduserer behovet for privat lagring. Likevel vil det fortsatt være behov for kommersiell eller offentlig hensetting av kjøretøy som ikke er i trafikk.

- **Vedlikehold:** I dag er vedlikeholdsansvaret i første rekke knyttet til eierskap og leasing, der operatører tar seg av vedlikehold i andre segmenter. Med AVer vil vedlikehold hovedsakelig bli en oppgave for tjenesteleverandører, noe som reduserer forbrukernes involvering.
- **Drift:** AVer vil føre til en grunnleggende endring ved å flytte ansvaret for drift fra forbrukere til tjenesteleverandører. I taxinæringen er dette i tråd med dagens praksis, mens det for privat bilbruk og leasing representerer en betydelig endring.

Vi kategoriserer transporttjenestene inn i tre segmenter:

- **Privat bilbruk:** Eierskap, leasing og abonnementsløsninger.
- **Tilgangsbasert bilbruk:** Bildeling og taxitjenester.
- **Kollektivtransport:** Offentlige transportmidler som busser, trikker og tog.

For hvert segment analyserer vi hvordan ansvar for lagring, vedlikehold og drift kan utvikle seg når driften blir automatisert. Den største endringen forventes innen privat bilbruk, der brukere vil gi fra seg driftsansvaret til tjenesteleverandører. For tilgangsbaserte og kollektive transportsegmenter vil endringene primært forsterke eksisterende praksis, med leverandører (enten private eller offentlige) som håndterer lagring, vedlikehold og drift.

Rapporten utvikler fire scenarier som belyser hvordan rollene og ansvaret kan fordeles basert på praksisene og transportsegmentene:

- **Business-as-Usual (BAU):** Privat eierskap forblir dominerende, men forbrukere gir fra seg driftsansvaret samtidig som dagens strukturer for lagring og vedlikehold opprettholdes.
- **Offentlig-privat tjenestemodell (PPS):** Personlige kjøretøy fases gradvis ut til fordel for et system dominert av kommersielle transporttjenester. Tjenesteleverandører overtar nesten alt ansvar for lagring, vedlikehold og drift, mens kollektivtransporten fortsetter i sin nåværende form.
- **Offentlig dominert scenario:** Alle transporttjenester, inkludert ulike former for automatisert transport, integreres i et samlet kollektivtransportsystem under offentlig kontroll. Dette innebærer en omfattende overgang fra privat tjenesteproduksjon (privatbil) til et mobilitetssystem der det offentlige spiller en veldig sterk rolle.
- **Privat-kommersielt scenario:** Både personlige kjøretøy og kollektivtransport erstattes av private kommersielle operatører. Dette scenariet fokuserer på produksjonseffektivitet, men kan skape skjevheter i tjenestetilbudet, spesielt i mindre lønnsomme områder. Og dermed et behov for å offentlig inngripen for å dekke markedssegmenter som ikke er privatøkonomisk lønnsomme.

Disse scenariene gir et rammeverk for beslutningstakere til å vurdere hvordan AVer kan påvirke fordeling av ansvar og roller i framtidens transportsystem.

Stier

Ved å kombinere tre sentrale dimensjoner for bruk av automatiserte kjøretøy – den **geografiske dimensjonen**, **tidsdimensjonen** og **delthet** – har vi identifisert åtte mulige kombinasjoner som kan fungere som «stier» for introduksjon av AVer. Hver sti representerer en unik kombinasjon av disse dimensjonene og fungerer som et konseptuelt verktøy for å forstå systemendringer.

De tre dimensjoner for AV-bruk:

- **Geografi** går fra faste stasjoner eller stop som i tradisjonell kollektivtransport, til Dør-til-dør (D2D). hvor kjøretøyet henter og leverer passasjerer ved ønsket adresse, som for drosje eller for privatbiler. Mellom disse ligger ulike former for Pick-Up/Drop-Off (PUDO) punkt, hvor passasjerer benytter faste hentings- og avleveringspunkter, men hvor disse ikke nødvendigvis innebærer noen fysisk infrastruktur.
- **Tidsdimensjonen** som går fra faste rutetider, tjenester som følger en på forhånd fast-lagt tidsplan, på samme måte som dagens kollektivtransport. Til etterspørselsstyrt, som innebærer fleksible tjenester som tilpasses brukernes behov i sanntid, som drosjetjenester.
- **Delthet** som går fra eksklusiv bruk hvor de reisende bestemmer hvem de deler kjøre-tøyet med (eller velger å ikke dele i det hele tatt). Til tvungen deling hvor de reisende deler kjøretøyet for å øke kapasiteten. En mellomsituasjon her er selektiv deling som vil si at deling kun gjøres innenfor spesifikke grupper, som medlemmer av en organisasjon eller et nabolag.

Samlet gir disse tre dimensjonene åtte mulige kombinasjoner. De åtte veiene framkommer gjennom ulike kombinasjoner av geografi, tidspunkt og brukertype:

Sti	Tid	Geografi	Delthet
P1	Dynamisk	Dør-til-dør	Eksklusivt
P2	Dynamisk	Dør-til-dør	Delt
P3	Dynamisk	Stasjon-til-stasjon	Eksklusivt
P4	Dynamisk	Stasjon-til-stasjon	Delt
P5	Fast	Dør-til-dør	Eksklusivt
P6	Fast	Dør-til-dør	Delt
P7	Fast	Stasjon-til-stasjon	Eksklusivt
P8	Fast	Stasjon-til-stasjon	Delt

Hver sti fremhever ulike kompromisser mellom **brukervennlighet**, **systemeffektivitet** og **miljø-påvirkning**. De gir innsikt i hvordan transportsystemet kan utvikle seg i tråd med regulatoriske valg, markedsdynamikk og samfunnets preferanser.

Disse stiene understreker også viktigheten av å integrere AVer i en større sammenheng med byplanlegging og bærekraftsmål. Beslutningstakere kan bruke disse veiene som en strukturert tilnærming for å evaluere hvilke kombinasjoner som best støtter samfunnets mål for mobilitet og miljø.

Diskusjon

Automatiserte kjøretøy har potensial til å redusere parkeringsbehovet dramatisk ved å øke utnyttelsesgraden av kjøretøyene, samtidig som en frikobler parkering fra bruk. Delte automa-tiserte kjøretøy kan potensielt redusere trafikken betydelig, samtidig vil stier med eksklusiv bruk kan øke trafikkbelastningen på grunn av tomgang og inaktivitet. Dette gir et behov for å endre politiske virkemidler. Eksempelvis vil regulering i form av parkeringsnormer vil i liten grad være relevant. Håndhevingsmekanismer, som tidsbegrensninger på parkering og bøter, må tilpasses andre mål, som å hindre at kjøretøy forflytter seg unødvendig. Videre kan strate-gisk konsolidering av parkering i knutepunkter, utnyttelse av underjordiske fasiliteter og inte-grering av parkering med kollektivknutepunkter optimalisere arealbruk og sikre tilgjengelighet, samtidig som trafikkbelastning reduseres.

Dagens kollektivtransportselskap har et motsetningsfullt mandat: På den ene siden skal de tilby reelle alternativer til privat bilbruk i byområder, samtidig som de opprettholder et minimumsnivå for mobilitet i distriktene, for ikke-bileiere og sårbare grupper.

Framveksten av autonome kjøretøy gir muligheter til å endre hva kollektivtransportselskapene skal tilby. Potensielt betyr det at de kan tilby mer effektive og inkluderende løsninger samtidig som man adresserer utfordringen med å balansere rettferdighet og effektivitet på tvers av geografi. Samtidig er det fult mulig å se for seg utfall hvor kostnadene løper og tilbudet forvitrer.

Autonome kjøretøy vil endre økonomien for alle transportsegmenter, både offentlige og private. Fra et økonomisk perspektiv forventes det at den generaliserte kostnaden – et økonomisk begrep som inkluderer både direkte kostnader, reisetid og annen ulempe – vil reduseres, uansett hvilken sti som velges. Hvor mye, vil imidlertid variere fra reise til reise, mellom ulike organisasjonsmodeller, og avhenge av faktorer som foreløpig er ukjente. Likevel kan noen utfall anses som mer sannsynlige enn andre.

For det første vil innvirkningen på kollektivsystemet trolig komme gjennom to mekanismer: 1) mindre avhengighet av sjåfører, som i dag er en stor mangelvare og betydelig kostnad; en omstrukturering av kostnader knyttet til drift av kjøretøyene vil sannsynligvis redusere de totale kostnadene, og 2) nye tjenester kan legges til kollektivsystemet. Dette vil trolig øke kostnadene og reiser en rekke spørsmål knyttet til fordeling, tilgjengelighet og ønskede servicenivåer.

For det andre vil dagens sosiotekniske regime sannsynligvis bli utfordret. Den nåværende ansvarsfordelingen mellom ulike myndighetsnivåer og offentlige og private aktører må revideres, men hvordan dette skal gjøres er ikke åpenbart.

For det tredje, dersom kollektivsystemet skal utvides, oppstår det spørsmål om rollen til offentlig versus privat mobilitet. Utfallet er uklart, men det er tydelig at et kommersielt system med åpen tilgang vil være svært forskjellig fra en organisasjon bygget rundt et utvidet kollektivsystem, med anbud eller løyver som politiske virkemidler. Lærdommer kan hentes fra nylige introduksjoner av Mobilitet-som-en-tjeneste (MaaS) og elsparkesykler. I dette ligger det også utfordringer knyttet til å potensielt endre det offentliges rolle, fra å være regulerende myndighet til å bli tjenesteutfører i segmenter som drosje og privatbil som i dag i all hovedsak drives privat og kommersielt. Dette er potensielt svært inngripende.

For det fjerde er det sannsynlig at kjøretøysegmentene som vil bli konsolidert inn i et automatisert system, eller forsvinne i møte med konkurranse fra AVer, er dagens bestillingstjenester for bilstørrede kjøretøy; drosjer, samkjøring og bildeling. Disse rollene kan alle bli dekket av etterspørselsstyrt tilgang på automatiserte kjøretøy.

Nøkkelområder for fremtidige studier inkluderer forståelse av kundereaksjoner, som tillit, betalingsvillighet og preferanser for tjenester, med utvikling av måleparametere for å vurdere disse langs dimensjoner som avstand, timing og belegg. De økonomiske implikasjonene av implementering av automatiserte kjøretøy krever også oppmerksomhet, inkludert kostnadene for myndigheter, forbrukere og privat sektor, samt nødvendige offentlige investeringer for å sikre rettferdige og bærekraftige systemer. I tillegg må kompatibiliteten mellom autonome kjøretøy og ulike transportformer utforskes for å identifisere levedyktige nisjer som kan dyrkes frem for overganger mot optimaliserte regimer. Til slutt må man studere hvilke motkrefter som kan gjøre seg gjeldende. Introduksjonen av AVer vil gi mobilitetsendringer, disse kan studeres nærmere for å forutse motstand og sikre at tiltakene er både effektive og sosialt akseptable.

1 Introduction

The introduction of autonomous vehicles (AVs) will impact all forms of passenger road transport, both private and professional. Discussions about AVs have persisted for years, but their increased deployment on roads today signals a critical juncture in the technology's introduction and adoption. Initially, the focus centred on whether such technology was technically feasible, reliable and safe. Today, however, we are moving closer to the mainstream application of AVs, marked by a steady progression of pilots that have grown increasingly ambitious in scope. These advancements raise critical questions about the complex and dynamic factors that come into play as AVs are integrated into the transport system. As we shift our attention toward the broader implications of AVs for the transport system as a whole, we recognize both the challenges and opportunities that the technology presents.

Transport is one of those backbone sectors in which “established technologies are highly intertwined with user practices and life styles, complementary technologies, business models, value chains, organizational structures, regulations, institutional structures, and even political structures” Rip and Kemp (1998) as cited by Markard et al. (2012). This makes the future of transport very uncertain when it comes to systemic changes. As such, the main purpose of this report is to help public sector actors think about the AV future. Specifically, we have developed a conceptual framework that will enable policymakers and public authorities to consider possible pathways to vehicle automation in road passenger transport in urban and peri-urban areas. It focuses on the organization of roles and responsibilities of actors within the system. We do not set out to provide predictive models of user behaviour or market response, but welcome those working with such tasks to use the scenarios and pathways articulated in this report.

One of the most profound impacts of AVs lies in their potential to disrupt the organization and operation of transport services. AVs could blur the lines between traditionally distinct transport modes, such as private car use, public transport, and taxis, creating entirely new dynamics in how mobility services are delivered and consumed.

The uncertainty surrounding AV integration raises a series of pressing questions. For instance, how will AVs redefine the boundaries between public and private transport? To what extent could AVs alter the relationship between public transport services and taxis? Will their introduction create new financial pressures on public transport systems, potentially changing subsidy requirements? Furthermore, what organizational models might emerge for operating AV fleets, and how could these influence the competitive dynamics between transport providers?

In this report, we aim to systematically explore these questions from a qualitative perspective by focusing on the organizational and operational dimensions of AV integration. Our primary objective is to provide a conceptual framework that policymakers can use to navigate the uncertainties of the AV future. By analysing how AVs could be organized within the transport system and identifying potential pathways to their adoption, we aim to shed light on the critical decision points that public sector actors will need to address.

To guide this exploration, we have structured the analysis into two key phases. The first involves identifying the core practices associated with motor vehicle use today, such as how vehicles are accessed, shared, and regulated. The second involves developing scenarios that reflect different ways AVs could be operated and integrated into the transport system. Together, these phases provide a foundation for understanding the transformative potential of AVs and the key decision points that will shape their impact.

1.1 The Oslo Study

The Oslo Study published by COWI and PTV on behalf of Ruter in 2019 serves as a valuable point of departure for this report. It is a quantitative modelling study that examines how users might respond to different types of AVs integrated into a Mobility as a Service (MaaS)[1] system. By simulating future scenarios in the Oslo region, the study provides insights into the potential impacts of AV adoption on traffic patterns, fleet size, and user behaviour. Specifically, it explores how shifts from private car use to shared AV systems, with or without ridesharing, could shape urban mobility.

The study's results highlight the transformative potential of shared AV systems. In the best-case scenario, traffic volumes, measured in vehicle kilometres, could be reduced by up to 31 percent, while the number of cars required to meet mobility needs could decrease by as much as 93 percent. These findings suggest that AVs, when integrated into a well-designed shared mobility system, could significantly alleviate congestion and free up urban space. However, the study also underscores the risks of less coordinated systems: without ridesharing, traffic volumes could double, leading to severe road network strain. These contrasting outcomes emphasize the importance of careful planning and policy to ensure that AVs are implemented in a way that benefits cities and their residents.

The Oslo study models four main scenarios, each with distinct assumptions about user behaviour and system design. For example, some scenarios assume that car users switch to shared AVs without ridesharing, while others incorporate ridesharing as a central feature. Public transport users are also considered, with scenarios exploring shifts to shared AVs from modes like buses and trams. These scenarios provide a spectrum of possibilities, from incremental changes to more transformative shifts in how mobility is organized and accessed.

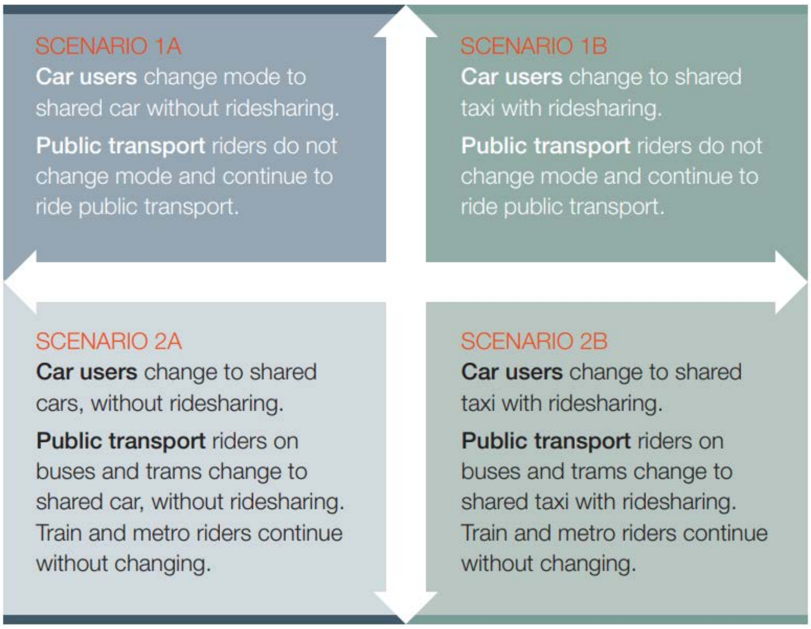

Figure 1.1: Scenarios used in the Oslo study COWI, (COWI | PTV Group, 2019).

Recognizing these valuable insights, our report aims to expand the scope by taking a qualitative approach that considers not just car users and public transport users but a full range of users of motor vehicles, including car sharing, ridesourcing, taxis and carpooling. Furthermore, rather than

[1] Mobility-as-a-Service usually abbreviated MaaS, is a concept used to describe intermodal travel through a single user interface.

using a predictive model of user behaviour, we examine the organizational structures and system dynamics that could enable or hinder AV integration. Our goal is to help public sector actors think strategically about the pathways to vehicle automation, with an emphasis on the roles and responsibilities of key actors within the transport system. This is a focus that is likely to be highly influential for the adoption of AVs, still there is very little systematic research on the topic (Greifenstein, 2024).

To this end, we introduce four scenarios for AV integration and articulate eight potential pathways to them. These pathways are defined by three key dimensions of AV use: the distance users must travel to access the service, the timing of service delivery (on-demand versus fixed schedules), and the type of occupancy (shared versus exclusive). By framing the discussion in terms of these dimensions, we provide a conceptual framework that enables policymakers to explore diverse futures for AV adoption and assess the implications for urban and peri-urban transport systems.

1.2 Legality and roles

Framing the introduction of AVs are a series of laws and regulations. Many of which will need to be amended to better address the critical pointes of AVs. As an example vehicle operation is described by the Road Traffic Act (*Vegtrafikkloven*) (Samferdselsdepartementet, 1965/2021). In this report we focus on service provision and organisational issues; these are described in The Norwegian Vocational Transport Act (*Yrkestransportlova*) (Ministry of Transport and Communication, 2003/2024), specifically **Section 2** on route transport, which establishes a clear regulatory distinction between public transport and other commercial transport forms like taxis. Public transport services, as defined by the Act, are required to operate on fixed routes with pre-set stops and schedules, creating a stable and predictable service model. Taxis, by contrast, are free from such constraints and operate flexibly on a demand-driven, door-to-door basis. This distinction underpins the traditional boundary between public and private transport services in Norway.

However, the introduction of AVs in public transport fleets challenges these boundaries. AV technology is inherently adaptable, capable of adjusting routes and service frequency in real-time in response to user demand. If AVs are integrated into public transport while retaining some operational flexibility, it could blur the distinction with taxi services, introducing regulatory ambiguities. For instance, a public AV service might operate as a "dynamic fixed route" that adapts routes and stops based on real-time demand, resembling the characteristics of a taxi or shuttle service more than traditional public transport. Both the Ruter pilot in Groruddalen and "Hent" service flow into this category.

This potential overlap raises questions about how AV services could legally fit into the current framework. As per the national legal frameworks, the role of the county governments is in purchasing public transport services, not regulating. As AVs become capable of offering hybrid service models that mix fixed routes with on-demand responsiveness, the Act may need to evolve to clarify whether public AV services can legally offer flexibility while maintaining their status as public transport. Without an update, the law could face challenges in accommodating AVs that, while technically part of the public transport fleet, may offer characteristics similar to commercial or taxi services. This distinction is critical in preserving operational and competitive boundaries, ensuring that the integration of AV technology aligns with the Norwegian regulatory framework while serving the public interest in mobility.

Furthermore, county governments in Norway play a central role in regulating the taxi sector, allowing them the flexibility to address local transport needs and respond to the unique demands of their regions. The Norwegian Vocational Transport Act grants (**Section 9a**) counties authority to issue taxi permits, establish operational standards, and even allocate exclusive service rights within municipal boundaries. This decentralization means counties can adjust taxi regulations independently of national authorities, enabling region-specific solutions.

As AVs become a potential part of the transport mix, this county-level authority could further influence the evolving boundaries between public transport and taxi services. For example, if AVs were introduced within county-regulated taxi fleets, counties could decide to apply more flexible standards, such as permitting AV taxis to operate in areas with limited public transport or setting unique emissions requirements that align with local environmental goals. They might even allow AV taxis to operate on quasi-public routes, bridging gaps in the public transport network while still technically functioning as taxis.

This flexibility provides counties with a powerful tool to experiment with AV integration in ways that could blur the line between fixed-route public transport and on-demand taxi services. Alternatively, counties can work to ensure that flexible autonomous public transport services are the primary offer in such areas. Such configurations may offer counties the ability to address underserved areas or dynamically meet changing demand without requiring national-level policy shifts, leveraging AVs to support both public transport goals and flexible mobility options within a localized regulatory framework.

1.3 Structure of the Report

Following this introduction, section 2 presents our research approach, combining a brief overview of the theoretical framework we use, key elements previous research that we draw upon and the basis for our scenarios. Section 3 presents the key practices of motor vehicle use that form the basis of developing our four scenarios. Section 4 presents the eight non-exclusive pathways for AV introduce-tion that can lead to the different scenarios. In section 5 we discuss the implications of AV introduce-tion with respect to economic dynamics, the relationship between public and private sectors, parking and urban space, vehicle segments, and levels of service. We conclude the report in section 6 with a summary of the discussion sub-sections and suggestions for future research.

2 Research approach

Our approach in this report is conceptual, mainly drawing on innovation studies and economic reasoning and some insights from political science. The emphasis is on investigating underlying processes surrounding AVs as an innovation, and by extension, how political decisions influence the market outcomes understood as a combination of levels of service, utility at individual and societal level, the need for market interventions and so on.

In recent years, there has been a shift in focus of research on AVs from technical feasibility to societal effects in terms of sustainability and functional mobility systems (Ceder, 2021; Golbabaei et al., 2021; Kovačić et al., 2022). Some studies have demonstrated that the potential societal gains from automation are large. These can materialize both in terms of a potential reduction of the amount of space and resources associated with mobility use (International Transport Forum, 2015; Martinez & Crist, 2015), and in terms of increased mobility for the public. A number of studies have emerged highlighting both the potential of automation and the importance of the underlying assumptions (COWI | PTV Group, 2019; International Transport Forum, 2015).

Further, the real world application of the technology has demonstrated that level-5 automation is no longer a hypothetical scenario. As the technology matures and introduction pilots continue, the questions shift from whether AVs will impact the mobility system to how and when.

2.1 Theory

Today's mobility system in Oslo and Akershus can be divided into a wide range of segments based on user practice. As the dominant mode of transport in Akershus is the use of private cars (Opedal et al., 2023), and the dominant policy objective relates to private car use (Zero growth objective; *nullvekst-målet*), our focus is private car-sized vehicles. This means that we spend less time discussing the impact of autonomous technology for conventional busses and trains. We recognize that these also will be affected, but for reasons shown in this study, the automation will impact car-sized vehicles, first and foremost.

As a background for this study we draw on secondary material such as studies and documents describing existing trials with automated mobility as well as conceptual studies and modelling exercises. As the scale and scope of automated mobility is limited, this means that there may well be large blind spots in the available literature. Though this limits the amount of empirical literature we can draw on, it also functions as a research gap for conceptual and future empirical studies.

We have identified three key practises associated with motor vehicle use that allows us to develop our scenarios. These are vehicle storage, maintenance, and operation. We relate these practices to existing vehicle segments including car ownership, leasing, subscription, car-pooling, car sharing, ridesourcing, taxi, and to some extent public transport. Each of the segments are characterized by a range of configurations in terms of which actors in the value chain are responsible. AVs will reconfigure these the responsibilities and activities, resulting in our scenarios, which are treated as logical extremes.

Our main framework for understanding socio-technical transitions is the multi-level perspective (MLP). We use a modified version of the standard framework (Geels, 2002) in order to emphasize that urban and sub-urban mobility represent a multi-regime system. We have further simplified this into a two regime system, with automobility (Geels et al., 2012) and multi-modality as the two regimes.

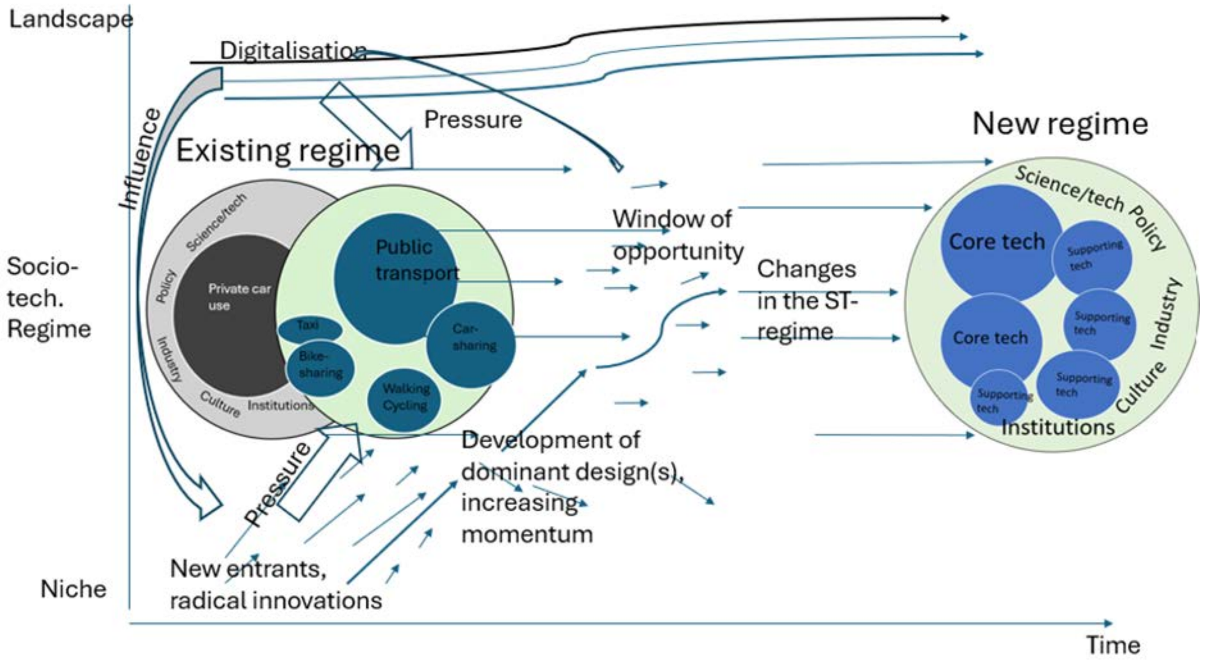

Figure 2.1: "General mobility in transition" MLP-framework.

Based on the standard MLP structure, the mobility system is subject to *landscape level* forces representing exogenous macro-level factors that are outside the control of the studied actors. Of particular interest is the trend of digitalization as a general purpose technology; vehicle automation can exploit windows of opportunity presented by digitalization and can even considered a part of the broader digitalization process in transport technology. Further, as with most transition analyses of transport, we must consider climate change as an important landscape level trend that guides our efforts to mitigate its impact.

At the centre of the figure are the *socio-technical regimes*. The figure illustrates the current urban mobility system with two competing regimes – automobility and multimodality – with their associated institutions, industry, policy, science and technology and culture. Both regimes represent deeply rooted ways of carrying out a societal function whereby regime actors adopt alternative scenarios concerning the AV future. Whereas the automobility regime treats the private car as the basis for mobility, there are various versions of "multi-modal" mobility centred around micromobility, walking, cycling and public transport, each with a range of practice-based segments (George, 2017; Aarhaug, 2023).

At the bottom of the figure is *the niche level* that represents new technologies, practices, organizational forms, and market entrants. These niches represent novel solutions to the overall challenges faced in urban mobility. With respect to the introduction of AV technologies, we are particularly interested in the interplay between public-sector actors and private companies that are not traditionally rooted in the transport sector, presenting alternative options for future mobility.

As one moves along the time axis from the current situation to the future, there emerges both systemic challenges and windows of opportunity created by the technological advancements and increasing pressure from environmental and economic factors. Although we do not know what the eventual regimes will look like, this study assumes that there is a key element of agency in shaping that future.

Historical analyses of transitions reveal that strong and stable socio-technical regimes tend to resist change, adapting incrementally rather than undergoing radical shifts. New technologies typically gain traction during windows of opportunity, which arise either from technological advancements outside the existing regimes (landscape-level trends) or from a weakening of the established regime. Strong and stable regimes often evolve through incremental adaptations, integrating new technologies while gradually reshaping their existing structures.

To better understand how AVs can play out in the urban mobility context we have created a series of scenarios and pathways based on how these practices can be reconfigured. These pathways are specific to this study and do not correspond to the traditional socio-technical transition pathways (Geels & Schot, 2007). Rather, they focus on the structural and organizational parameters of AV integration, specifically in terms of space, time, and exclusivity.

2.1.1 Understanding AVs as a socio-technical transition

There is no single formula for how an innovation is adopted. If and how it is put into use is influenced by many factors. In particular, innovations must contend with the existing scientific, technological, political, industrial, cultural and institutional structures that constitute the extant socio-technological regime. The historical study of technological transitions has highlighted that they tend to follow a set of pathways (Geels & Schot, 2007), typically assessed by researchers on a scale from strong and stable to weak and unstable. Regimes are typically assessed by researchers on a scale from strong and stable to weak and unstable. Regimes that are strong and stable are able to incorporate niche innovations while maintaining the overall logic of the system, a process known as transformation. With weak and unstable regimes, more radical systemic change is likely as niche innovations bring about new regimes..

AV services can be provided by existing regimes as well as alternative ones that have yet to manifest. Such complexity and multiplicity are frequently described as a multi-regime system (Geels, 2018; Marletto, 2014; Moradi & Vagnoni, 2018). For mobility, the two regimes of automobility and multimodality can be both competing and complementary to one another.

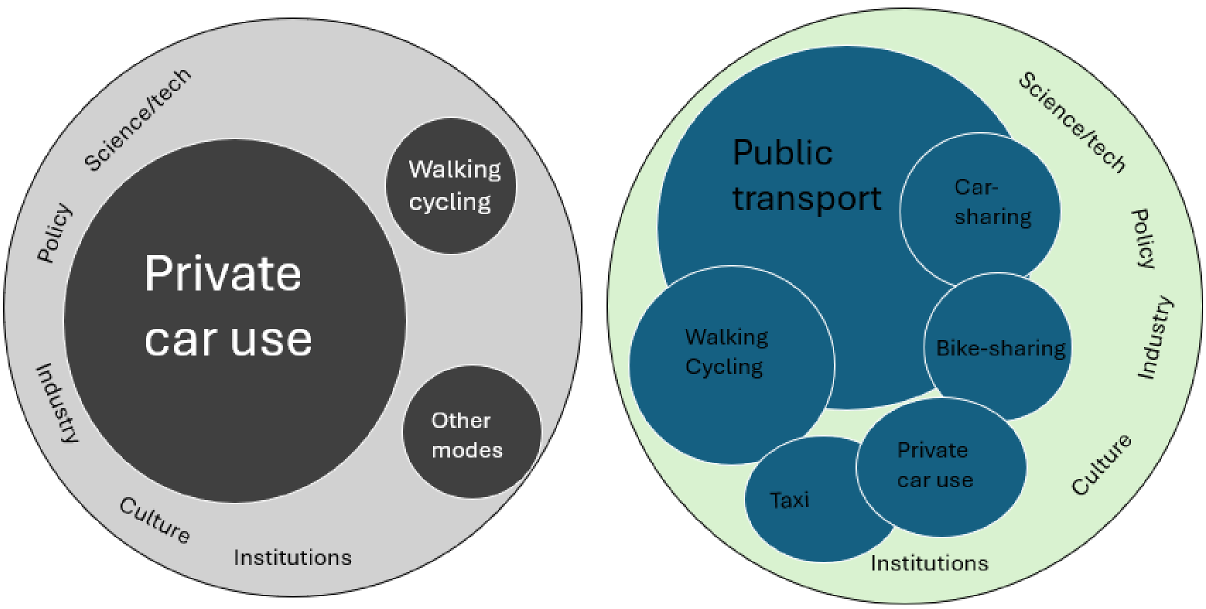

Figure 2.2: Urban mobility as a two regime system (adapted from Aarhaug (2023).

Figure 2.3 illustrates a two regime system, where automobility is a regime, centred around private car use, with its own set of *science and technology*, linked to traffic safety, road development etc.; *policy*, linked to Road Traffic Act (*Vegtrafikkloven*) (Samferdselsdepartementet, 1965/2021); *industry*, linked to the manufacturing of vehicles and provision of supporting services, such as garages; *culture*, the idea of the private car as an icon; and *institutions*, such as the Norwegian Public Roads Administration (*Statens vegvesen*). Largely independent of these institutions, there is a separate multimodal regime built around public transport at its core and its own configuration of science, technology, policy, industry, culture and institutions.

In some ways, these regimes can be understood as competing. Both provide mobility in urban and sub-urban contexts. Still, the regimes at least partially interdependent, with distinct visions for the future, including the role for AVs. The most relevant visions here are:

- Private car-based system => private ownership of AVs.

As a continuation of today's automobility regime, one can imagine a future where AV ownership follows the same structures. The actors and institutions largely remain the same, but the extant technology is gradually phased out in favour of more automated vehicles. In a transition perspective, this is a change along either the transformation or reconfiguration pathways (Geels & Schot, 2007). Studies, such as the Oslo study by COWI | PTV Group (2019), highlight some of the problematic aspects of continuing an automobility based transport system. In particular are challenges related to generated traffic and low vehicle occupancy as a larger segment of the population will be able to use individual car-sized vehicles, and as the expected disutility of driving decreases.

- The PT centric => public operations of AVs.

In parallel to this extension of the automobility regime, is the future vision of the PT-dominated multi-modal regime. Introducing AVs in the heavier segments, such as trains, metros, trams and mainline busses would be less controversial than in private segments. It is a "simpler" change to the system, as compared with private cars, in that the roles and responsibilities associated with vehicle use would largely remain with the PTA or its partners. This should, with standard assumptions on costs (and cost structures), result in a system where the marginal cost of operation decreases together with labour costs. In other words, this would result in more service for a similar costs, which should result in slightly higher market shares for PT, all else being equal.

However, taking this model to the extreme, all AV operation could be conducted within the scope of a new all-encompassing PTA dominated multi-modal regime, with a gradual phasing out of automobility.

- An alternative regime that establishes AVs as something new, in addition to the extant regimes, with connections both to the digital (e.g., Google) and extant vehicle industries.

There is the possibility that AVs will be introduced with a third regime in parallel with the two described above. This can happen either through disruption, or other mechanisms that introduce new institutions, cultures and practices without dramatically impacting the pre-existing regime structures.

Between these extremes are various possible combinations. In order to consider transition pathways, we start of by identifying key practices within the current regimes that are influenced by automated vehicles; operations, maintenance and parking. Further, we have identified three aspects of the AV technology that are likely to be of key importance in the transition process; spatial access, timing, and exclusivity. These are used to create our pathways. Together these point towards a series of possible outcomes that we have mapped into four different scenarios; business as usual, public-private mix, public and private. Neither the pathways nor the scenarios are mutually exclusive. In a modelling language they can be seen as corner solutions.

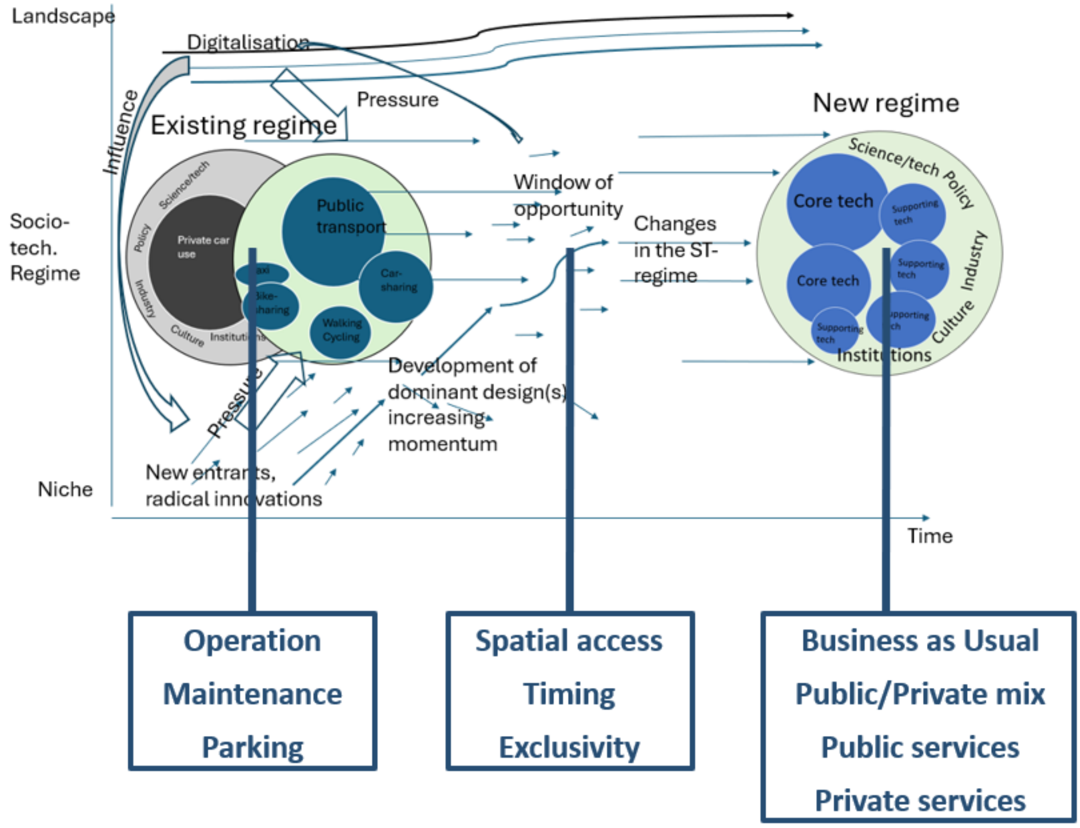

Figure 2.3: Transition in a mobility system.

Figure 2.3 presents how our practices, pathways and scenarios are located in relation to an adapted MLP-transition scheme. The motor vehicle practices help articulate the rules and practices that currently guide regime actors. Simply put, they are the key practices that capture the logic of the mobility system's organization. The dimensions of AV use are the basis for eight pathways that will see the development of dominant designs and exploitation of windows of opportunity, often in conjunction with landscape pressure. The scenarios are possible outcomes that are the result of one or multiple (either in succession or simultaneous) pathways, i.e., potential regimes.

2.2 Public-private dynamics in a MaaS context

AVs are not the only innovation that is challenging the extant urban mobility regimes in recent years. Other examples include Mobility-as-a-service (MaaS) and shared micromobility. Both of these innovations have in common that they were originally introduced outside of the established socio-technical regimes. However, the path to upscaling for both has resulted in a complex set of interactions with the established regime actors (Aarhaug & Tveit, 2023) and outcomes that vary across different contexts.

Vehicle automation can also be seen as emerging in parallel with or as part of the landscape trend of digitalisation. This affects mobility and service formation along several dimensions. In particular, the integration of various modes of transport into cohesive MaaS platforms would offer users access to multiple transport options under one digital roof. However, even if we reach a stage where such integrated MaaS platforms are fully realized, it will be further complicated and transformed by the introduction of AVs, especially in how we define and differentiate transport segments.

In this report we focus on the organizational structure surrounding AVs. This has many parallels to the introduction of MaaS in that both actors from within the extant regimes and outside of these have clear and differing ideas on how this market should best be organized, and further, that the market outcomes are highly likely to depend, at least in part, on how the services are organized.

Smith, Sochor and Sarasini (2018) and Ydersbond et al. (2020) have discussed the application of MaaS in different regulatory contexts. A key takeaway from these discussions is that although MaaS in Finland was seen as a start of a new paradigm, similar technical solutions in Sweden and Norway were seen as incremental improvements to a public transport system. Before the pandemic, both approaches seemed plausible future developments. After the pandemic only the public-sector driven, incremental expansion of public transport is still in operation.

Relating to AVs, a takeaway is that a priori market organization matters, both in terms of actors involved and the role and relative strength of those actors. However, it also shows that business models have different risks and transformative potential.

Focusing on the potential future organisational structures MaaS could be developed through, Smith, Sochor and Karlsson (2018) did a scenario analysis. Their starting point was that MaaS is a bundling of services characterized by the presence of operators and integrators in between the users and providers. In this model, users access services through a middle layer of operators and integrators who connect them with public transport agencies and commercial transport companies.

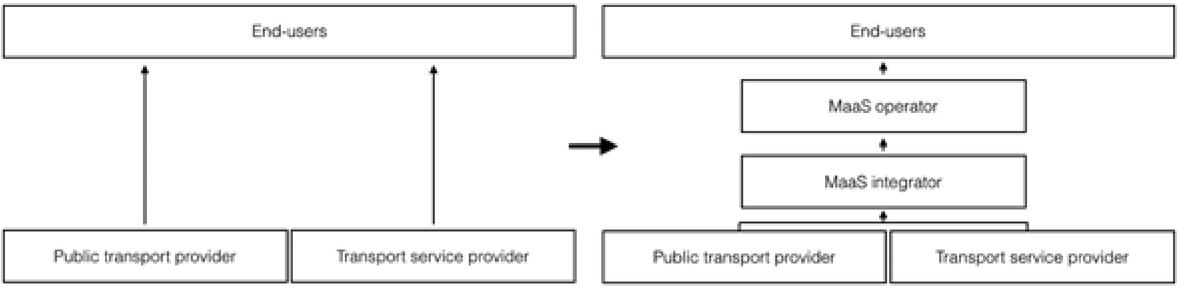

Figure 2.4: Framework for discussing MaaS-introduction (Smith, Sochor, & Karlsson, 2018).

The scenarios created represent the different logical combinations of public and private responsibilities. This includes a market driven approach where MaaS is provided by private actors, either from established mobility technology companies or startups. It also includes a public-controlled development where the PTA takes responsibility for the development of MaaS, as has been the case in Norway. Finally, there is a middle option, where MaaS is developed through a public-private partnership where the MaaS operator and integrator roles differ, with the integrator being public and operator being private. In other words, there is a separate market driven organisation facing the consumers, while the PTA is responsible for the relationship towards the transport service providers, both private and public. sThis discussion of alternative ways of organizing MaaS has implications for the introduction of AVs, as it is not clear who should be responsible for which level of the service. On the one hand, AVs may very well be introduced by private vehicle producers to a market of private consumers, in the same way as private cars are today. At the other extreme, a PTA may create a very detailed specification of the vehicles to the extent that only inhouse operations make practical sense. In between, there is a substantial space where the authorities can license the operation at fleet level, pointing in the direction of commercial fleets operating to a specific set of criteria. A further possibility is for the PTA to operate the user intersection, with the day-to-day operation being conducted by private companies on contracts tendered by the PTA, as is the case with most bus operations today.

2.3 AVs in relation to the existing mobility system

Automation is part of a long development in mobility, where digital technologies are introduced in extant mobility solutions in order to assist the driver and improve service. These developments range from crude cruise-control systems on cars to fully automated vehicles. Automation by itself is not linked to a specific size of vehicle or form of organization. Still, automation will affect modes differently and both have an impact on, and be impacted by, how the technologies and services are organized.

There are many transport modes and users of transport that AVs would contend and interact with along any introduction pathway. Drawing the modes along two dimensions, shared vs exclusive and spontaneous vs planned/scheduled, we can identify two main clusters.

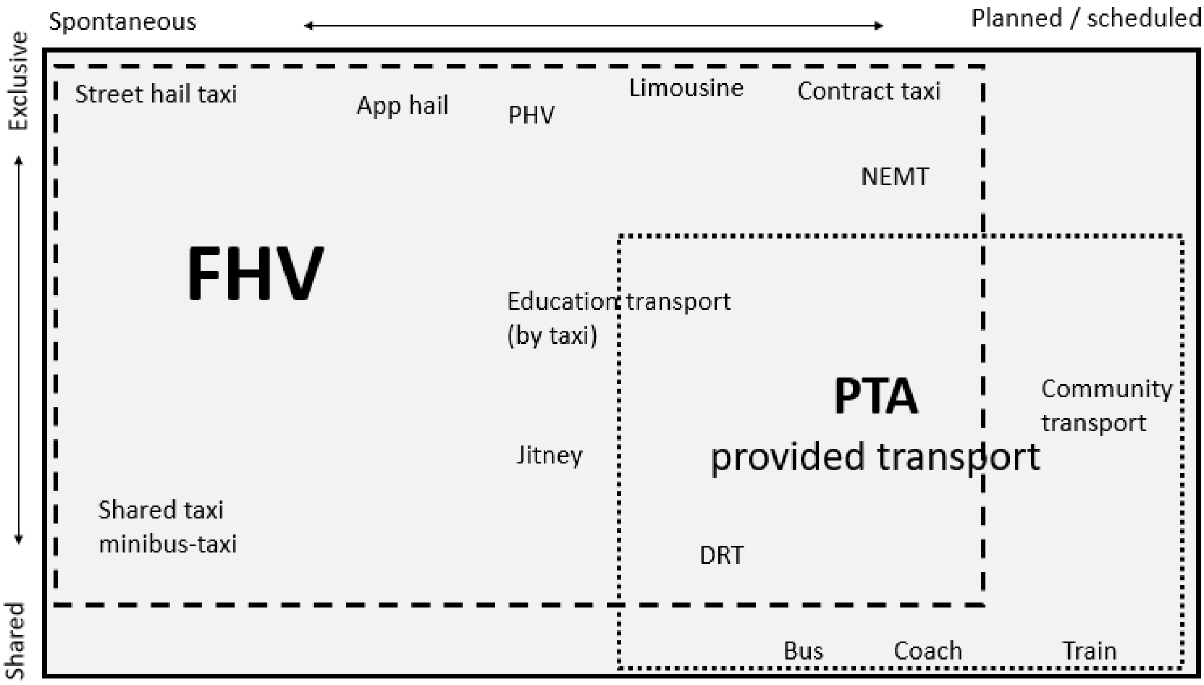

Figure 2.5: Vehicle categories available to the public organized by shared and spontaneous character, adapted from (Cooper et al., 2023).

Figure 2.5 illustrates that there are two main clusters of transport services provided to the public. First, the PTA dominated cluster, where vehicles are more shared and more planned, and more likely to be subsidized. Second, the for hire vehicles (FHVs), that include various forms of taxis and private hire vehicles, limousine services, etc. In between these services there are many overlaps, consisting of vehicles and operational patterns that can be provided to the public by both the public and private actors. This middle space is where many of the experiments with AVs have been taking place. The upscaled experiments, such as the Cruise, Waymo and Zoox trials in San Fransisco, are however all placed in upper left corner of this figure, focusing on on-demand and exclusive services. Ruter's ongoing trial in Groruddalen is placed closer to the centre of the figure, with a stated objective of being more shared and less geographically granular than the services taxis presently provide.

2.4 Scenarios

We present four scenarios for the organization of the passenger transport system.

The *first*, which we call the **business-as-usual** scenario, is similar to today's mobility system in that it is a combination of personally owned cars, commercial transport services and public transport services. A key point here is that there are no new restrictions introduced to ownership. The distinction between cars, taxis and public transport remains as described in Road Traffic Act (*Vegtrafikkloven*) and the Vocational Transport Act (*Yrkestransportlova*).

In the *second*, which we call the **public-private mix** scenario, personally owned vehicles are phased out and replaced with fleets of AVs operated and managed by commercial transport service providers alongside conventional public transport services, which may or may not consist of AVs. This is in line with the situation in San Francisco where Waymo has introduced commercial AV services, but has yet to pose a significant threat to public transport services.

In the *third*, which we call the **public** scenario, personally owned vehicles are phased out and are replaced with fleets of AVs managed by PTAs (presumably through tendered contracts with commercial operator companies) serving as an expansion of the public transport domain. This would imply that many commercial segments like taxis, car sharing and ridesourcing would be absorbed into the public transport portfolio.

Fourth, in **private commercial** scenario**,** private consumer ownership is phased out such that AVs are owned and managed by private commercial entities, both large and small. In this scenario, public transit is either phased out completely or is limited only to the largest forms of mass transit like metro and tram. All other trips would be conducted through a market for AVs that would offer on-demand services as well as longer-term arrangements similar to vehicle subscriptions or leasing.

To better understand how these different scenarios can manifest, we have identified three key dimensions of AV use:

- Timing (fixed scheduling vs. on-demand services),
- Geography (station/stop vs. door-to-door services), and
- Occupancy (exclusive vs. shared vehicles).

Although all of these have elements of continuousness to them, our initial analyses will treat them as dichotomous for the purpose of simplicity. Based on different configurations of these three dimensions, we have developed eight potential pathways towards an AV future, which we have categorized as being either problematic, mixed or promising in terms of their impact on the transport system.

3 Scenarios for transport system organization with AVs

In this section we describe the roles and responsibilities for vehicle ownership, maintenance and storage, and discuss how they would change with AVs in different passenger road transport segments. We then present four scenarios for system organization with implications for vehicle segments and vehicle practices.

3.1 Sub-practices of vehicle use

Our point of departure is to focus on storage, maintenance and operation because they are the most work and resource intensive sub-practices associated with motor vehicle use that stand to change hands (i.e. in terms of who is responsible for it) in an AV world.

On the surface, **vehicle storage** seems like a proxy for vehicle ownership, but storage responsibilities also apply to additional forms of car use like leasing and subscriptions, and even car sharing and rental insofar as consumers are responsible for parking during the booking period. The main value of considering this practice is that it highlights the responsibilities and resources associated with car use when the car is not actively being used. As such, it is the long-term storage of vehicles that is the most resource intensive and demanding in terms of responsibility; if and when short-term parking costs rise to the point of being too expensive or burdensome, it is more likely that the responsible party would choose a more effective long-term solution (e.g. a driving commuter opting for a long-term rental agreement for a parking space instead of street parking on an ad hoc basis). If the AV future is to be one in which passengers are picked up and dropped off, then the need for private space dedicated to such vehicle storage could diminish. Commercial or public space for vehicle storage, on the other hand, would persist as it is reasonable to assume that vehicles will not be in operation 24 hours per day. Simply put, parking is important, and AVs will likely shift responsibility from the private consumer to transport service providers in all scenarios that involve an increase in transport services.

Vehicle maintenance is another key practice associated with motor vehicle use. Although most maintenance is carried out by paid professionals, it is the responsibility for maintenance, both in terms of decisions and costs, that is worth considering in an AV context. Today, vehicle ownership and leasing are the only segments that assign responsibility to the private consumer. Some leases even include scheduled maintenance as part of the agreement. In all other segments, the transport provider or authority is responsible for maintenance. For AV transport services, responsibility for vehicle maintenance would fall exclusively within the domain of the provider.

Vehicle operation is the easiest of the three practices to grasp. Today, vehicle operation is the responsibility of the consumer for owned, leased, rented and car sharing vehicles (in addition to car-pooling and ridesourcing for which consumer owners are typically peer-to-peer [P2P] providers). In an AV future, we will simply no longer drive. Consumers would no longer have the responsibility, and providers would have all of it, albeit through some agreement with the vehicle manufacturer and ICT companies. Focusing on vehicle operation allows us to gain insight on (1) how existing segments would be affected by the introduction of AVs, and (2) identifying pathways for introducing AVs depending on the respective compatibilities of different segments.

3.2 Passenger transport segments

3.2.1 Private Car Use: Ownership, Leasing, and Subscriptions

Personal ownership is the most dominant segment within passenger transport in Norway. In 2023, there were over 2.6 million privately owned cars nationally, of which about 340,000 were in Akershus county (Statistics Norway, 2024). In the same year, there were 146,818 leased and rental vehicles in Norway in 2023, of which 34,550 were in Akershus county (Statistics Norway, 2024). Vehicle leasing is very similar to ownership, the main difference being that vehicles are typically at the disposal of the user for 2-3-year periods instead of indefinitely. Vehicle subscription services are very similar to leasing but are more flexible in that they offer access to vehicles on a monthly basis rather than 2-3 years at a time.

Across all three models – ownership, leasing, and subscriptions – users are responsible for managing both short-term parking and long-term storage during their period of use. This includes finding parking at destinations and ensuring the vehicle is securely stored when not in use, whether at home, in a garage, or other designated spaces. The key difference in subscription services is that once the subscription period ends, storage responsibilities shift to the provider, who must accommodate vehicles that are not under active contract, requiring greater storage capacity due to the more frequent turnover of vehicles.

Maintenance responsibilities also vary slightly across these models. With both ownership and leasing, users handle routine upkeep, including scheduling maintenance, transporting the vehicle to service centres, and covering related expenses. However, many leasing agreements include scheduled maintenance and servicing as part of the package, reducing the user’s direct involvement. Subscription services take this a step further by including most maintenance and servicing tasks within the subscription package, thus offering a simpler alternative for the consumer, albeit at a price.

Operation across all three models are currently the user’s responsibility. Whether owning, leasing, or subscribing, the user is required to drive and manage the vehicle during their period of access. As vehicle autonomy progresses, the degree of user involvement in operation would decrease, with AVs potentially taking over driving tasks and shifting the user’s role from active driver to passive passenger across all private car use scenarios.

3.2.2 Access-based use: carpooling, car sharing, car rental, ridesourcing, taxi

Access-based vehicle use encompasses various modes of transport where users share access to vehicles rather than owning them. This category includes carpooling, car sharing, traditional car rental, ridesourcing, and taxi services. These models provide flexible alternatives to private vehicle ownership, with responsibilities for storage, maintenance, and operation distributed among users and service providers.

Storage responsibilities in access-based car use vary depending on the model. In carpooling, the vehicle owner is responsible for both short-term parking and long-term storage. In car sharing and car rental, the service provider typically handles long-term storage, ensuring that vehicles are available at designated locations when needed. However, users are responsible for short-term parking during their booking period. Ridesourcing and taxi services eliminate the need for users to worry about storage at all. Instead, storage and parking logistics are entirely managed by the service providers, who may also optimize vehicle locations to reduce wait times for users.

Maintenance responsibilities are also managed differently across these models. In carpooling, the private vehicle owner handles all aspects of maintenance, ensuring that the vehicle is safe and operational for shared trips. In car sharing and car rental services, the provider is responsible for maintaining the fleet, performing regular servicing, and addressing any repairs. This maintenance is typically included as part of the service, ensuring that vehicles are ready for use by the next customer. With ridesourcing and taxi services, on the other hand, the vehicle owner, not the consumer facing company, is usually responsible for upkeep and repairs. In all of these transport service segments, the end user is not involved in these tasks.

Operation in access-based car use varies significantly depending on the mode. In carpooling, the private vehicle owner typically drives, although this responsibility can be shared among other passengers. Car sharing and car rental services require users to drive the vehicles themselves during the rental period, similar to how they would operate a privately owned car. In contrast, ridesourcing and taxi services shift the operational responsibility entirely to the driver, relieving consumers of any such responsibility during the ride.

3.2.3 Public transport

Public transport in Oslo and Akershus includes a range of modes including bus, tram, the metro rail, regional trains, and boats, all overseen by the city's PTA. The PTA is ultimately responsible for storage, maintenance, and operation; the day-to-day responsibilities for these practices are handled by public and private transport operator companies through tendered contracts. These operators manage the depots, garages, and docking facilities, handle regular servicing and repairs, and operate the vehicles according to the schedules and standards stipulated in the contract. Of all the transport segments, public transport is the one in which the providers are responsible for all the key practices.

3.3 Scenarios

In this section, we will go through the four scenarios for AV passenger transport and go through how they would, respectively, impact the distribution of roles and responsibilities for storage, maintenance and operation across transport segments. The main distinction is between consumers and product/service providers, the latter of which can be further broken down into traditional B2C enterprises and P2P providers who often work as independent contractors. For the purpose of comparison, the scenarios can be assessed in comparison to the baseline scenario presented in the following table.

Table 3.1: Baseline distribution of responsibilities in passenger transport (Colours signify the personal, commercial, and public character of the segments).

Scenario 0:	Storage	Maintenance	Operation
Ownership	Consumer	Consumer	Consumer
Leasing	Consumer	Consumer	Consumer
Subscription	Consumer	Provider	Consumer
Car pooling	Consumer (P2P)	Consumer (P2P)	Consumer (P2P)
Car sharing	Provider	Provider	Consumer
Car rental	Provider	Provider	Consumer
Ridesourcing	Provider	Provider (P2P)	Provider (P2P)
Taxi	Provider	Provider	Provider
Public transport	Provider	Provider	Provider

3.3.1 Business-as-usual scenario

The business-as-usual (BAU) scenario is an intensification of the baseline situation whereby private ownership of automobiles is the dominant segment within the transport system, especially outside of urban core areas. The main difference as compared with the baseline is that the responsibility of operation is shifted from the consumer to the vehicle or service provider.

Users of private cars (owners, leases and subscribers) are currently responsible for both short-term parking and long-term storage, typically at home or in a private garage. This would still be the case with AVs, although some of the burden of short-term parking could be reduced. AVs could drop off the owner at their destination and then autonomously relocate to a more convenient or cost-effective storage area. This shift could reduce the immediate need for parking close to destinations and alleviate some of the space and cost concerns associated with vehicle storage in densely populated areas. Furthermore, it opens for the possibility of shifting responsibility to vehicle providers or third-party parking service providers who would be responsible for short-term parking in such situations.

For access-based AV services, the responsibility for storage remains with service providers, who must manage fleets of AVs and strategically coordinate their storage when vehicles are not in use. There are instances in which consumers may be responsible for short term parking, e.g. with AV car sharing or car rental when consumers are responsible for vehicle storage during the booking period. Public transport storage responsibilities remain with the operating companies under the PTA's oversight. We foresee no definite changes in responsibility for maintenance in any of the segments.

For privately owned AVs, the shift in responsibility for operation would depend on the level of autonomy. For lower levels of autonomy (Level 2-3), the owner might still need to monitor the vehicle's operation and be prepared to take over in certain situations. As autonomy increases (Level 4-5), the vehicle could handle most or all driving tasks independently, reducing or even eliminating the owner’s role in operation. However, there might still be grey areas, such as navigating complex environments or unexpected conditions, where the owner's involvement could be required, depending on the capabilities of the AV. As the technology advances, these grey areas can diminish, eventually leading to a situation in which the vehicle fully assumes responsibility for all operational aspects, making the owner experience completely passive.

Furthermore, when we say that operational responsibility shifts toward the provider, it is unknown how the provider landscape will be organized in the future, but it may include one or a combination of manufacturers, transport service companies, and public authorities. The following table shows the distribution of responsibilities in the BAU scenario with red text highlighting the key changes from the baseline scenario.

Table 3.2: Distribution of responsibilities in the business-as-usual scenario (Colours signify the personal, commercial, and public character of the segments, and ***change in responsibility****)*

Scenario 1: BAU	Storage	Maintenance	Operation
Ownership	Consumer	Consumer	**Provider**
Leasing	Consumer	Consumer	**Provider**
Subscription	Consumer	Provider	**Provider**
Car pooling	Consumer (P2P)	Consumer (P2P)	**Provider (P2P)**
Car sharing	Provider	Provider	**Provider**
Car rental	Provider	Provider	**Provider**
Ridesourcing	Provider	Provider (P2P)	**Provider**
Taxi	Provider	Provider	Provider
Public transport	Provider	Provider	Provider

3.3.2 Public-private service scenario

In the public-private service (PPS) scenario, private automobiles are effectively phased out. While ownership, leasing and subscriptions may exist for niche customers, the overwhelming majority of users in this system would rely on transport services for everyday mobility.

The segments that we refer to today as car sharing, car rental, ridesourcing and taxis would persist in some form, but the boundaries between them may shift. Some segments may absorb others; by removing the driver from the equation, for example, AVs would eliminate the main difference between taxis and car sharing. It is also possible that these segments will merge into a single consolidated transport service segment consisting of different ways of accessing AVs, most likely based on vehicle type, booking duration and distance travelled. In this scenario, the provider takes on the main responsibility for all key practices.

Public mass transit would continue and may or may not consist of AVs, but, more importantly, the distribution of responsibilities would remain the same as in the baseline scenario. The following table shows the phasing out of personal vehicles and the shift in responsibilities in the transport service segments.

*Table 3.3: distribution of responsibilities in the public-private service scenario (Colours signify the commercial, and public character of segments, **change in responsibility**, and ~~phasing out of segments~~).*

Scenario 2: PPS	Storage	Maintenance	Operation
~~Ownership~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Leasing~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Subscription~~	~~Consumer~~	~~Provider~~	~~Consumer~~
~~Car pooling~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~
Car sharing	Provider	Provider	**Provider**
Car rental	Provider	Provider	**Provider**
Ridesourcing	Provider	**Provider**	**Provider**
Taxi	Provider	Provider	Provider
Public transport	Provider	Provider	Provider

3.3.3 Public transit scenario

The public transit scenario is similar to the PPS scenario in that personal vehicles are phased out in favour of transport services whereby the provider assumes responsibility for storage, maintenance and operation. The main difference is that all the transport segments would fall within the domain of the public transport authority. As with the PPS scenario, a range of AV offerings based on the mobility needs of the users can be made available, but under one service umbrella alongside conventional mass transit. The following table shows this consolidated public option.

*Table 3.4: Distribution of responsibilities in the public transport scenario (Colours signify the public character of segments, **change in responsibility**, and ~~phasing out of segments~~)*

Scenario 2: PT	Storage	Maintenance	Operation
~~Ownership~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Leasing~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Subscription~~	~~Consumer~~	~~Provider~~	~~Consumer~~
~~Car pooling~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~
Car sharing	Provider	Provider	**Provider**
Car rental	Provider	Provider	**Provider**
Ridesourcing	Provider	**Provider**	**Provider**
Taxi	Provider	Provider	Provider
Public transit	Provider	Provider	Provider

3.3.4 Private commercial scenario

The private commercial scenario represents the most radical transformation of the transport system with AVs, as it phases out both consumer ownership of vehicles and public transport entirely. In this scenario, all transport is provided by private commercial entities, operating fleets of AVs to meet mobility needs. Given that the system today already has significant build-up of public transport infrastructure, it is possible that some of this could be taken over and operated by private commercial actors, but on a for-profit basis.

The shift away from public transport and private consumer-owned transport would necessitate extensive new regulations to ensure that private operators provide sufficient mobility options across all areas, including those that might not be profitable under a purely market-driven approach.

While this scenario could theoretically streamline transport operations under a unified private sector framework, it carries significant risks. The reliance on profit-driven models could lead to a lack of service in less profitable or peripheral areas, leaving many people without adequate mobility options. Moreover, the complete removal of public transport could exacerbate social inequalities, as access to mobility becomes increasingly dependent on one's ability to pay.

In essence, the private commercial scenario could result in a highly fragmented and unequal transport system, with substantial portions of the population potentially underserved. While it may offer efficiency in high-demand urban areas, the overall system is likely to face significant challenges in ensuring equitable and universal access to mobility.

*Table 3.5: Distribution of responsibilities in the commercial scenario (Colours signify the commercial character of segments, **change in responsibility**, and ~~phasing out of segments~~)*

Scenario4 COM	Storage	Maintenance	Operation
~~Ownership~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Leasing~~	~~Consumer~~	~~Consumer~~	~~Consumer~~
~~Subscription~~	~~Consumer~~	~~Provider~~	~~Consumer~~
~~Car pooling~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~	~~Consumer (P2P)~~
Car sharing	Provider	Provider	**Provider**
Car rental	Provider	Provider	**Provider**
Ridesourcing	Provider	**Provider**	**Provider**
Taxi	Provider	Provider	Provider
~~Public transport~~	~~Provider~~	~~Provider~~	~~Provider~~

4 Pathways to the scenarios

In the previous section, we laid out three dimensions of practice to differentiate between AV scenarios for the broad organization of the road passenger transport system. But how might a city or region arrive at these scenarios?

In this section, we will use three dimensions of AV use to help articulate the different pathways towards the scenarios. Each dimension is considered to exist along a spectrum between two extremes, but we begin our analysis by treating them dichotomous. These dimensions are geography (station/stop vs. door-to-door services), timing (fixed scheduling vs. on-demand services), and occupancy (exclusive vs. shared vehicles). By going through the different combinations of these dimension settings, we have identified eight pathways to AV integration in the transport system. One of these corresponds to the BAU scenario, whereas the other seven can lead to either the other three scenarios with varying levels of private or public control.

4.1 Dimensions of AV use

4.1.1 Spatial or geographical dimension

In considering the spatial or geographical dimension of AV use, the options span from fixed stations or stops to dynamic, door-to-door services. Once vehicle operation shifts from the consumer to the vehicle or provider, all vehicular transport effectively becomes a service, even when the vehicle is personally owned.

Figure 4.1: Spatial dimension dynamic to fixed.

At the fixed-location end of the spectrum, passengers travel to predetermined geographic points, commonly referred to as stations or stops. These are typically associated with public transport. However, within public transport, the degree of fixedness varies depending on the time horizon. For daily commutes, all stops may seem fixed, but over months or years, differences emerge. Bus routes, for example, can be altered to accommodate changes in demand or road conditions, while rail-based transport is more permanent due to its infrastructure. Rail stations, therefore, have a lasting impact not only on everyday transport behaviour but also on broader trends like residential choices and real estate development. A case in point is Bergen, where the Bybane tramline spurred significant development and residential growth along its route.

On the other end of the spectrum are on-demand services, where passengers are picked up and dropped off at locations of their choosing. Personal cars, taxis, and ridesourcing services exemplify this type of transport.

Between these two extremes lies a hybrid option known as PUDO (pick-up/drop-off) points. These are predetermined locations that exist as potential stops rather than fixed ones. Vehicles only go to these points if requested, creating a flexible network of nodes that adapts in real-time. While there would likely be regular patterns, such as daily commutes, this system could accommodate varied needs, such as stopping at a hardware store or visiting a family member on the way home from work.

4.1.2 Temporal dimension

The timing dimension of AV transport spans a spectrum from fixed scheduling to fully on-demand services. Much like the geographic dimension, timing influences how predictable and flexible AV services can be for users and providers.

Figure 4.2: Temporal dimension dynamic to fixed.

At the fixed end of the spectrum, AV services would operate similarly to conventional public transport, where vehicles run according to a set schedule. Passengers must plan their travel around these predetermined times, which are typically designed to accommodate the greatest number of people during peak periods. This model is efficient for moving large numbers of passengers at once and ensures a level of predictability that many people rely on for their daily routines. However, it lacks flexibility, as users have little control over the exact timing of some trips.

On the opposite, dynamic end of the spectrum are on-demand services, which operate similarly to personal cars, taxis, and ridesourcing platforms. In this model, users can request a vehicle to pick them up and drop them off whenever they want, providing maximum flexibility and convenience. This approach suits those with unpredictable schedules or specific timing needs, offering a level of responsiveness that fixed schedules cannot match. However, the trade-off is less predictability in service availability and potential inefficiencies in vehicle usage, as vehicles may be underutilized during off-peak times or required to travel longer distances to meet individual demands.

As with the spatial dimension, there is a middle ground, where timing is semi-flexible. This might involve services that allow users to choose from a range of time windows for their trips rather than having strict schedules or complete on-demand availability. For example, commuters could book rides to work from among a range of time slots that are not necessarily predetermined. This middle approach could also allow for better planning and vehicle allocation than purely on-demand models, while still catering to individual needs more effectively than fixed schedules. As transport technology becomes increasingly digitalized, there will be greater opportunities for adaptable scheduling options that can dynamically adjust based on real-time data, user preferences, and traffic conditions.

4.1.3 Occupancy dimension

The occupancy dimension of AV transport refers to the range of options available for how passengers share or do not share vehicles with others. This dimension influences the social and logistical dynamics of AV usage, affecting everything from privacy and comfort to efficiency and cost.

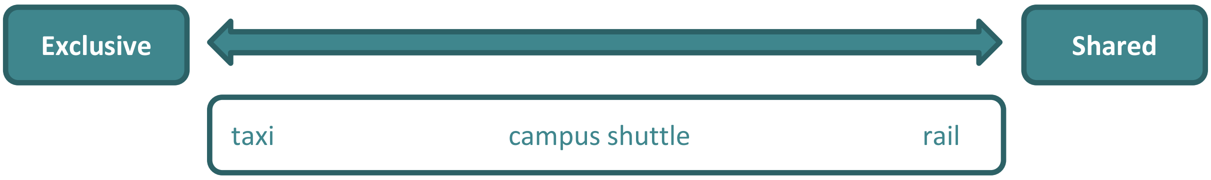

Figure 4.3: Occupancy dimension exclusive to shared.

At one end of the spectrum is exclusive use, where individuals or groups have full control over who occupies the vehicle. In this model, passengers can choose to ride alone or select specific people to share the journey with, such as family members, friends, or colleagues. This level of exclusivity is akin to how consumer-owned cars are used today, offering maximum privacy, security, and control over the travel environment.

On the opposite end of the spectrum is shared use, where passengers share the vehicle with others, typically strangers, in a manner similar to current public transport or ride-sharing services. This model maximizes the efficiency of the transport system by filling vehicles to their capacity, at peak hours at least. However, it can also involve trade-offs, such as reduced privacy, the need to coordinate with others' schedules and destinations, and a less personalized travel experience.

Between these two extremes lies a middle ground where occupancy is shared, but within defined boundaries that are more selective than in fully public systems. The boundaries and criteria for who rides together can vary, reflecting different preferences and requirements. For example, an AV shuttle bus might be dedicated to transporting employees to and from a specific office park, or a vehicle could be reserved for students at a university. This could resemble already existing mobility platforms like car sharing that currently require membership, and sometimes membership fees, for access to the platform.

4.2 Eight pathways to an AV future

In this section, we describe the eight possible combinations of the timing, geography and occupancy dimensions. The pathways are not mutually exclusive; they are intended to be conceptual tools to help articulate system change, which can involve multiple simultaneous, albeit weighted, pathways.

Table 4.1 Eight pathways for AV introduction (colours represent expected outcomes as problematic, mixed or promising)

Pathways	TIME	DISTANCE	OCCUPANCY
P1	Dynamic	D2D	Exclusive
P2	Dynamic	D2D	Shared
P3	Dynamic	S2S	Exclusive
P4	Dynamic	S2S	Shared
P5	Fixed	D2D	Exclusive
P6	Fixed	D2D	Shared
P7	Fixed	S2S	Exclusive
P8	Fixed	S2S	Shared

4.2.1 Pathway 1: temporally dynamic, door to door, and exclusive

This pathway is the one that is most similar to our current mobility system. All of the transport segments mentioned earlier would be maintained in this pathway, even privately owned automobiles, the only difference being that the owners would not be driving their own cars. It is, therefore, the pathway that will lead us to the business-as-usual scenario described earlier.

Insofar as the consumer's *initial* choices are concerned, this would be the clear preference because it maintains the greatest amount of flexibility in terms of when you travel, where you get picked up and dropped off, and who you ride with.

We do have reason to view such a pathway with suspicion because it is a reinforcement of the system of automobility. Knowing nothing about costs of ownership and operation, if a product or service becomes more convenient, and presumably, that is what the introduction of AVs would bring about, it is more likely that consumption would increase. This new transport demand would place additional pressure on infrastructure that is already operating at capacity.

We do not envision a sustainable or equitable mobility system with this level of flexibility and options for the consumer; we foresee gridlock and alongside a fleet of empty vehicles waiting to pick up their owners who are busy shopping. There are, however, possible measures to avoid the worst of these outcomes; when the system perspective is not in line with the consumer perspective, regulation (e.g. congestion pricing, dynamic parking fees) can be used to create better market outcomes.

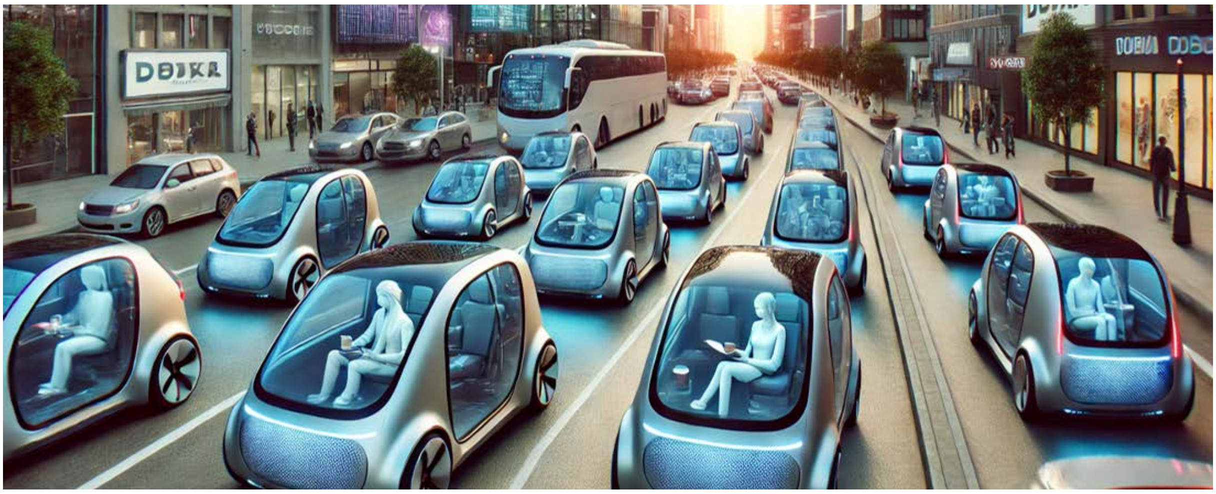

Figure 4.4: AI representation of Pathway 1: on-demand, exclusive, door-to-door service (image: ChatGPT4o).

4.2.2 Pathway 2: temporally dynamic, door-to-door, and shared

This pathway resembles P1 but introduces shared AVs instead of exclusive-use vehicles. In this scenario, AVs operate on-demand, providing door-to-door service to multiple occupants who may be strangers or members of a shared platform.

In its fullest form, this pathway envisions a future where personally owned, leased, and subscription vehicles are phased out, replaced by on-demand transport services that function similarly to modern taxis and ridesourcing platforms. Traditional carpooling, car sharing, and car rentals would no longer exist in their current forms; instead, these services would evolve into on-demand options for each individual trip. For example, rather than renting a car for an entire vacation, a family would book on-demand AV services for each segment of their journey, potentially sharing rides with others to maximize efficiency.

This system requires a willingness from passengers to accept occasional detours to pick up additional riders, akin to today's Uber Pool or Lyft Shared services. If coupled with effective regulations, the efficiency gains from shared occupancy and dynamic routing may reduce the total number of vehicles needed, easing congestion and lowering the environmental impact of transport. This pathway could lead to either the PPS or public transport scenarios, depending on how these on-demand services are managed. If public enterprises dominate the market, the system might evolve into a more structured, transit-like service with widespread accessibility and standardized pricing. Conversely, if private companies control the majority of services, the result could be a more fragmented and competitive market, where service quality and availability vary based on market dynamics.

Figure 4.5: AI-generated representation of Pathway 2: on-demand, door-to-door, shared service (image: ChatGPT4o).

4.2.3 Pathway 3: temporally dynamic, geographically fixed, and exclusive

This pathway envisions a transport system where AVs operate on-demand, providing exclusive use for each passenger or group, but with geographically fixed PUDO points. For this pathway to function effectively, the number of stations or stops must be significantly increased beyond what exists today. This could involve the introduction of a network of PUDO points, allowing for more widespread coverage, while maintaining the geographically fixed nature of the service.iIn this scenario, privately owned, leased, and subscription-based cars are phased out, meaning that AV services would need to cater to a diverse range of mobility needs. Since not everyone lives close to traditional transit stops, the expansion of fixed pick-up points becomes crucial to ensuring accessibility. The exclusive nature of these rides means that passengers won't share their vehicle with others, avoiding the detours associated with shared services.

While trips may be quicker compared to shared services, since vehicles won't need to stop for additional passengers, potential trade-offs include increased congestion resulting from each person or group uses their own exclusive AV. Essentially, this pathway resembles a large fleet of taxis, but with the added requirement that users might need to walk a short distance to or from a PUDO point.

This pathway could appeal to those who prioritize privacy and direct routes over the convenience of door-to-door service. However, the system's overall efficiency would depend heavily on the strategic placement of PUDO points, the ability to manage traffic volumes, and potential integrations with public transport or among different platforms.

Figure 4.6: AI-generated representation of Pathway 3: on-demand, station/stop-based, exclusive service (image:ChatGPT4o).

4.2.4 Pathway 4: temporally dynamic, geographically fixed, and shared

This pathway closely mirrors P3 but introduces shared AVs instead of exclusive-use vehicles. The system remains on-demand and is still based on stations, stops, and PUDO points. While P3 resembled a fleet of autonomous taxis, this pathway is more akin to a fleet of autonomous busses, prompting considerations about the types of vehicles that might be used.

In today's transport system, vehicles are typically designed for individuals or small groups, such as nuclear families, or for large groups, as with buses and metros in public transport. However, this pathway suggests a need for something in between, such as a large fleet of AV minibuses. These vehicles would offer the flexibility of on-demand services, allowing passengers to be picked up from nearby PUDO points, but they would also accommodate multiple passengers, potentially requiring detours to pick up and drop off others along the way.hWhile this model provides the flexibility of on-demand services, passengers might face varying wait times depending on the availability of vehicles and the number of passengers sharing the ride. The shared nature of the service means that passengers will need to compromise on privacy and may have to take detours, but this trade-off reduces the overall number of vehicles needed, easing traffic congestion concerns.

Similarly, the use of PUDO points offers a compromise between the convenience of door-to-door service and the efficiency of fixed-route transport. Passengers may need to walk a short distance to reach a PUDO point, but this helps streamline vehicle routing and reduces the need for extensive road coverage.

Overall, this pathway represents a compromise between the different dimensions of AV use, balancing flexibility, efficiency, and resource use. It offers a middle-ground solution that could be especially appealing in the urban periphery where connection to the urban core is important, but public transport coverage is limited. In such places the introduction or a large PUDO network could greatly improve access as compared with today's stations and stops.

Figure 4.7: AI-generated representation of Pathway 4: on-demand, station/stop-based, exclusive service (image:ChatGPT4o).

4.2.5 Pathway 5: temporally fixed, door to door, and exclusived

In this pathway, AVs operate on fixed schedules while providing door-to-door service exclusively for individual passengers or groups. This means that although the vehicles pick up and drop off passengers at their precise locations, the timing of these services is predetermined and not flexible. This pathway could be particularly appealing for certain niche segments, such as patient transport or non-emergency medical visits, where scheduled, reliable, and private transport is essential. However, for general use, this model presents several significant drawbacks. The combination of fixed timings and exclusive use leads to a high number of single-occupancy vehicles on the road, which could exacerbate congestion, especially during peak commuting hours.

Furthermore, this pathway lacks flexibility in terms of time, which could make it less attractive to the broader population who value the ability to travel on demand. Additionally, the inefficiency in vehicle occupancy, where each vehicle serves only one person or a small group, means that the system would require a large fleet of vehicles to meet demand, further contributing to traffic and environmental concerns.

While this pathway might appeal to a niche market of users who can afford the convenience of scheduled, exclusive door-to-door services, it is not the ideal solution around which to base a sustainable and efficient urban transport system. Its limitations in terms of flexibility and efficiency make it less viable as a widespread transport model.

Figure 4.8: AI-generated representation of Pathway 5: scheduled, door-to-door, exclusive service (image:ChatGPT4o).

4.2.6 Pathway 6: temporally fixed, door to door, and shared

This pathway is similar to Pathway 5 but introduces shared vehicles instead of exclusive use. In this scenario, AVs operate on fixed schedules while providing door-to-door service, but passengers share the vehicle with others, much like a modern version of a school bus.

The concept of fixed scheduling combined with door-to-door service can be challenging to implement on a large scale due to the logistical complexities involved. Fixed door-to-door services require pre-arranged routes that can accommodate multiple pick-ups and drop-offs along the way. As a result, this pathway is most suitable for specific types of trips, such as daily commuting or school transport, where routes and schedules can be planned in advance.

However, the need to take detours to pick up additional passengers could lead to longer travel times and reduce the efficiency of the service. This trade-off might make the service less appealing for users who prioritize direct routes and quick travel times.

While the pathway could work well for structured, repetitive trips where participants are traveling to similar destinations, such as workplaces or schools, it is unlikely to be a practical solution for more spontaneous or varied travel needs. It is, however, important to recognize that commuting and regularly scheduled activities, such as bringing kids to school or other routine appointments, represent a significant portion of our transport needs, making this pathway potentially impactful despite its limited scope. The challenge of coordinating fixed schedules with the door-to-door nature of the service limits its flexibility, but such a pathway could work alongside another pathway that compensated for this.

Figure 4.9: AI-generated representation of Pathway 6: scheduled, door-to-door, shared service (image:ChatGPT4o).

4.2.7 Pathway 7: temporally fixed, geographically fixed, and exclusive

In this pathway, AVs operate on fixed schedules, with pick-up and drop-off limited to predetermined stations, stops, or PUDO points. Each vehicle is used exclusively by an individual or a small group, offering no flexibility in terms of timing and little in terms of geographic locations. The lack of flexibility in both time and location means that passengers must adhere strictly to predetermined schedules and fixed points, which can be inconvenient and limit the appeal of the service. Additionally, because the vehicles are used exclusively, this pathway would require a large fleet to meet the transport needs of all users, resulting in inefficient use of resources and potential congestion. Overall, this pathway presents significant challenges and is not an optimal solution for urban mobility. It would likely lead to an oversupply of vehicles on the road, without providing the flexibility or efficiency needed to address the diverse transport needs of a city region.

Figure 4.10: AI-generated representation of Pathway 7: scheduled, station/stop-based, exclusive service (image:ChatGPT4o).

4.2.8 Pathway 8: temporally fixed, geographically fixed, and shared

This pathway involves AVs operating on fixed schedules with pick-up and drop-off limited to predetermined stations, stops, or PUDO points, but with shared occupancy. While similar to Pathway

4, the key difference here is the lack of demand responsiveness; vehicles adhere strictly to set schedules and routes, offering less flexibility for passengers but more predictability for operators. This pathway closely resembles today's public transport systems but with a much more granular network of stops and potentially more lines to increase coverage and accessibility. The fixed nature of both the timing and geography means that passengers can rely on consistent service, though at the cost of the flexibility that demand-responsive systems provide.

One significant challenge with this pathway is the potential for inefficiency, particularly the risk of having a large fleet of vehicles operating with few or no passengers during off-peak times. This could lead to a scenario where a substantial number of vehicles are in operation without fully utilizing their capacity, which would undermine the efficiency of the transport system and contribute to unnecessary congestion and energy consumption.

Despite these challenges, this pathway could appeal to urban areas that require reliability and predictability for daily travel, but do not currently have this with public transport services.

Figure 4.11: AI-generated representation of Pathway 8: scheduled, station/stop-based, shared service (image:ChatGPT4o).

5 Discussion

AVs will have a system wide impact on mobility. In this section we discuss some of the properties of AV technologies against different aspects of current mobility system.

5.1 Changing the economics

AVs will change the economics of mobility. Some of the change is linked to aspects of AV technology, while other changes are linked to the business models and organizational structures that will surround AV technology. As a starting point, this can be discussed as changes related to the costs associated with private cars today.

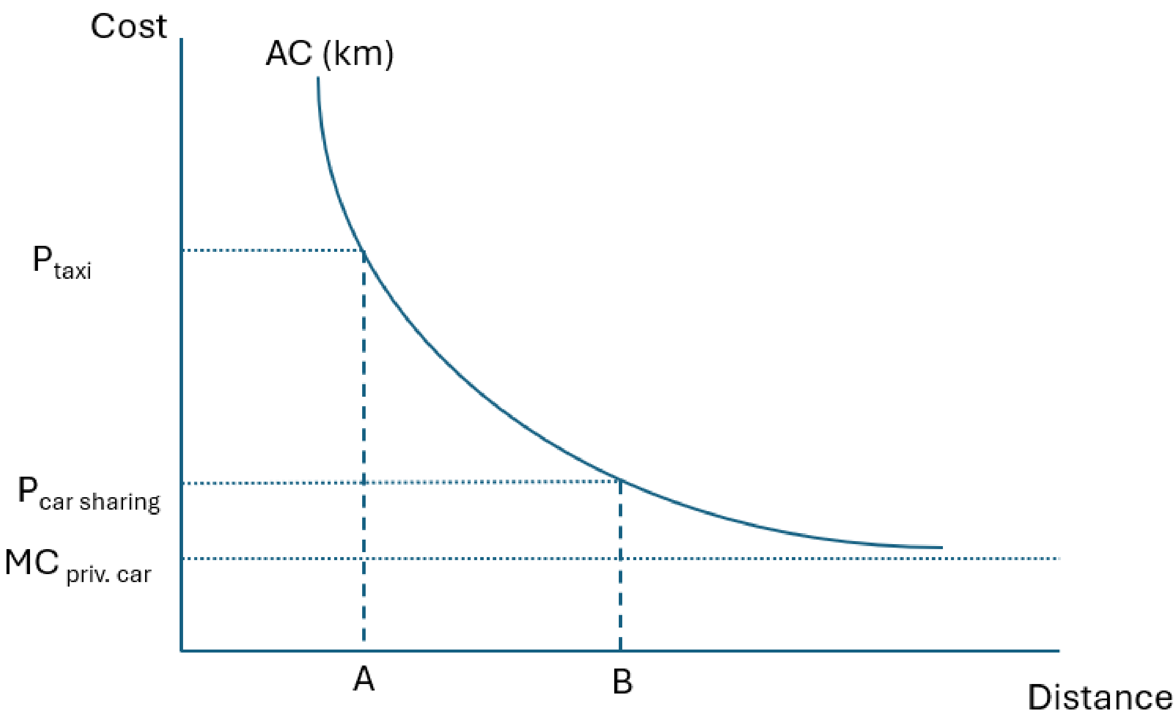

Figure 5.1: Cost of vehicle operation.

Figure 5.1 illustrates the costs of private car use with conventional vehicles. The costs are presented as a function of distance (in kilometres). The average cost (AC) curve falls in the relevant area due to high initial cost, the purchase of the vehicle. As the distance driven increases, the AC comes closer to the marginal cost (MC) of operating the vehicle. The MC being the cost associated with driving one additional kilometre, and is assumed to be constant in the model. P_{taxi} is the consumer facing price of a taxi service, while $P_{car\ sharing}$ is the consumer facing price of a car sharing service. This shows that if a consumer has a mobility demand of less than A kilometres, it is rational to go by taxi. If the consumer wishes to drive between A and B kilometres it is rational to go by car sharing, and if the consumer wishes to drive more than B kilometres, private car is the least costly option.

From an economics perspective, the decision each individual takes when choosing between different modes of transport is a result of an assessment of the relative disutility presented by the modes in question. The concept of generalised costs is used for quantifying and comparing the disutility presented by the alternatives. The underlying assumption is that reaching the destination is the objective of the trip, not the trip itself[2]. Therefore, reaching the destination as quickly as possible, and with the lowest possible hassle and expenditure, becomes the preferred choice. For most trips, the major disutility is associated with the time spent travelling. Valuation studies show that travel times is valued differently between modes, with public transport having lower disutility per unit of time than car driving (Flügel et al., 2020). Travel times with public transport is however generally longer than with private car (Lunke et al., 2022).

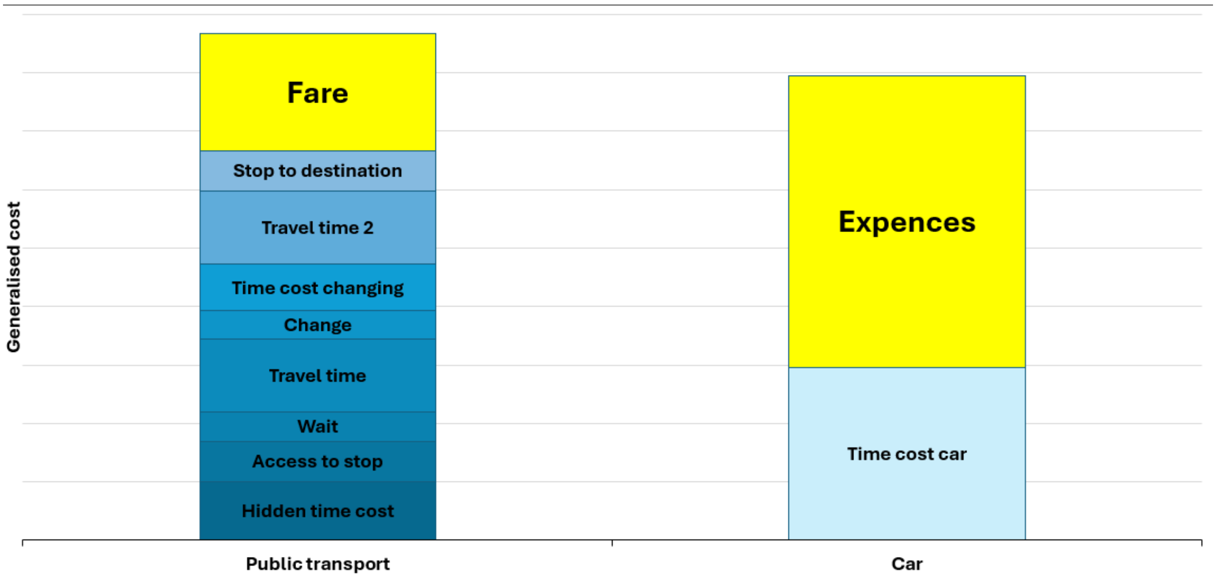

Figure 5.2: Generalised cost comparison between public transport and private car (Fearnley et al., 2023).

Figure 5.2 illustrates a generalised cost comparison for a specific trip, where private car is the preferred option. In the figure, yellow boxes represent out of pocket expenses, while blue represent different disutilities associated with travel time. The key takeaway is that time costs and other disutilities are of paramount importance for PT-competitiveness in the current mobility system.

The expectation from AVs is that as the driver is no longer required to pay attention and drive the car, the disutility from driving will decrease. The disutility per unit of time may even fall below that of public transport, as the service is exclusive. For public transport, the costs related to changing vehicle may decrease with more direct travel options, however any shared or scheduled mode will have to make detours and not cover all trips door-to-door, presenting a time penalty, compared to an exclusive AV. Adding these into a figure gives the following.

[2] According to Munby (1968) "only the psychologically disturbed or inadequate want transport for its own sake" as cited in Button (2010).

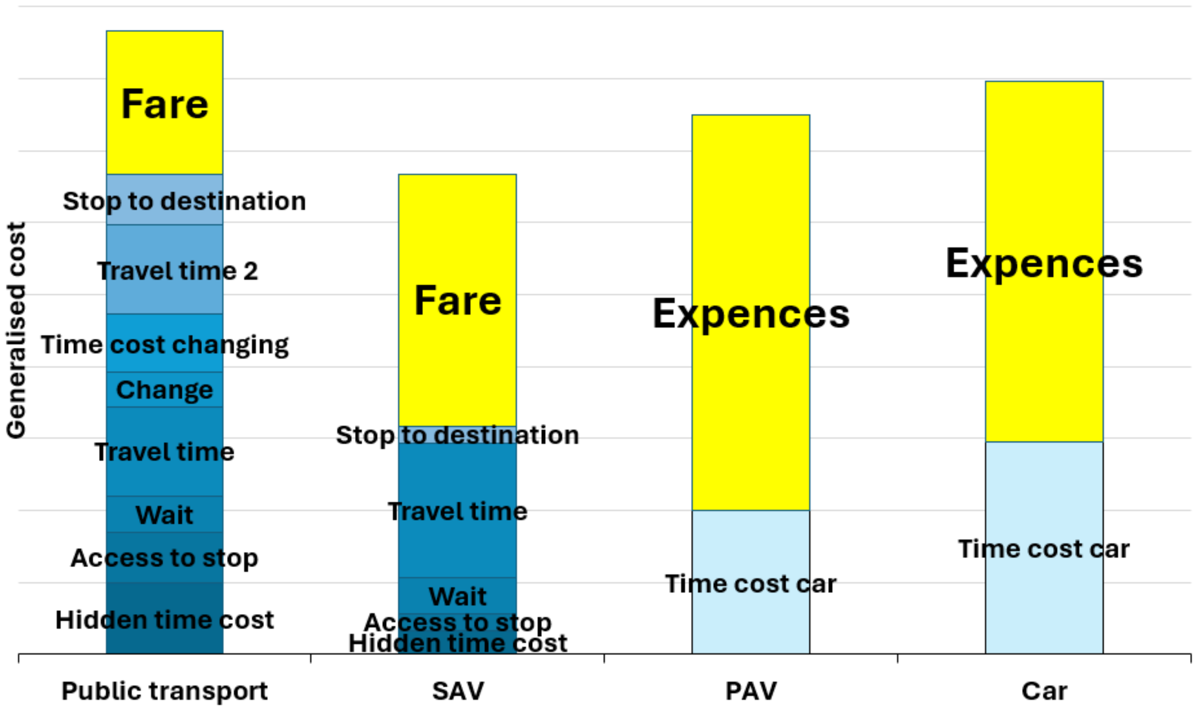

Figure 5.3: Generalised cost PT, SAV, PAV and conventional car (own estimate)[3].

Figure 5.3 uses estimated values for a shared AV (SAV) and a private AV (PAV). Presently we do not know the true costs of operating AVs. What we know is that AVs have had a large upfront costs in preparing the technology. This is a sunk cost, but still something that the mainly private investors are likely to try to recover. Furthermore, the materials and sensors currently being used in an AV make an AV at least equal the costs of a conventional vehicle to produce. In terms of operation, the marginal costs, that is to say the costs per kilometre, is likely to be equal to that of a private car. However, since the AV is likely to do at least some kilometres without passengers, the MC for a passenger kilometre is likely to be slightly higher than that of conventional cars. Similarly, we do not know how AVs will be priced in the market; we have assumed values based on a representative trip and what we perceive to be plausible values. This places both shared AVs and private AVs as having lower generalised cost compared to today's mobility options. In this example, AVs will be preferred to conventional modes even though they would be more expensive to operate, and irrespective of whether they are organised as a shared or a private mobility option[4].

[3] This is based on the following assumptions. For PT and car, value of time relative travel time, generalised travel time components, from Fearnley et al. (2023), Who uses a representative trip in Stavanger as a starting point. For SAV the fare = 1,75 PT fare; access time , hidden time cost, wait, = PT*0,33; travel time = PT*0,75. PAV = private car but, value of time = Car* 0,67, and cost = car *1,1.

[4] A caveat in this reasoning is the underlying assumption that the cost of infrastructure, both in terms of resources used and land use, is not included in the equation. This is a reflection of today's situation, but not an ideal situation, where the true external costs would be presented to the user.

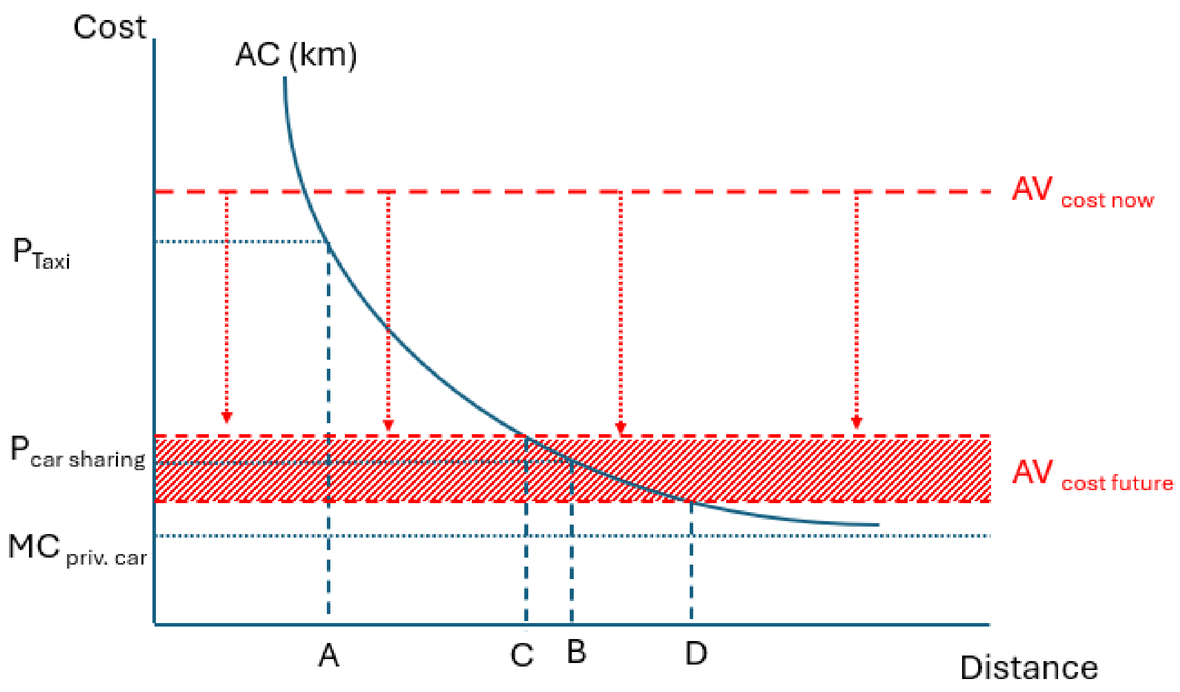

Figure 5.4: Vehicle cost figure, with Avs.

Figure 5.4 illustrates how AV costs relates to conventional car costs. Presently, AVs cost more. However, as the technology matures we expect the initial costs to come down, through a combination of economics of scale and the establishment of dominant designs. Still, we do not find it likely that AVs will cost less than the current MC of a private car. This is based on the assumption that AVs need almost all of the material components of a conventional vehicle and more developed sensors, computers and software in addition. This does not mean that AVs cannot compete with private car ownership, nor that AVs can be preferred to conventional cars (as illustrated by figure 5.3). AVs may very well do both, but this is due to higher utility for the users, not lower costs in absolute terms.

Presently, AVs are not economically viable as an alternative to private car use, irrespective of how many kilometres you drive. It is introduced as pilots and trials. From anecdotal evidence the marginal costs of AVs in the larger scale pilots are comparable to or lower than P_{taxi}. The expected development is that the cost of operation comes down to the band labelled AV $_{cost\ future}$, at the high point this is slightly higher than the price charged by car sharing actors, at the low end it is between car sharing and conventional cars.

Irrespective of the true long term marginal costs of AV operation, it is clear that it will increase the expected travel distance from which it is cheaper for the consumer to purchase a private car. The point may shift form A in areas where car sharing is not available to C or D, depending on the costs associated with AV operation. This should by itself reduce the demand for private vehicles, but increase the demand for mobility and increase the demand for car-sized vehicles in the mobility system. However, as demonstrated by Clayton et al. (2020) there is likely to be a strong preference for exclusivity.

5.1.1 Economic impact on PT

How does AVs change the economics of public transport services? Will it influence the need for special versus ordinary services? Will it change the need for subsidies?

In relation to the PT system, AVs may have two functions. First, to reconfigure the extant PT system by improving efficiency and second, to expand it by adding more mobility options. The economic consequences are different in these two functions.

In the first function, automation of existing modes may gradually reduce the need for drivers. But, it will not remove the need for humans in providing mobility services. Automation may contribute to a "deskilling", where the skills needed to handle the vehicle is decreased, (or "upskilling" where drivers are replaced by fewer individuals with specific skills that require longer and different training processes). As highlighted by Acemoglu and Restrepo (2018) the exact outcome is not clear, but it is clear that the skills required will change. Given that access to skilled drivers is a major constraint for PT service provision and the single most important cost component, automation should result in increased economic viability for existing services. In other words, is likely that existing trunk services operated by conventional PT modes (busses, trams, metros and trains) are likely to become less costly from the introduction of AVs[5].

In terms of reconfiguring the extant PT system, AVs should have the effect of changing the cost structure, pointing towards more capital-intensive production, which again points in the direction of larger units, and broader geographical scope of service provision (see section 5.1.2).

In the second role, automation may add to the extant modes by supplementing them. i.e. it may increase the total available mobility, both adding services that were not possible earlier and by moving services away from private car use. Imagine adults driving children to various activities. In addition many trips that are not made today, from either the lack of mobility options (the bus does not fill the demand and a car is not available) or from decreasing disutility of travelling, may emerge. In other words, generated traffic. Trips that are not conducted today, that will become a reality when the disutility of moving or barriers against moving are reduced. It is likely that many of these services will take the form of additional services added to the PT system, as today's modes are closely linked to the scheduled station-to-station shared operating structure, while these new services will probably at least in part will depend on relaxing this the constraints presented by this (see section 5.1.3).

This points towards an important discussion that needs to be addressed, relating to how many of these new services should be included as PT services, and who should pay for these. To what extent should users pay, and to what extent should non-users pay. The new services will increase utility for the users, and most likely generate more traffic. Consequently, possibilities for co-location of services and a consequential contribution to the general welfare exist. In order to achieve this welfare contribution, it is crucial that more people are included in private car-like mobility. In other words, persons who for various reasons, both legal and economical, do not have access to these services today. If these services are to be provided by the public in a way that promotes social inclusion, this will result in a need for significant economic support. If not, the services will most likely materialize, but through user paid forms of organization. The longer term outcomes of this is unclear.

5.1.2 Changing the extant regime

Mobility occurs at different scales, with daily trips being local or regional, and longer distance trips (usually) being less frequent. From political science, Oates' theorem (Oates, 1999) points at a division of responsibilities between different tiers of government. In short it states that a central government is incapable of providing a set of services to regions with different demands. Regional governments will prioritize differently and thus, it is more efficient to shift responsibility from the central government to regional governments in order to take heterogeneous preferences into account. The struc-

[5] There may be other reasons that cost operating costs may increase in the future, such as increasingly high standards, new infrastructure requirements, energy costs and other landscape level developments.

ture of transport regulation in Norway largely follows this theorem. By having modes used for local trips governed by local authorities while longer trips is governed by the central government.

Onto this comes the observation that more capital intensive services should be regulated or provided by a larger public entity (Hooghe & Marks, 2003). Labour intensive services should be provided locally while capital intensive services should be provided or regulated by a more central authority. Automation is likely to shift the underlying economic properties of public transport towards more capital intensive production. This points towards regulation at higher levels of government. Opposed to this is the notion that the externalities from transport provisions are largely experienced at a local level. Which points towards local regulation of critical aspects such as curb access and congestion charging.

This dilemma points towards an important discussion on which level the organisation of new automated mobility services should be organised. It is not obvious that today's division of responsibility between different tiers of government is suitable for regulating and providing AV based services. The increased capital intensity points towards fewer and larger regulatory units, while the very local issues of urban space and externalities points towards an increased number of (smaller) units. AVs require policy decisions both at local, regional, national and super national level. Also, today's users typically switch between modes for different types of travel, with PT playing a larger role for regional and urban commutes and a smaller role for leisure travel and longer distance travel. A move away from the private car in both roles opens up a gap in the leisure travel segments.

5.1.3 Expanding PT to a larger section of the mobility system

A key potential contribution of AVs is that the technology has the potential to make more tailored transport options available through the PT system. The most critical of these expansions is the expansion in the direction of today's dominant mode in regional (as well as interregional) transport, the private car. This can be motivated both by economic arguments, that society as a whole presently are overinvesting in mobility providing capacity that is underused (i.e. private cars that costs way more than their transport use justify), and environmental arguments, including the externalities both in terms of congestion and energy use associated with private car based mobility. Furthermore, it can be argued that by adding more tailored mobility options to the PT system, the overall mobility offering becomes more equitable.

Any expansion of PT services into other modes than the present includes changing the organizational structure for how these services are provided. A different business model is required, with new pricing structures and ways of prioritizing between user groups. From the analysis of pathways in section 4.2 it seems clear that all actors cannot be offered the level of exclusive mobility presented by today's private cars, without putting strains on the current infrastructure system. In particular, peak capacity is reached regularly in urban areas, and the negative externalities of personal mobility is much higher than what is currently being charged the users.

We have identified some points where an expansion of the PT current system meets challenges.

- Replacing a self-funding, revenue-generating sector of the economy operating in a market context with a social welfare structure focusing on maximizing a undefined utility function is a radical shift.

As the discussion and scenarios show, shared use of AVs has many benefits. However, creating a regulatory system that realizes the benefits of a technological transition will require some large changes in policy. In the present regulatory regime, door-to-door services, both exclusive and shared, are provided commercially by the taxi industry. The taxi industry mostly delivers this through exclusive services, although examples of shared exist. Following advances in coordination technologies, several schemes of shared taxi services have been tried, but they have mostly been economically unsuccessful. Still, granular and unscheduled services are presently being provided by two main actors, taxis and private cars. Replacing either with a shared service is challenging in that it shifts responsibility from the default solution in the economy, private and commercial, to the second best, public and, if utility is to be maintained, systems that are likely to require subsidies. An argument that would justify this move includes that the present services fail to internalize their social costs. In other words, people using private cars do not pay the full societal costs of their activities. Along this argument, an expansion of the PT system into what is currently taxi and private car operations can be justified with reference to maximizing social welfare. A weakness in this argument would be that this probably is not the least intrusive way of addressing the problem of private car use being priced too low, road charging would be an obvious alternative policy.

There is also an alternative to introduce direct regulatory measures to reduce the use of modes outside the PT system, i.e. re-introducing limits to private car ownership or similar, or in the form of buy-back schemes for reducing car ownership in certain areas. This type of regulatory change will have large implications for other parts of society as well. It will shift significant parts of the economy from the private sector to the public sector.

- AVs offered as part of public transport are likely to increase the need for subsidies, in order to be able to compete with private ownership, without restrictions on private car use.

Closely linked to the regulatory challenge presented by offering a service within a public transport system that is currently offered commercially is the challenge of redistributing funds. The underlying reasoning is that, if the utility level shared and PTA provided AVs are to present is to be equal of today's private cars, this will require funding. At the societal level, this may not require more funding than presently, which means that the total amount of expenditure on mobility may decrease. It does however mean reallocating resources between private and public actors. In particular, a much larger proportion of the money private individuals currently spend on their own private cars would need to be reallocated for public service provision. This is a radical pathway to introducing new services which is likely to face pushbacks from established actors.

- Conflict between regimes => head-on competition with, private car, carsharing, carpooling, ridesourcing, taxis. And to some extent Micromobility, MaaS

Presently, both the PTA centred multimodal regime, the private car centred automobility regime and the taxi regime is challenged by AVs. At the same time actors from all of these regimes perceive AVs as a potentially useful technology that can improve the level of service they are currently operating. In addition, it is likely that new actors will enter the market alongside the introduction of the technology. Most likely these actors will have a different idea of how the mobility sector is best organized, and this alternative organization may be regarded as an alternative socio-technical regime.

This is not a unique occurrence facing today's mobility regimes, it has parallels to the introduction of dockless-shared micromobility, mobility-as-a-service, and ridesourcing, all of which have taken place after 2010. These historic and concurrent examples show that there is no pre-determined pathway from viable technology to practical implementation. Micromobility, for example, are presently having a series of alternative outcomes, from out-right bans (as in Paris), to inclusion in the pre-existing multi modal mobility system (as in Oslo), with various combinations along the way. Economically, micromobility go from being excessively taxed to being subsidized depending on (mostly) local decisions. Similarly, proponents of MaaS have presented it as an additional tier in the mobility system aggregating mobility services from different regimes. Presently however, the seemingly most successful approach to some of the MaaS vision has been through incremental the introduction of MaaS features into the services provided by the PTAs. Both MaaS actors and ridesourcing actors have to various degrees been able to change the legal framework in order to suit their services and business models. This links to the question of legality.

- Questions relating to legality

In Norway, the vocational transport act does not, even in its undergoing revisions, address the challenges created by AVs. It is however not difficult to introduce AVs within the current set of define-tions, rather, unresolved questions are relating to the distinction between the actors' responsibilities. If, as this study suggests, shared AV options are to be preferred, the economics of the service shift form more labour intensive to more capital intensive, and the distinction presented by scheduling becomes less relevant, this points towards a rethinking of the relevant dimensions for dividing responsibility between modes of transport and levels of government responsible for regulating them.

- Generalized cost assessment

AVs are likely to change the GC of driving. Experience from the introduction of ridesourcing points towards a shift from shared to exclusive services (Rayle et al., 2016). Looking at the GC, the time component and interchange penalty of public transport, this is very understandable. Offering a faster and more direct service did make ridesourcing an alternative option to public transport, even though it was more expensive. In extension, more direct and faster mobility presented by a fleet of AVs would make it preferable to extant PTA services.

Overall, the reflections of the economics of AVs points towards lowering the costs for the services that all of the potential involved actors are currently providing. It offers the possibility of reducing the cost of conventional public transport, it can potentially dramatically decrease the cost of taxi travel, to the point where the distinction between taxis and car-sharing becomes irrelevant. AVs will also increase the utility presented by private cars, more people will have the opportunity to use them and the non-direct disutility of owning and operating a car will decrease. AVs may also provide an opportunity for new actors to enter mobility markets. And the potential value created by the technologies points in the direction of tremendous potential for revenue generation, which again points towards expected attention from investors.

By themself, AVs does not increase the need for subsidies, nor change the need for special services currently being offered. However, AVs will create new opportunities. New possibilities for mobility will emerge, and depending on how the mobility market is organized this may both result in an increase and reduction of the public authorities role in service provision. If the public sectors is to take a larger part of the total mobility market, that is to say replace private car ownership with shared autonomous vehicles organized by a PTA or similar, that is likely to require increased subsidies compared to today. This is because the PTA will need to offer more and better services, not that the costs increase.

5.2 Changes in personal transport

How does AVs change the relationship between personal and non-personal (i.e., service) transport?

By personal transport, we mean situations in which private individuals own and operate motor vehicles, a norm that forms the basic logic of the automobility regime. We wish to emphasize the difference between such personal mobility and the broader category of private mobility, which can also include commercial services owned by private entities such as taxi companies or car sharing platforms.

At a principal level, the AV reduce the burden that rests with the driver in terms of operation. Relieving the user of operational responsibility opens up car-based mobility to a larger segment of the population. Persons who presently do not have access to private cars for legal and practical reasons would be beneficiaries. This is expected to result in an increase in mobility demand.

Furthermore, if storage and maintenance can be more effectively handled by service providers instead of private individuals, the role of the individuals would further diminish. Such changes are captured in scenarios 2-4. This would mean reductions in two of the main economic incentives for owning a private car, immediate access and reliable performance.

As storage is disconnected from use, parking in particular becomes less of a constraint than it currently is, pointing again in the direction of access without ownership. Similarly, maintenance of AVs could be carried out “at the push of a button” whereby individual owners send vehicles for maintenance without actually going along. Even if the individual owner maintains the responsibility of scheduling and paying for such services, the savings in terms of time and effort are worth considering. The effects of removing the disutility associated with vehicle ownership – parking and time spent with maintenance – should increase the attractiveness of the car as a mode, though not necessarily car ownership by private individuals.

Furthermore, if private car ownership ceases to be the default and car-based mobility increasingly relies on transport services provided by public or private entities, the role of the car as a status symbol is likely to diminish. Today, the personally owned car carries significant symbolic value, associated with social status, individual freedom, and identity, including gendered and political dimensions. The extent to which this symbolic meaning will erode is uncertain, but a shift towards service-based access rather than ownership would likely redefine the car’s cultural significance. In such a scenario, the car may be perceived less as a personal artefact and more as a functional tool, its value measured by efficiency and utility rather than its role as an expression of individual identity.

5.3 Changing organizational structure

How does AVs change the relationship between public and private transport?

Discussions concerning the introduction of Maas systems provide a useful starting point from considering the impact of AVs on the relationship between public and private sectors. Smith, Sochor and Karlsson (2018) characterized MaaS by the presence of operators and integrators in between the users and providers. In this model, users access services through a middle layer of operators and integrators who connect them with public transport agencies and commercial transport companies.

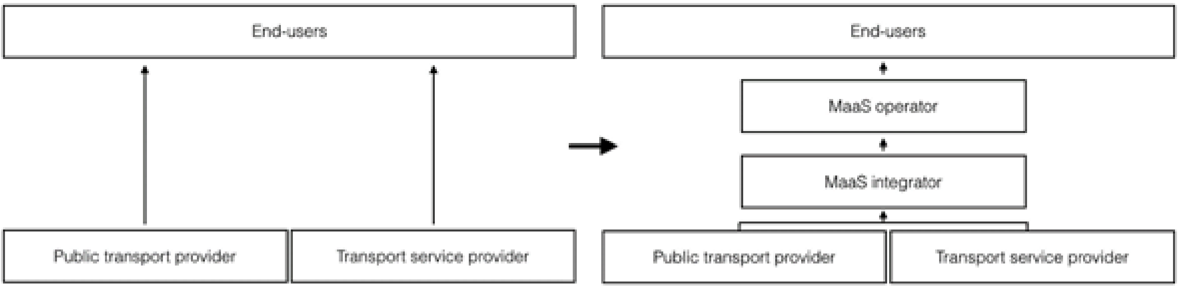

Figure 5.5: MaaS organisational models.

Using this model, Smith, Sochor and Karlsson (2018) shows that there is not a single technology-driven way of dividing the responsibility of the services between the private and public sectors. MaaS can be offered both by private and public actors under a variety of contracts. At the time of writing, Oslo and Akershus has one of the more successful integrated PT systems in the world, with many MaaS components already in place, created and operated mostly as a pure public service. This contrasts with services in other countries where private companies have been active in establishing a commercial MaaS system.

Similar to the experience with MaaS, the introduction of AVs will shift this dynamic. AVs have the potential to ‘flip the script,’ placing transport providers (both public and private) in the role of intermediaries that act as filters between the user and the various vehicle types or segments.

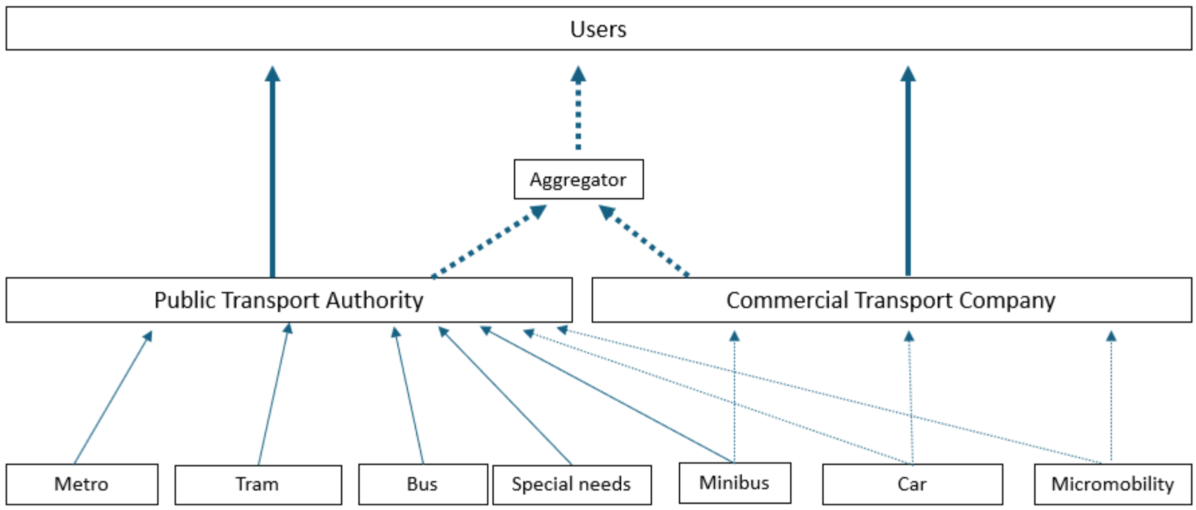

Figure 5.6: Role of PTA vs CTO.

Figure 5.6 presents possible system configurations for the relationship between different transport modes and their users. The key point is that the introduction of AVs can allow more services to be coordinated through intermediaries than what is the case today. This can occur both through the expansion of responsibilities for the PTA, but also by existing modes being offered through comercial intermediaries. Although the focus of this study is car-sized vehicles, this possibility may also be relevant for somewhat larger vehicles, such as minibuses or various shuttle services, or for micro-mobility or transport pods.

With respect to car-sized vehicles, our pathway analysis suggests that the segmentation will also become simpler with AVs. Today, we differentiate between services based largely on who parks, maintains and operates the vehicles. In an autonomous future, such distinctions will become irrelevant, as human drivers will no longer play a role. Instead, the focus will shift to the types of vehicles themselves, whether it's an AV pod, a car, or a bus, rather than the particularities of who operates them.

This change will lead to more fluid roles for both public and private providers. In some cases, both PTAs and private companies could provide the same mode of transport. For instance, PTAs may operate AVs as seen in the Grorud AV pilot, while commercial companies like Uber could offer competing AV services. Additionally, smaller-scale, private options like car-sharing clubs (e.g. Bilkollektivet) can maintain small fleets of AVs for use among a predetermined group of users (e.g. employees at an office building).

Currently, the distribution of transport modes maintains a prominent role for mass transit options like metro, trams, and buses. However, with the rise of AVs, it is likely that in some areas, smaller more individualized modes of transport will become more common. Historically, as smaller transport options have become more economical, they have tended to outcompete larger modes, which are increasingly sustained by subsidies and regulation. As shown by Clayton et al. (2020), AVs may continue this trend, especially outside the urban core, potentially reducing reliance on larger, traditional public transport systems in favour of more flexible, smaller-scale transport ones. In core urban areas, however, it is unlikely that smaller AVs will be able to move as many as effectively as mass transit, especially rail-based modes.

There is no need for AVs to result in one-stop-shops for mobility, combining both the role of mobility provider, operator and integrator. There are still multiple possible configurations of public-private partnerships, typified by tendered contracts, in all of the scenarios.

5.4 Changing the relationship between PT and taxis

How will AVs influence of the relationship between PT and taxis?

AVs are currently entering the market at the intersection between PT and taxis, and to some extent as part of the existing automobility regime, as private cars. The overall outcome with respect to the relationship between these segments is not given.

In terms of the Vocational Transport Act, whether a vehicle is automated or not is not part of the distinction between PT and taxis. However, the opportunities created by AVs may well change this. The most interesting, and challenging application of AVs is at the intersection between PT and taxis. AVs change the costs of shared vehicles, which opens for to more granular service in terms of geographical scope. The use of smaller vehicles in PT and increased geographical connectiveness will likely reduce the expected demand for taxis.

Furthermore, there are reasons to believe that the marginal cost of using AVs will drop over time. Although they are more capital intensive than conventional vehicles, much of this is tied up in software and sensors. They do not have costs increasing with scale, which means that on the margins, cost per vehicle kilometre is expected to fall. This points towards an expansion of PT into current taxi markets. However, the opposite is also a plausible with taxis or new actors within the transport service segments offering door-to-door and on-demand mobility that compete successfully, in terms of both price and convenience, with public transport. If AVs enable the scaling of such services profitably under commercial conditions, they could replace PT in all but the most densely trafficked corridors.

These two conflicting potential outcomes highlight that the relationship between PT and taxis (and the private car) will change due to automation, but that the outcome is decided by how the services are introduced and scaled.

5.5 Parking and urban space

The introduction of AVs will reshape the urban landscape fundamentally, and the best lens through which to investigate this is parking. While shared AV systems could dramatically reduce the need for parking spaces, exclusive AV models may exacerbate issues such as congestion, idling and non-use. AVs with exclusive occupancy could lead to cities clogged with vehicles either circling aimlessly or waiting for passengers, creating inefficiencies that undermine the technology's potential benefits.

In contrast, shared AV systems minimize idling and non-use time by continuously serving multiple users. This reduces the need for cars to park but does not eliminate parking infrastructure entirely. Cities will still need strategically placed spaces to accommodate vehicles near potential users, ensuring operational efficiency without aimless driving. Policymakers must rethink parking capacity and placement while aligning regulations with broader urban planning objectives, such as congestion reduction and sustainability.

5.5.1 Regulation and parking norms

AVs have the potential to reduce the amount of land dedicated to motor vehicle infrastructure. Large swathes of urban land currently allocated to roads and parking could hence be converted to green space, real estate development, and infrastructure that prioritizes pedestrians, bicyclists and public transport users. Historically, parking norms have centred on minimum requirements to ensure ample space for private vehicles. However, many municipalities now focus on maximum allowances, particularly in PT-accessible urban areas, to encourage sustainable transport modes and better land use. The AV future introduces new dynamics to these norms. Exclusive-use AVs may sustain or increase parking demand, while shared AV systems could reduce the overall need for spaces by maximizing vehicle utilization.

A critical question concerns the definition of parking. For instance, should vehicles idling at PUDO points be classified as parked? What is the threshold after which idling becomes parking? These ambiguities highlight the need for innovative parking regulations. Additionally, parking norm buy-out schemes – where developers pay a fee instead of providing parking – may gain relevance in an AV context. Funds from such schemes could support shared parking solutions or other urban mobility initiatives, although transparent criteria and fair implementation will be key.

AVs also raise interesting questions concerning residential parking, especially for vehicles that will be shared among multiple users, but not with the general public. An example of this could be a vehicle or fleet of vehicles that serves a residential complex, but not non-residents. It is important here to remember that shared and exclusive occupancy are not binary categories, but rather a spectrum of options. As with other AV schemes, sharing will lead to reduced demand for space, but the more exclusive the scheme, the more space would be required.

5.5.2 Enforcement

Time limitations for parking have traditionally ensured turnover in high-demand areas, but AVs challenge this measure's effectiveness. Autonomous vehicles can circumvent time restrictions by relocating or circling, potentially creating inefficiencies and congestion. Policymakers will need to redesign and enforce time limitations that address AVs' capabilities while prioritizing accessibility and urban mobility goals.

Similarly, parking fines are vital for regulating behaviour and ensuring compliance with parking policies. However, several of Akershus' municipalities[6] lack enforcement powers, which could undermine parking management as AVs become prevalent. Granting enforcement authority to either the municipalities or the county as a whole could enable more effective regulation, particularly for AV staging areas and shared vehicle hubs outside of the major urban centres.

5.5.3 Placement

The placement of parking spaces will play a critical role in shaping the efficiency and accessibility of AV systems. Consolidating parking into strategically located hubs, rather than scattering spaces across urban areas, could reduce congestion and free up valuable land for alternative uses. These hubs could be designed to serve multiple users dynamically, enabling AVs to reposition themselves as demand fluctuates.

AVs also open possibilities for leveraging underground parking facilities more effectively. While expensive to construct and maintain, underground parking could become more economically viable in a shared AV future. If fewer overall spaces are required, costs could be distributed among a larger pool of users. This approach could enable cities to reclaim surface areas for pedestrian zones, green spaces, or commercial development while providing centralized, high-capacity parking options below ground.

Another critical consideration is the integration of parking facilities with PT hubs and stations. Park-and-ride systems, for instance, may evolve to accommodate shared AV fleets, acting as multi-purpose hubs that combine parking with pick-up, drop-off, and charging services. Ultimately, the effective placement of parking facilities, whether underground, consolidated in hubs, or integrated

[6] As per the Norwegian Regulation on Public Parking Fees, these municipalities are Aurskog-Høland, Eidsvoll, Gjerdrum, Hurdal, Jevnaker, Lunner, Lørenskog, Nannestad, Nes, Nittedal, and Vestby (Parkeringsrett, 2024).

with PT systems, will be key to maximizing the benefits of AVs and creating liveable, efficient, and sustainable urban environments.

5.6 Emerging segments

Traditional analyses of car use have primarily focused on car ownership and leasing, the latter being functionally similar to ownership from an everyday perspective. However, new forms of car access, such as car sharing, offer alternatives to ownership and are most effective in high-density, transit-oriented, mixed-use, walkable, and bikeable neighbourhoods. Another emerging model, vehicle subscriptions, has yet to establish its role within the broader transport system, but may have a big impact.

On one hand, subscriptions could reinforce traditional patterns of car use by operating as an alternative form of leasing, providing long-term, private access to vehicles. On the other hand, they have the potential to offer more flexible, temporary access, aligning them closer to models like car sharing or rental services. The degree to which subscriptions resemble automobility will largely depend on the duration of access provided – longer periods are more likely to perpetuate private car use, even in an AV future.

Subscriptions also have the potential to support a variety of arrangements along the spectrum of shared and exclusive use. In the modern "sharing economy," sharing is often associated with making resources available to the general public. However, subscriptions could enable more selective sharing, involving smaller defined groups. For instance, a company or housing cooperative might subscribe to a small fleet of vehicles for exclusive use by employees or residents, creating a club-like model of shared access. This approach allows for medium- to long-term access without relying on the broader public, blending elements of car sharing and private use.

Currently, vehicle subscriptions function as a novel form of leasing. However, with the right policy frameworks and incentives, they could evolve into AV models more aligned with shared mobility. Policymakers should aim to shape the vehicle subscription market to prioritize shared pools that do not generate additional traffic and complement sustainable transport modes, such as walking, cycling, and public transport.

5.7 Minimum levels of service / geographic exclusivity

PTAs have a divided mandate, with a set of different, and to a certain extent, conflicting policy objectives. In a county such as Akershus, this has clear implications. On the one hand there is a clear mandate for the PTA to focus its services towards presenting an alternative to the private car for daily mobility, linked to the zero-growth objective. On the other hand, the county is to provide a minimum level of mobility service for the broader population, located in both rural and urban areas. There is also a set of legal requirements to provide transport to pupils. The requirements for serving these very different market segments are, to some extent, in conflict with each other.

A strong PT system that can present an alternative to the private car require high levels of service with low headways, and good coverage of key nodes. That is to say, the PT system must have a design that is competitive for potential and actual car owners for their daily travels. As time analysis studies have shown (Lunke et al., 2021), a critical factor is for the perceived relative travel times using PT to be less than twice as long as for private car use. Providing such services currently requires considerable levels of subsidies.

The second objective, to provide a minimum level of service for vulnerable groups of non-car owners, rural inhabitants, school children, persons with disabilities etc., require a different approach. For these persons, the impact of relative travel times are less of an issue, but they do need area coverage to reach specific services at a given point in time; as with the rest of the population, they can be assumed to derive utility from being able to access services. In order to cater to these needs, a series of schemes are used in the existing mobility system. This includes PTA-organized services with school routes, in combination with services provided by the taxi industry. The taxis are acting as subcontractors to bus companies on tendered services, as well as having several independent services including "TT-services", typically organized as a set amount of money allocated to the individual for purchases of taxi trips. Still, these contracts have not, by themselves, provided a strong enough economic foundation to maintain a minimum of services at the desired levels in rural areas. Rather, the number of taxi services in rural areas falling over time (Oppegaard et al., 2023).

5.7.1 Jurisdictional Exclusivity (Monopoly) in the Taxi Sector

An important policy instrument to help provide a minimum of taxi services in rural areas has been the 'needs test'-based licensing system for taxis and dispatchers. Within this system, access to the taxi market was regulated by the counties. The ruling principle was a system of local monopolies, with prominent exceptions in larger regions such as Oslo and Akershus County.

The reform introduced in November 2020 opened the market by eliminating the county's possibility to exclude formally qualified applicants. The architecture of the system was also changed from the system of local monopolies as a rule, towards open entry both at the vehicle and at the dispatcher level, with one important caveat: counties were still able to award exclusive contracts (*enerett*) to taxi operators in areas with specific characteristics, particularly those with lower population densities. According to §48a of the Vocational Transport Regulation (*Yrkestransportforskriften*), these monopolies are most common in regions with fewer than 20,000 inhabitants and population densities under 80 persons per square kilometre. This corresponds almost exactly to the areas where the local monopolies were in place before the regulation changed in 2020 (NOU, 2024).

Today, several jurisdictions in Akershus have exclusive contracts for taxi services. As seen in the table below, areas like Vestby, Nesodden, and Enebakk have awarded monopoly rights to local taxi companies such as Ski Taxi and Follo Taxi until 2024. Similarly, other regions, such as Aurskog-Høland and Jevnaker, have extended monopoly contracts into 2025. These contracts ensure that a single operator has the exclusive right to provide taxi services within the designated areas.

Table 5.1: Jurisdictional Exclusivity in Akershus county.

Municipality	Period	Monopoly holder
Vestby	15.08.22 – 31.12.24	Ski Taxi
Nesodden	15.08.22 – 31.12.24	Follo Taxi
Enebakk	15.08.22 – 31.12.24	Ski Taxi
Aurskog-Høland	01.02.23 – 01.02.25	Aurskog-Høland og Sørum Taxi
Gjerdrum, Nannestad, Nes, Eidsvoll, Hurdal	01.02.23 – 01.02.25	Øvre Romerike Taxi
Jevnaker og Lunner	01.08.23 – 01.08.25	Taxi 03650 AS

With the rise of AVs, these existing monopolies may face challenges. AVs have the potential to make it more economically feasible for other transport providers, both public and private, to offer competitive services in these areas. This brings a critical question for county governments: Should these monopolies continue? And if so, to what extent should they be maintained or adapted to accommodate new technologies and market conditions?

On the one hand, local governments may still see value in awarding exclusive contracts, especially in low-density areas where market competition might not organically provide sufficient transport services; AVs may provide the means to do this more efficiently than the current system can. Furthermore, the contracted monopolies ensure that a single operator has the incentive to serve sparsely populated regions that might otherwise be neglected. On the other hand, AV operated by both local and regional providers could potentially serve these areas more effectively and efficiently than a monopoly-based system. AVs operated by multiple providers, whether public, private, or a combination, might create a more competitive and responsive environment that benefits users.

However, this transition to AVs isn't without risks. While AV systems could enhance service efficiency, there's also the concern that profit-driven AV operators might neglect less profitable, rural, or low-demand areas. County governments, therefore, face the challenge of weighing these trade-offs carefully. They must ensure that any future AV system, whether monopolistic or competitive, provides sufficient coverage in underserved areas. This could mean maintaining certain monopolies, integrating AV services under PTAs, or offering special incentives to private operators to cover areas that might otherwise be left behind.

As AV technology continues to mature, counties will need to reassess their transport strategies to balance innovation with equitable service provision, ensuring that even the most remote areas remain well-served.

5.8 Options for organizing AVs – influence on market outcomes

What are the options for organizing AVs, and how will this influence the market outcome?

Studies of AV introduction have so far mainly focused on the theoretical potential of AVs for solving current (mainly urban) mobility issues. Briefly summarized, these studies find that the potential is there, and that the key component is sharing. Our findings are in line with this, as the pathways discussed in section 4.2 highlights the most important factor in determining the market (and traffic) outcomes of AVs is the degree to which they are introduced as shared mobility. The temporal and geographical dimensions also play a role, but the key is that a vehicle is shared.

A second brand of study focus on the acceptance for sharing AVs (Clayton et al., 2020; Aasvik et al., 2024). These studies highlight that public acceptance for sharing is a complicated field of research. It is not obvious that the willingness to share will increase with vehicles becoming automated. Even though this is a default assumption in several of the early modelling studies (International Transport Forum, 2015). This finding highlights a potential pitfall for AV schemes that is exclusively built around shared vehicles.

In our study we have focused on bridging the gap between user practices and organization of a future AV based mobility system. This has been done by analysing current car based practices and looking at how these practices will be affected by AVs. To look into the impact of organizational issues we have used scenarios that represent logical extremes.

5.8.1 BAU – personal ownership of cars

The core component of the BAU scenario is that all present mobility regimes expand into AVs. In other words, both private vehicles, taxis and public transport increasingly become autonomous. This scenario is a likely outcome if no strategic action is taken from the authorities and the relationship between the different regimes surrounding the current modes of transport remains unchanged. The latter is unlikely.

As shown by actor behaviour based modelling studies, this scenario is likely to become a mess in the cities, as traffic volumes increase, with persons preferring autonomous vehicles over other modes, and with more people being able to access motorized mobility. Furthermore, this scenario is likely to reduce the demand for public transport, as people choose to use private AVs or exclusive taxi like AV based services over shared AVs. At least if we are to take the present findings from the acceptance literature at face value.

In rural areas this solution is less problematic. Having a large component of privately owned and funded vehicles may be a preferred option to only having shared AVs. The reason for this is that the underlying demand is lower compared to urban areas, and that as sharing is less likely to happen without the users changing their preferred travelling schedule, resulting in a lot of empty vehicle kilometres. Private vehicles may offer higher mobility and lower costs compared to shared vehicles in rural areas.

5.8.2 Public-private

In this scenario private cars are increasingly being phased out. This is either because of some form of regulation make private car ownership less attractive, or from the “pull” sides with benefits of AVs and different properties of the vehicles making private ownership superfluous. In this scenario “niche” car segments such as car sharing, car rental and taxis merge into one on demand and exclusive mode. In this mode a variety of AV types operated on commercial grounds by “fleet” operators dominate the market. However, public-transport remains as in the current situation, so does the supported mobility services that exists today.

In urban areas the effect of this scenario is undecided. It will depend on how private car use is replaced with commercial AVs and public transport. If this is done through regulation, limiting access to private car, the outcome may be a maintenance of today’s traffic volumes or they may well be reduced. The reason is that we expect a higher marginal cost associated with driving in a commercial AV compared to a situation where vehicles are owned and operated by the user. However, apart from correcting a potential “over investment” in private vehicles found in today’s mobility system, this regulation may well reduce the overall utility, and for some individuals reduce their mobility. If user utility is to be maintained, this scenario will increase traffic in urban areas.

In rural areas, this scenario is likely to reduce utility and accessibility. This can be compensated by increasing transfers to rural services or more efficient road user taxes.

The scenario will require a series of niche services for specific groups of people, and this will need to be supported either through transfers from the users of the commercial services or from subsidies.

5.8.3 PTA-dominated scenario

In this scenario personal vehicles are phased out, and all remaining car-sized vehicles are used in a system coordinated by the PTA.

In this system the PTA takes control of all vehicles, irrespective of their size and legal status. This allows for a regulation with sharing as the main way of utilizing the vehicles.

In urban settings this allow the current accessibility levels to be reached with a much lower number of vehicles, as shown by the various simulation studies. If this is reached, a significant social cost, the amount of resources locked in underutilized private vehicles can be put to better use. However, this scenario has challenges in particular related to the possible decrease in utility for individuals who today have access to a private car and in this scenario would both have to pay a time penalty for accessing an on-demand vehicle and possibly be forced to share the vehicle and take detours. These negative effects are likely to be strongest in less densely populated areas. If the decrease in utility presented by this is to be compensated it would require substantial economic transfers. And the traffic outcome may become less obvious.

In rural areas this solution will decrease accessibility or increase the need for subsidies, as distances between an accessible vehicle and a user increase the expected distances covered by empty vehicles increase.

This scenario has a huge potential upside, in that the number of vehicles required will decrease. However, it has a series of challenges both in terms of current regulations which allows private ownership of vehicles, and gives preference for private operation on commercial grounds over public service provision where that is possible. It also faces a scale issue for tackling interregional travel.

5.8.4 Private commercial scenario

As in the previous scenario, personal vehicles are phased out, but instead of being replaced by a public service provider they are replaced by commercial fleets. In this scenario the commercial fleet operators operate services on either purely commercial grounds or under a licensing agreement with the government. If they operate on purely commercial grounds the effects will probably be a focus on the more commercially attractive areas to serve. With current taxi markets being likely to be affected first. As in the case of micromobility, many of the potential negative effects for society of an open access solution can be mitigated by a licensing scheme. Such a scheme would allow the authorities to place societal objectives into the operation.

In urban areas this outcome will depend on regulation. An open access approach will most likely result in congestion and increased traffic in the most central areas, while the less central areas will become underserved. The market dynamics are likely to follow that observed from the introduction of e-scooters (Aarhaug et al., 2023), with a strong effort placed on gaining market shares and strategic behaviour.

In rural areas the scenario is likely to result in undersupply, as the profitability is linked to density. The lower the density the less attractive the service, and the longer the time spent between revenue generating trips. In other words, the service will cost comparatively more and have lower revenue earning potential in rural areas. This will probably result in a need for regulatory intervention, either in the form of license requirements (like *enerett* in taxi, or the e-scooter scheme in Oslo with market caps and zones with direct regulation), or in the form of subsidies.

6 Conclusions and recommendations

6.1 Summary discussion

Parking and urban space

The integration of AVs into urban mobility systems necessitates a re-evaluation of parking and urban space allocation. A critical question is how much parking will be required in an AV-dominated future, as shared AV systems could reduce the overall demand, while exclusive-use pathways might maintain or even increase it. Determining the optimal amount of parking involves balancing efficiency with accessibility, ensuring that urban areas are not overrun by idle or circulating vehicles. Equally important is the question of who should oversee parking enforcement and regulation. Assigning these responsibilities, whether to local municipalities or a county-level body, will be crucial to maintaining compliance and managing the dynamic needs of AV systems. Finally, the placement of parking infrastructure must be strategic, prioritizing consolidated hubs near transport nodes or high-demand areas to reduce congestion and optimize land use. Thoughtful consideration of these factors is essential for ensuring that AVs contribute to more sustainable and liveable urban environments.

Emerging segments

New segments of vehicle access, like subscriptions, car sharing and ridesourcing, have the potential to impact urban mobility in both positive and negative ways. On one hand, they could reinforce traditional patterns of automobility, perpetuating reliance on individual vehicles and sustaining the dominance of private car use in daily transport. On the other hand, they offer a promising opportunity to introduce alternatives that could diversify and enrich urban mobility options. For this potential to be realized, mobility stakeholders must approach AV introduction with an eye towards shared use, and ensuring that it do not merely replicate the characteristics of traditional car ownership. Instead, these models should be deliberately steered to align with broader sustainable mobility objectives. This would likely involve fleets of shared vehicles that supporting multimodal transport networks that prioritize walking, cycling, and public transport as primary modes.

Changing economics

We expect AVs to have a higher marginal cost of use than conventional cars, but lower costs compared to existing transport services, both public and private. This cost structure is likely to make AV transport services more attractive, though not necessarily on a shared basis. Achieving a significant reduction in the number of vehicles in the transport system will require robust regulations, as market forces alone are unlikely to prevent a flood of AVs into the system.

While the integration of AVs into public transport services has the potential to improve efficiency and accessibility, the coexistence of AV services with conventional public transport raises two critical questions: (1) Can traditional public transport effectively compete with these new service segments for ridership? and (2) Who will bear the cost of these services, whether they be through fares or subsidies? Furthermore, without new restrictions on private AV use, public transport may face significant challenges in remaining competitive and could require increased subsidies to sustain its operations.

As AV systems rely more on capital investment than on labour, their introduction suggests a shift toward a more centrally managed transport system. However, since the externalities of such systems – such as traffic congestion and air pollution – are experienced at the local level and vary significantly by geography, there is a strong case for localized control. This creates a policy dilemma regarding which levels of government are best positioned to oversee AV regulation and use.

Any scenario in which public transport expands its scope to incorporate AV systems would require a significant regulatory and legislative transformation at both national and European levels. This would entail replacing market-driven transport segments, such as private car ownership and taxis, with publicly managed services designed to maximize societal utility.

Today's transport system is composed of distinct modal segments, including private cars, carsharing, carpooling, ridesourcing, and taxis. The introduction of AVs will bring new dynamics to these segments, potentially resulting in either complementarity or competition. The latter can result in substitution among segments or consolidation. The interplay between public transport and taxis is especially noteworthy, as AVs are likely to blur the boundaries of operation, jurisdiction and authority.

Changes in the relationship between public and private sectors

Research indicates that individuals often prioritize exclusive mobility and demonstrate a willingness to pay for such services. However, the stated preference studies that most of this research relies on have limitations, as actual behaviour often depends on the convenience and cost competitiveness of alternatives. For instance, despite the availability of private transport options, many still rely on public transport where regulations and service offerings make it an attractive choice.

It is essential not to assume that the market will naturally tip toward exclusive, frequent services with short access distances. Such outcomes are always shaped by regulation and intervention. Urban mobility is not governed by a pure market dynamic; instead, it reflects a complex interplay of public policy and private sector participation.

Big picture regarding the scenarios

All the scenarios presented in this report presuppose levels of transport needs and expectations across urban and non-urban areas, which will inevitably influence the outcomes and implications of AV introduction in terms of service costs and market acceptance. In low-density areas, where private cars currently provide highly accessible and low marginal cost of use, new AV services would need to offer a similar level of convenience to gain traction. Conversely, in high-density areas, the primary challenge would be ensuring that an AV fleet can match or be comparable with the capacity and efficiency of established modes like rail and bus.

The pathways outlined in this report are not mutually exclusive. While we argue that exclusive pathways are unlikely to serve as a viable foundation for system organization, some exclusive services may still play a role – for example, catering to those with specific needs or a willingness to pay a premium. Therefore, any eventual scenario is likely to consist of multiple tiers of AV segments, with their prevalence shaped by a combination of regulatory priorities, market acceptance, and industry strategies.

6.2 Further research

This report presents a conceptual framework designed to guide thinking about the integration of AVs into the transport system. While it offers a structured approach to exploring potential scenarios and pathways, it is ultimately a starting point – a tool for facilitating discussion and identifying critical areas of focus. Moving forward, more empirical research is necessary to consider metrics and indicators that can assess the impacts of AV systems across multiple societal domains.

One key area for further research is understanding customer responses, not just in terms of trust in AV technology but also in their willingness to pay and the specific services they value. The work presented here is primarily qualitative, providing a foundation for more quantitative analyses. Building on studies like the Oslo Study, which modeled user behavior and system impacts, future research could develop metrics to quantify customer responses to the three dimensions of AV use – distance, timing, and occupancy.

A second critical research area concerns the costs of AV operation and subsidies. Transport systems, even those dominated by market-driven segments like taxis and private car ownership, rely heavily on public infrastructure and regulation. Understanding the financial implications of AV deployment for governments, consumers, and the private sector is essential. What level of public investment will be required to support AV systems, and how will these costs be distributed across stakeholders?

Thirdly, it is essential that we consider the diversity of transport modes and their compatibility with AV technology. It is no longer a simple dichotomy between car ownership and non-car ownership; modern transport systems encompass a wide array of interfaces, from car subscriptions and car sharing to ride-sourcing and traditional taxis. Some of these segments may be more suitable for AV adoption than others, offering opportunities to target strategic interventions. In terms of transitions, this involves identifying niches that are most likely to be viable and contribute to an optimized regime. By nurturing and shielding the segments that align with sustainable, equitable, and efficient transport systems, policymakers are better placed to guide the transition toward desirable outcomes.

Another promising avenue for further research involves understanding how the symbolic meaning of the car may evolve in an AV-dominated future. The privately owned car has long been a powerful cultural artefact, embodying notions of status, independence, and identity. A transition toward service-based access models, whether through shared fleets, public transport integrations, or commercial AV providers, could fundamentally alter these associations. However, the pace and extent of this shift remain uncertain. Studying how changing perceptions of car ownership influence user behaviour, market adoption, and societal acceptance will be essential for anticipating the broader cultural dynamics of AV integration.

Finally, public response extends beyond mere system usage; it encompasses broader political and societal reactions. Transport is deeply embedded in daily life, and significant changes to the system can provoke public backlash, potentially derailing even the most well-intentioned plans. Future research should explore the potential for public resistance, including how activism and electoral behaviour might respond to shifts in mobility systems. Anticipating these reactions will be critical for policymakers to design interventions that are both effective and socially acceptable.

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