

Opportunities and challenges for automated vehicles in a city without private cars



Delft, 21st January 2026

Author(s):

Alex Roocroft (TU Delft), Tom Alkim (MAP TM), Tom van Dam (Connekt), Vincent Joanknecht (City of Rotterdam), Maaïke Snelder (TU Delft, TNO), Bart van Arem (TU Delft)

The XCARCITY project aims to explore what it would be like to live in a city without private cars. Could shared automated vehicles be part of a sustainable mobility package that can safeguard the accessibility of a city without private cars? The Interactive XCARCITY CAV Workshop brought together around 20 participants for the afternoon session, representing a broad cross-section of Dutch transport practice, including public authorities and regulators (e.g. Municipality of Rotterdam), universities and applied research (e.g. TU Delft, TNO), and consultancies and mobility technology firms (e.g. Royal HaskoningDHV, Pon), to explore the opportunities and challenges of connected and automated vehicles (CAVs) in an urban future that shifts away from private car use. The afternoon combined short scene-setting presentations (introducing XCARCITY, the role of CAVs in future urban mobility, and the Rotterdam Merwe-Vierhavens (M4H) development) with interactive group work and discussion. The aim was twofold: (1) to test how CAV concepts could be applied in a real-life redevelopment context (M4H), and (2) to pool lessons from Dutch and international experience to identify best practices for executing CAV pilots.



The agenda and presentation slides are included in the appendix. The summaries below capture the main insights and recommendations that emerged from the presentations, the group activity and moderated discussion.

1.1. Current trends in CAV development

In the presentation by Tom Alkim, connected and automated vehicles (CAVs) were presented as one possible component of “responsible mobility”, with their societal value depending on the choices cities make about outcomes such as quality of life, space allocation, and the balance between individual convenience and collective goals. Rather than assuming that automation would automatically improve mobility, the presentation raised system-level questions around whether CAV services should be privately owned or shared, and whether optimisation should prioritise individual users or overall network performance, particularly in dense urban environments. A central theme was the co-existence of cycling and CAVs in the Dutch context, highlighting practical requirements such as reliable detection of bicycles, safe interaction between CAVs and vulnerable road users, and the need for clear behavioural guidance in mixed traffic. The presentation also linked CAVs to broader accessibility objectives, including mobility for all, and discussed whether attractive shared automated services, potentially integrated with public transport and first- and last-mile solutions, could help reduce reliance on private car use.

1.2. The Merwe-Vierhavens (M4H) project

Rotterdam’s Merwe-Vierhavens (M4H) is a former port and harbour area on the north bank of the Nieuwe Maas that is being redeveloped into a mixed urban district combining housing, employment, education, and cultural functions with a strong focus on innovation and the maker economy. As part of the Rotterdam Makers District, the area is envisioned as a testing ground for the future port city, with sustainability, circularity, and new forms of urban production at its core. The redevelopment strategy places strong emphasis on a car-low urban environment, prioritising walking, cycling, and public transport, supported by shared mobility services and mobility hubs rather than private car ownership.

1.3. Case study group activity: ‘How best to utilise CAVs in M4H?’

As part of the workshop, participants worked in small groups to explore how Connected and Automated Vehicles (CAVs) could support mobility in the Merwe-Vierhavens (M4H) redevelopment in Rotterdam. The exercise was framed around the idea that, to create a new neighbourhood within the city, an alternative mobility approach is needed to meet the project’s goals (e.g., accessibility, liveability, sustainability). Groups were asked to consider how CAVs could help achieve these goals, and to rank potential interventions by feasibility and impact, drawing on likely user behaviour, operational constraints, and the specific context of M4H.

They were asked to consider the following questions to start the discussion:

- Which user groups in M4H are most likely to be early adopters of CAVs?
- Which application should be prioritised first—and why?
- How should the shuttle system work best in practice?
- Could M4H infrastructure change to better support CAVs?

Group 1 recommendations

- Structure M4H CAV planning around who benefits and how trips behave (fixed vs variable routes; lower vs higher income), and choose early pilots that are the most “adoptable”.
- Prioritise early deployments in constrained, predictable operations (e.g., ferries/shuttles serving everyday users) and/or premium flexible services (e.g., tourist water taxis) to build momentum.
- Build a multi-modal CAV portfolio that includes road, water and air applications where relevant (e.g., shuttles/taxis, logistics, ferries/water taxis, drones, special-needs services).
- Phase ambition deliberately: start with district shuttles linking pickup points to hubs, then scale toward fully on-demand, destination-to-destination services.
- Create the enabling environment with low-speed or AV-only zones, clear physical cues (e.g., markings/lighting), strong digital infrastructure and enforceable rules, and education/training to support safe adoption.

Group 2 recommendations

- Make first/last-mile links to existing public transport the top priority, because cycling dominates short trips and CAVs must complement (not compete with) bikes.

- Deploy CAVs early to shape long-term travel behaviour, and delay parking-led strategies until later phases of development.
- Provide intra-M4H circulation as a second step, but design it for equity by dividing M4H into operational zones aligned with land use and guaranteeing fair service levels across zones.
- Operate a hybrid on-demand service: run vehicles only when requested, but use data to predict demand and pre-position vehicles to improve availability and reduce waiting.
- Target initial services at existing commuters and companies, then expand as residential demand emerges.

Group 3 recommendations

- Prioritise CAVs that connect people to the metro/PT, because parking constraints and costs will push users toward transit-based access.
- Design CAV services primarily for accessibility, especially for people with physical difficulties, while assuming most able-bodied users will continue to walk or cycle in a 15-minute district.
- Avoid a generic district shuttle by default; instead, use geofenced/park-at-edge concepts where they solve a clear access problem.
- Match service mode to demand: run fixed routes in peak hours for reliability and capacity, and switch to free-ranging on-demand off-peak, with vehicles dispersed to cut pickup wait times.
- Protect the quality of public space: keep streets friendly, healthy, and climate-adaptive; ensure vehicles can reach front doors for those who need it; and concentrate operations on cycle-street-like corridors to reduce conflicts.

1.4. Group discussion : Best practice for CAV pilots in the Netherlands

The last session of the workshop took the form of a facilitated group discussion on best practice for CAV pilots in the Netherlands, with a particular focus on lessons learned from international pilots. Attendees pooled insights from their own projects and experiences, sharing what has worked (and what has not) in past and ongoing pilots. The discussion was synthesised into a set of practical “do’s and don’ts” intended to guide how future urban CAV pilots in the Netherlands should be scoped, governed, evaluated, and scaled. The main points raised were as follows:

- Make pilots durable and purposeful: aim for sustainability and continuity (multi-year partnerships), and avoid “pilot theatre” (piloting just to pilot).
- Be explicit about goals and success criteria: define why the pilot exists, what it will prove, and prioritise essentials like safety, the most-relevant activities, and the impacted stakeholders.
- Use a stepwise adaptive rollout: progress in stages (by technology maturity and user groups), with the option to evolve toward something more permanent rather than stopping at a demo.
- Enable collaboration and standardisation: require stakeholders to share learning and align on data, standards, and vehicle/system interfaces, so results transfer between cities and pilots.
- Coordinate pilots in a longer-term programme: multiple pilots should fit a shared agenda, draw on international lessons, and prevent unnecessary duplication by sharing results.
- Enable delivery conditions: build political support and start with practical requirements (governance, permissions, operations), plus “future-proof” thinking (space for new modes like air mobility; consider opportunities for waterways in the Netherlands).
- Example future pilots: a Rotterdam logistics/port pilot was raised as one of interest (with ideas like dedicated lanes and drones at the port).

1.5. Acknowledgement

This workshop was organised as part of the XCARCITY project funded by the Dutch Research Council NWO as part of the *Perspectief programma* P21-08.

2. Appendix

2.1. Agenda

The agenda containing the presentations and discussion was as follows:

| | |
|----------------------|--|
| 13:30 – 13:45 | Introduction to XCARCITY - <i>Bart van Arem</i> |
| 13:45 – 14:00 | The potential role of Connected and Automated Vehicles in future urban mobility - <i>Tom Alkim</i> |
| 14:00 – 14:20 | Rotterdam Merwe-Vierhavens (M4H) project introduction - <i>Vincent Joanknecht</i> |
| 14:20 – 15:10 | Case study group activity (introduction + group work) - <i>Alex Roocroft</i> |
| 15:10 – 15:30 | Coffee break |
| 15:30 – 15:50 | Group feedback (moderator Alex Roocroft) and reflection on case study - <i>Vincent Joanknecht</i> |
| 15:50 – 16:25 | Translating insights into best practice for CAV pilots in the Netherlands (incl. lessons from international pilots) discussion moderated - <i>Maaïke Snelder</i> |
| 16:25 – 16:30 | Wrap-up and closing remarks |

2.2. Presentation Slides

In the following pages, the slides are provided from the following presentations:

1. Introduction to XCARCITY - *Bart van Arem*
2. The potential role of Connected and Automated Vehicles in future urban mobility - *Tom Alkim*
3. Rotterdam Merwe-Vierhavens (M4H) project introduction - *Vincent Joanknecht*



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Tom Alkim, Bart van Arem, Tom van Dam, Alex Roocroft

Interactive XCARCITY CAV Workshop
Connekt, Delft, 21st January 2026



1

Program

13:30 – 13:45 — Introduction to XCARCITY - Bart van Arem

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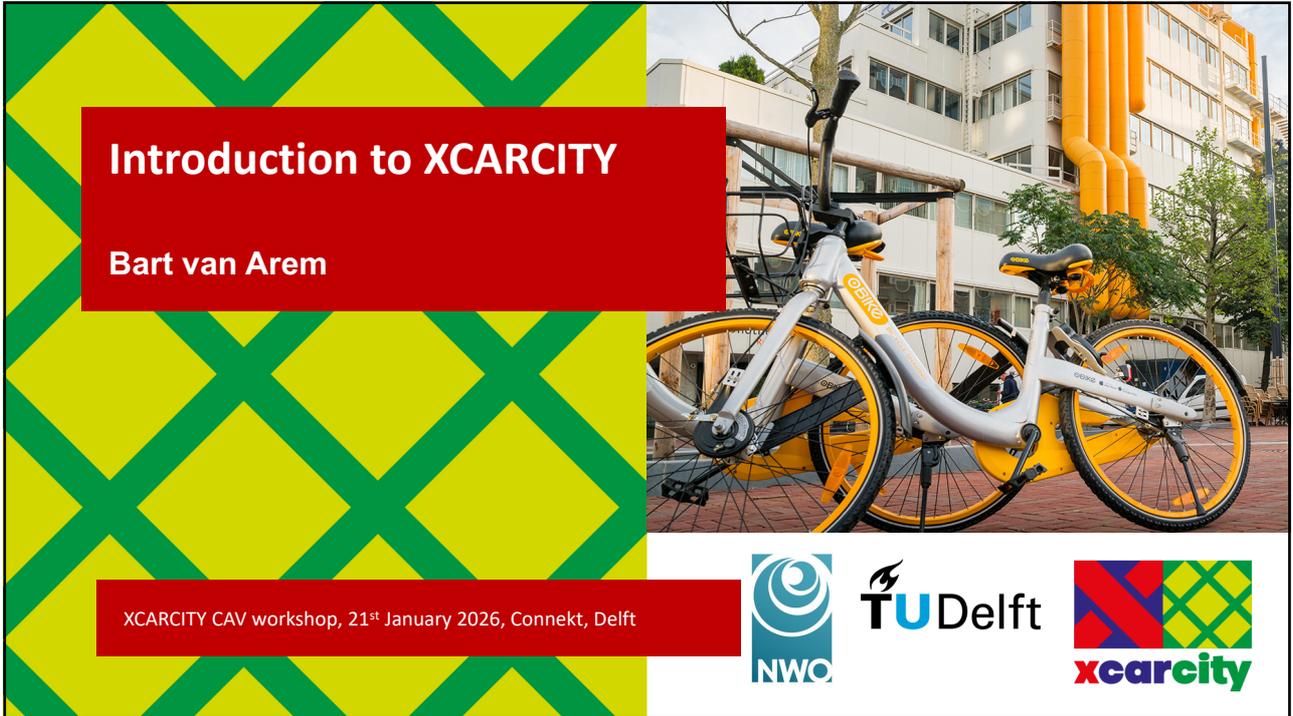
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2



Introduction to XCARCITY

Bart van Arem

XCARCITY CAV workshop, 21st January 2026, Connekt, Delft



The slide features a green and yellow geometric pattern on the left and a photograph of a white bicycle with yellow accents on the right. The bicycle has 'eBike' written on the frame. The logos for NWO, TU Delft, and xcarcity are positioned at the bottom right.

3



4

Urbanisation increasing

11 SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient and sustainable

Population growing world-wide; number of mega-cities increasing



EU: limited population growth; population in cities increasing, population in rural areas decreasing

<https://www.un.org/development/desa/pd/>
<https://urban.jrc.ec.europa.eu/thefutureofcities/>



5

The Netherlands



Population large cities growing (Amsterdam, Rotterdam, The Hague, Utrecht)

1 Million new houses planned by 2030

Mostly densification within existing cities

17,5 Million population
41.850 km²

Randstad area
 (Amsterdam, Rotterdam, The Hague, Utrecht)
 8,5 Million population
 11.370 km²



6

1 Million new houses? What about accessibility and liveability ?



- The road transport system has reached the limits of what is:
 - usage of space
 - externalities
- Public transport system has also reached capacity limits.

Can we imagine a city without private cars?

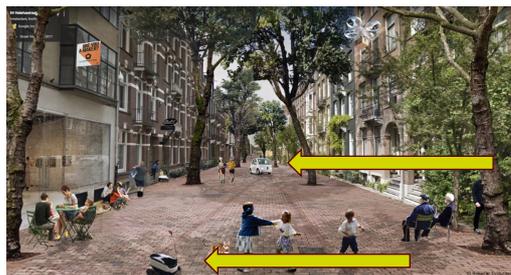
Scarcity of space
eX Car City
----- +
XCARCITY?

7

Smart mobility – promising solutions



- Flexible combinations of:
- walking and cycling
 - shared electric vehicles
 - transport hubs
 - traffic management



Building on service orientation and electrification of mobility.

What about automation?



8

XCARCITY facts and figures

- Duration: 1st June 2023 -1st June 2029
- Budget: 4 M€ by NWO, 2 M€ by partners
- 9 PhD candidates, 2 postdocs, 1 programmer, TNO researchers (60 person years)
- 33 partners from academia, public and private sector
- Lead by TU Delft: Bart van Arem (PI), Maaïke Snelder (co-PI)



Perspectief programme of NWO (Dutch Research Council)

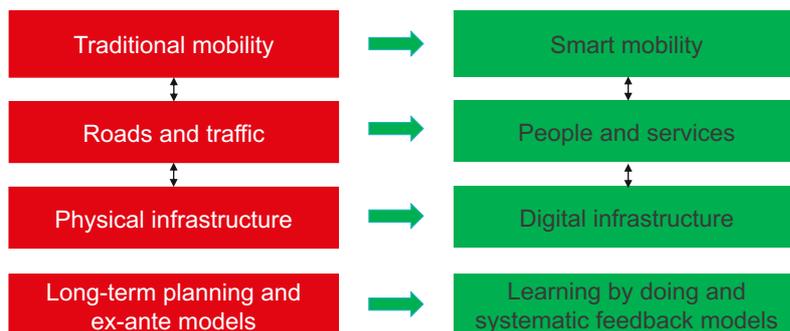
New, challenging research projects within the application-oriented and technical sciences that generate economic and social impact in thematic areas relevant to the Netherlands.

<https://www.nwo.nl/en/researchprogrammes/perspectief/previous-awards>



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Traditional theories and methods are out dated



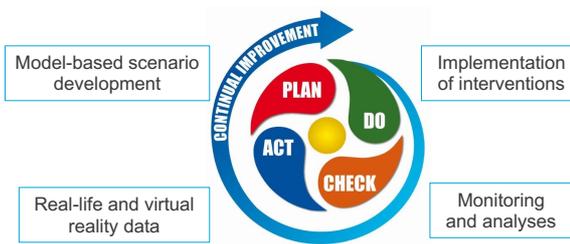
We need new theories and methods to start collecting evidence what works (and what doesn't).



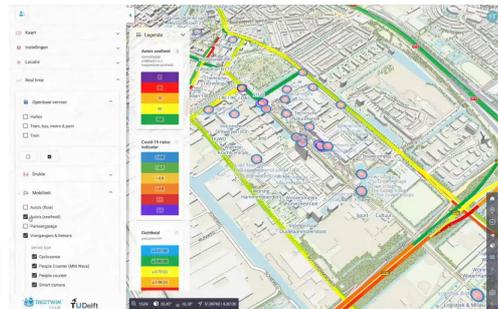
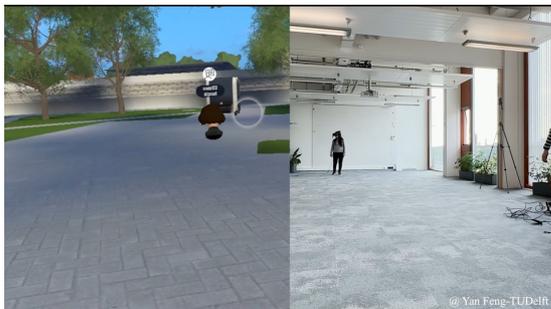
10

Proposition XCARCITY

Digital twin federation
Real-time management & Strategic planning



11



← Interactive urban planning digital twin

↑ Real-time mobility digital twin

← Immersive, multi-user VR digital twin

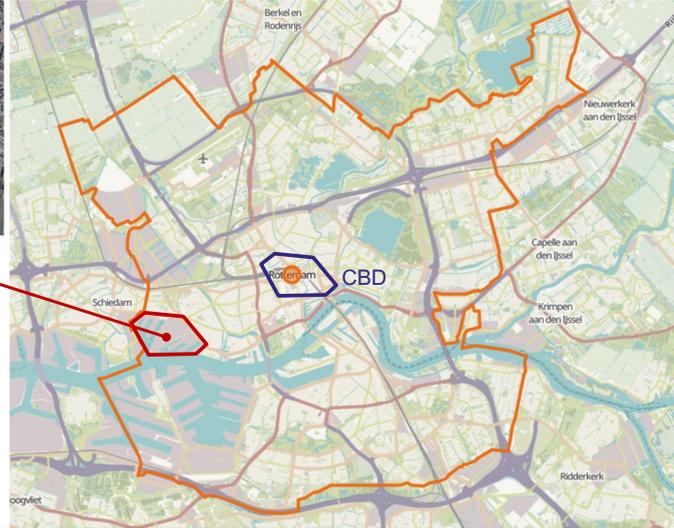


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Case study: Rotterdam Merwe4Haven

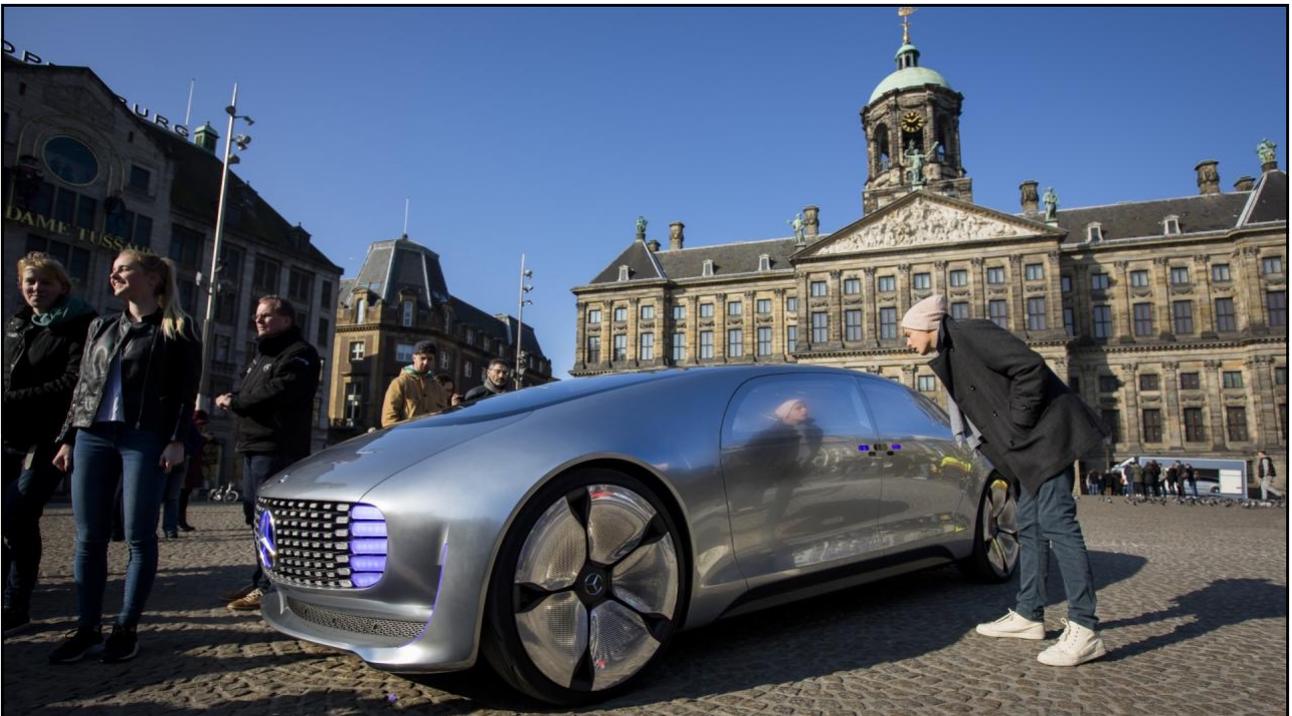


MerwevierHaven



ty

13



14

Shared space

- Close interactions
- Low speeds
- No clear rules
- Negotiations and social interactions

(15).de_Kaden_shared_space.wmv - YouTube

How can ADS use shared spaces without jeopardizing the safety and comfort of VRUs?

15

Automated vehicles in shared space?

Automated vehicles for passengers, freight, services, people with special needs

Ultimately, 1 Shared Automated Vehicle could replace 20 regular private vehicles!

Is it safe?
Is it efficient?
Who is responsible?

How to drive an automated vehicle responsibly in shared space?

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This is not a new problem



xcarecity

17

Opinions differ...



<https://www.saferroadsforall.org/>



<https://www.safestreetrebel.com/>

xcarecity

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**COMMISSION IMPLEMENTING REGULATION (EU) 2022/1426
of 5 August 2022**

laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of the automated driving system (ADS) of fully automated vehicles

Scope

This Regulation applies to the type-approval of fully automated vehicles of category M and N, with regard to their automated driving system, for the following use cases:

- (a) Fully automated vehicles, including dual mode vehicles, designed and constructed for the carriage of passengers or carriage of goods on a predefined area.
- (b) 'Hub-to-hub': fully automated vehicles, including dual mode vehicles, designed and constructed for the carriage of passengers or carriage of goods on a predefined route with fixed start and end points of a journey/trip.
- (c) 'Automated valet parking': dual mode vehicles with a fully automated driving mode for parking applications within predefined parking facilities. The system may use or not external infrastructure (e.g. localization markers, perception sensors, etc.) of the parking facility to perform the dynamic driving task.



<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R1426>



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Automated bus at RTHA



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Towards opportunities and challenges

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xcarcity

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How best to utilise CAVs in M4H?

Explanation: To create a new neighbourhood within the city, an alternative mobility approach is needed to support the goals of the project.

How can CAVs help achieve these goals?

Can you rank these interventions, based on feasibility and impact?



xcarcity

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How best to utilise CAVs in M4H?

- Which user groups in M4H are most likely to be early adopters of CAVs?
- Which application should be prioritised first—and why?
- How should the shuttle system work best in practice?
- Could M4H infrastructure change to better support CAVs? What would matter most?



xcarcity

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xcarcity

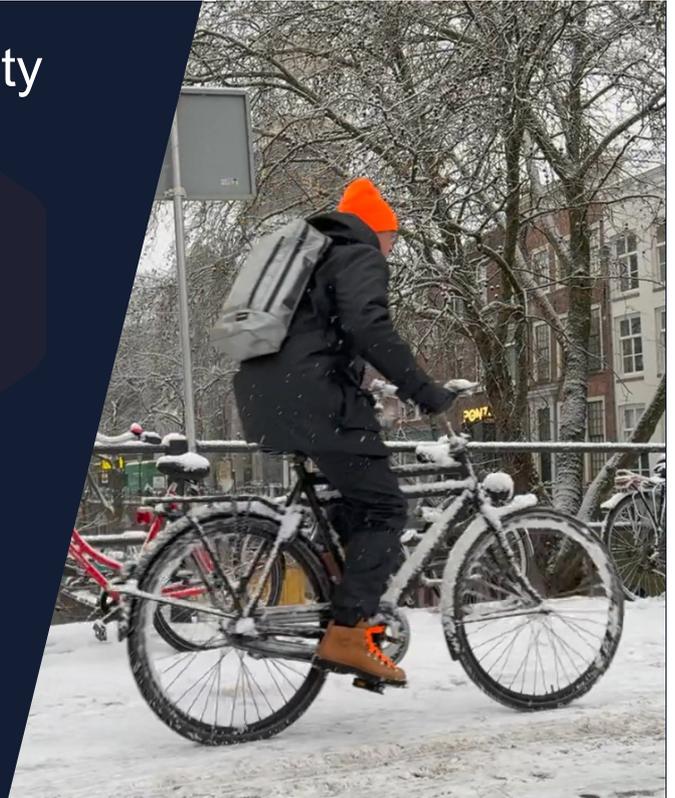
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Cycling and CCAM for responsible mobility

CCAM Kennissessie

Tom Alkim – Strategic Advisor
Connected & Automated Mobility

Delft
21 January 2026



Vision

- >> Quality of life, Society 5.0
- >> Do the things we like, when and where we like it
- >> Mobility is giving us the opportunity to do so, it is essential
- >> But, there are side-effects and limits, so choices have to be made, it's all about balance
 - >> What modality?
 - >> Owning or sharing?
 - >> Individual optimization vs collective optimization
 - >> Is there a limit to mobility, should cities facilitate that?
- >> Short term – given the mobility options we have, what do we choose?
- >> Longer term – if we can design the system, how do we want to do that?
- >> Co-existence of cycling and CCAM

Mobility for everyone



Ecosystem or Ecosystem?



Active mobility, reality check



Infrastructure is destiny, but it can be changed



Responsible mobility includes vehicles



Working on better cities with fewer cars

[LEARN MORE](#)

5

XCARCITY is a **five-year program**, packed with research and pilots, aimed at making urban regions sustainably accessible.



XCARCITY Partner Meeting: Smart Infrastructure (WP 5)
Posted on December 3, 2025
Author: Authors: Fahmeh Mazarin, Sahel Dehghani
Figure: Participants actively engaged at the WP 5 meeting. The WPS meeting brought together researchers and partners to share progress, capture gains...

7

The XCARCITY project consists of **seven work packages**, ranging from in-depth research to the co-creation of new mobility systems.



XCARCITY Design Session – 24 November 2025, Rotterdam
Posted on December 3, 2025
Author: Yuxing Cheng
How can we use research by design methods to enhance real-world impact? This question was at the heart of the XCARCITY design session held on 24 November 2025 in Rotterdam, where...

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In XCARCITY, **thirty-two parties** – research institutions, governments and companies – join forces to make our cities more livable.



XCARCITY–University of Tokyo workshop and AV insights in Tokyo
Posted on December 1, 2025
Author: Dr. Jie Gao
On 7 November 2025, XCARCITY (TU Delft) and the Institute of Industrial Science at the University of Tokyo co-organized a joint workshop on Urban Surface...



Discussion

- Distribution of public space
- Co-existence of cycling and CCAM
- Accurate detection of bikes
- Can car owners be nudged to give up their car by attractive, shared, automated, public transportation?
- Safer interactions between bikes and CAVs?
- Guidelines for AV-VRU interactions



<https://waymo.com/community/articles/advocacy-meets-innovation-the-league-of-american-bicyclists/>

9



GUIDELINES FOR AV INTERACTIONS WITH PEOPLE ON BIKES

The League has long been advocating for putting the safety of people biking and walking first in the development of self-driving vehicle technology. That's why we're excited to partner with companies like Cruise and Waymo that share our vision of improved safety for all road users.

We hope that the technical guidelines help this emerging technology contribute to a more Bicycle Friendly America for everyone by ensuring the future of transportation in the United States is one where people bicycling, walking and rolling are made safer, and their rights to the road are preserved. Protecting people biking, walking and rolling is not an edge case for Automated Vehicles, but must be a core competency.

- | | |
|--|---|
| #1: Cyclists Should Be a Distinct Object Class | + |
| #2: Typical Cyclist Behavior Should Be Expected | + |
| #3: Cycling Infrastructure and Local Laws Should Be Mapped | + |
| #4: A SDS Should Drive in a Consistent And Understandable Way | + |
| #5: Prepare for Uncertain Situations and Proactively Slow Down | + |
| #6: Cyclist Scenarios Should Be Tested Continuously | + |

<https://bikeleague.org/take-action/policy-advocacy/on-the-issues/automated-vehicles/>

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MAP>> Transforming Mobility

Thank you for your attention

Let's discuss!

Tom Alkim – Strategic Advisor Connected & Automated Mobility

tom.alkim@maptm.nl



**ROTTERDAM
MAKERS DISTRICT**

M4H **RDM**
ROTTERDAM ROTTERDAM

**FUTURE IN THE
MAKING**

AREA DEVELOPMENT M4H

XCarCity
Session Autonomous Vehicles
January 21st 2026



1



2

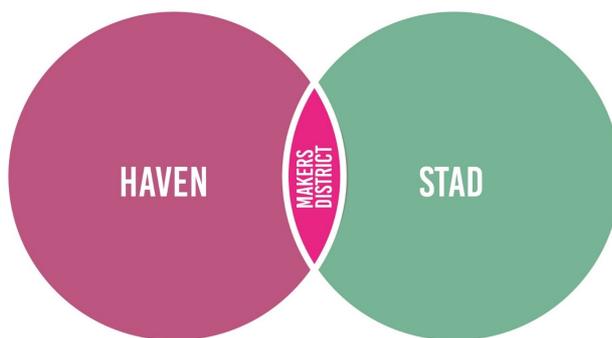
MAKERS DISTRICT = RDM + M4H



ROTTERDAM
MAKERS DISTRICT

3

COLLABORATION MUNICIPALITY AND PORT AUTHORITY



NOT:
PORT OUT, CITY IN

BUT:
TESTING GROUND
AND DISPLAY FOR
PORT CITY OF THE
FUTURE

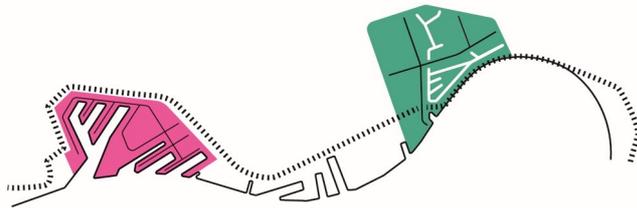
ROTTERDAM
MAKERS DISTRICT

4

M4H

ATTRACTIVE LIVING AND WORKING ENVIRONMENT

- High ambitions for sustainability, greenery and environment
- City housing
- Attracting innovative companies
- Job opportunities for the breadth of society
- Developing the area as a testing ground and display



ROTTERDAM
MAKERS DISTRICT

5

PROGRAMME

Hoofdzakelijk wonen, kleinere makers

Gemeente Rotterdam

Kantoren en wonen, kleinere makers mogelijk

Gemeente Rotterdam

Urban Communities Merwehaven

Makers Mix Gustoweg

Urban District Marconikwartier

Testing & Prototyping Galileipark

Makers mix Keilekwartier

Grotere technische maakbedrijven, onderwijs, horeca, geen wonen

Gemeente Rotterdam

Mix van wonen en ambachtelijke en creatieve makers, cultuur

Gemeente Rotterdam

| | 2035 | | 2050 | |
|--------------------|---------|---------|---------|---------|
| | laag | hoog | laag | hoog |
| werken [m2] | 202.000 | 288.000 | 498.000 | 584.000 |
| wonen (aantal) | 3400 | 5100 | 5200 | 9200 |
| voorzieningen [m2] | 36.000 | 58.400 | pm | pm |

ROTTERDAM
MAKERS DISTRICT

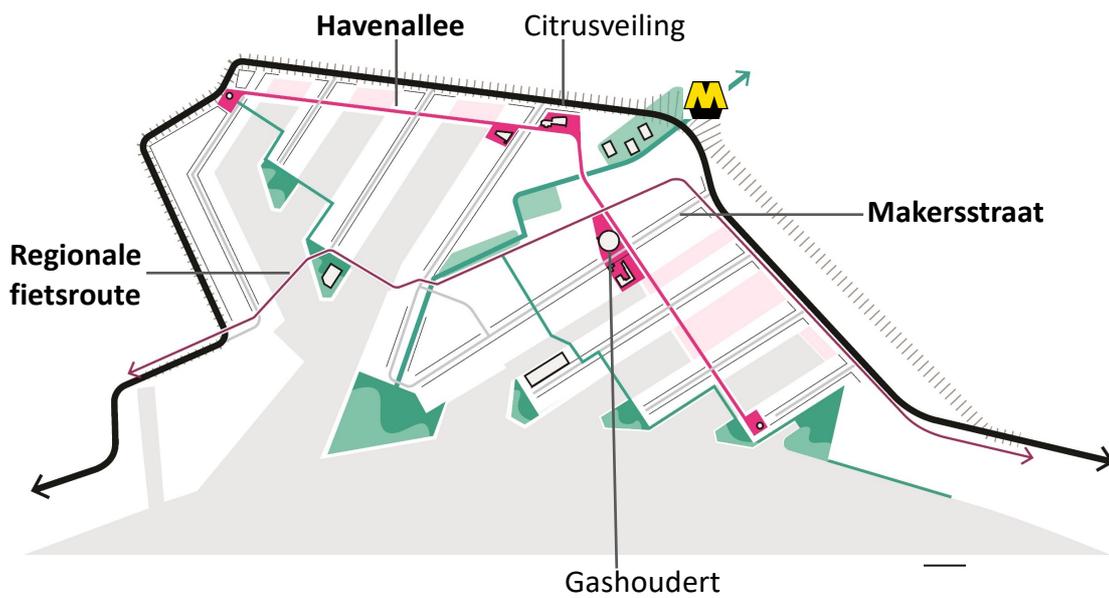
6

SPATIAL FRAMEWORK 2035

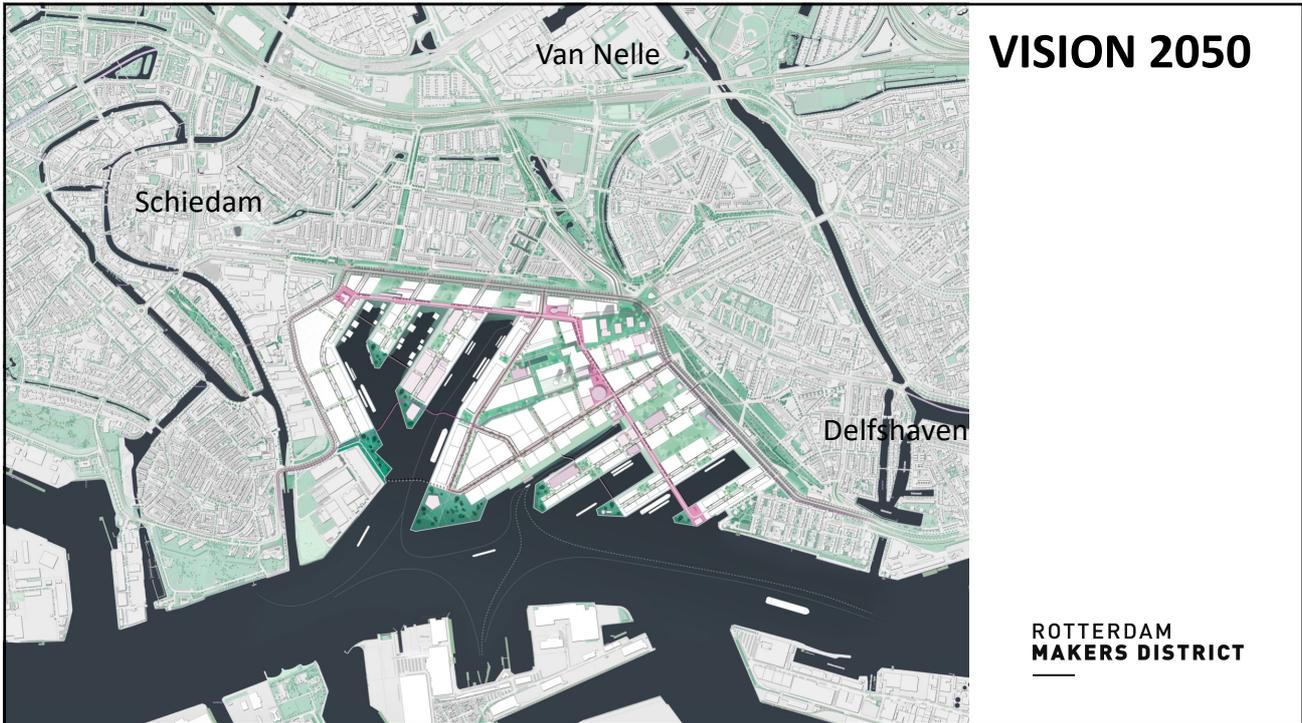


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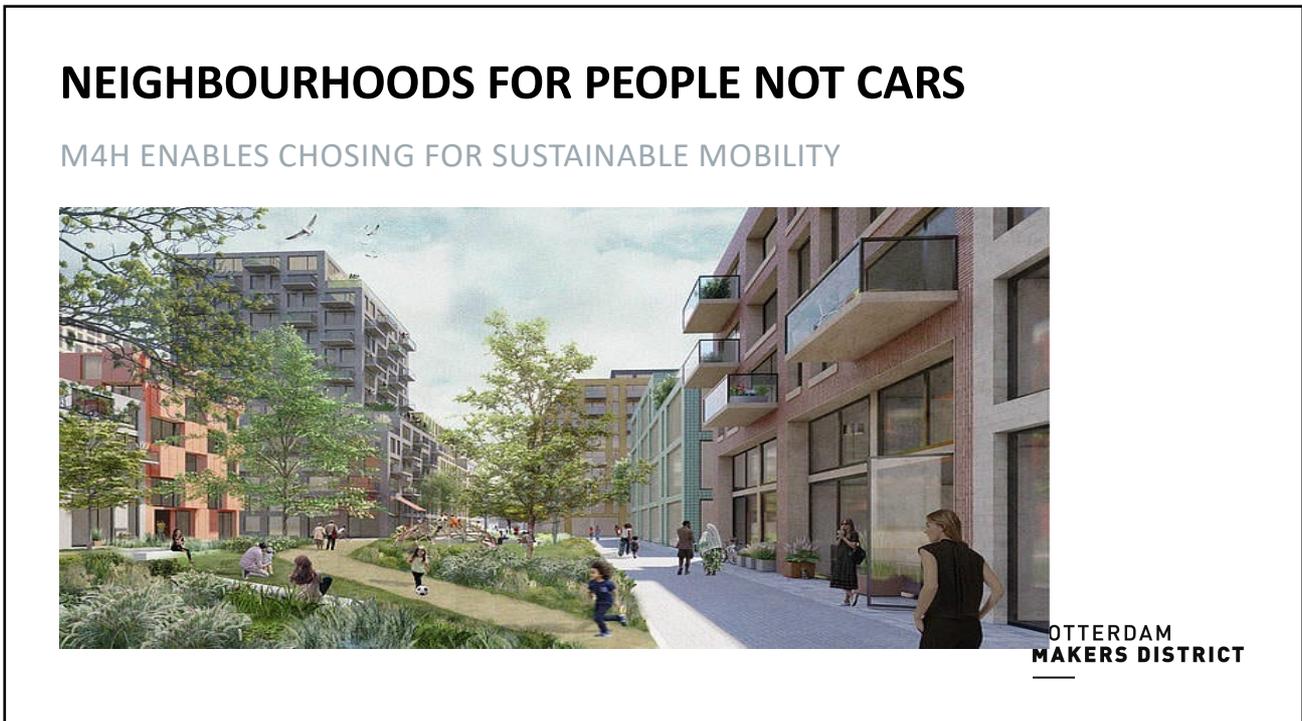
SPATIAL MAIN STRUCTURE



8



9



10

ENABLING SUSTAINABLE MOBILITY

Promoting alternative modalities:

- Good cycling and walking network: comfortable routes and pleasant environment
- Improving accessibility of existing Public Transport routes
- Broad range of shared mobility

Reduction of car trips in the area:

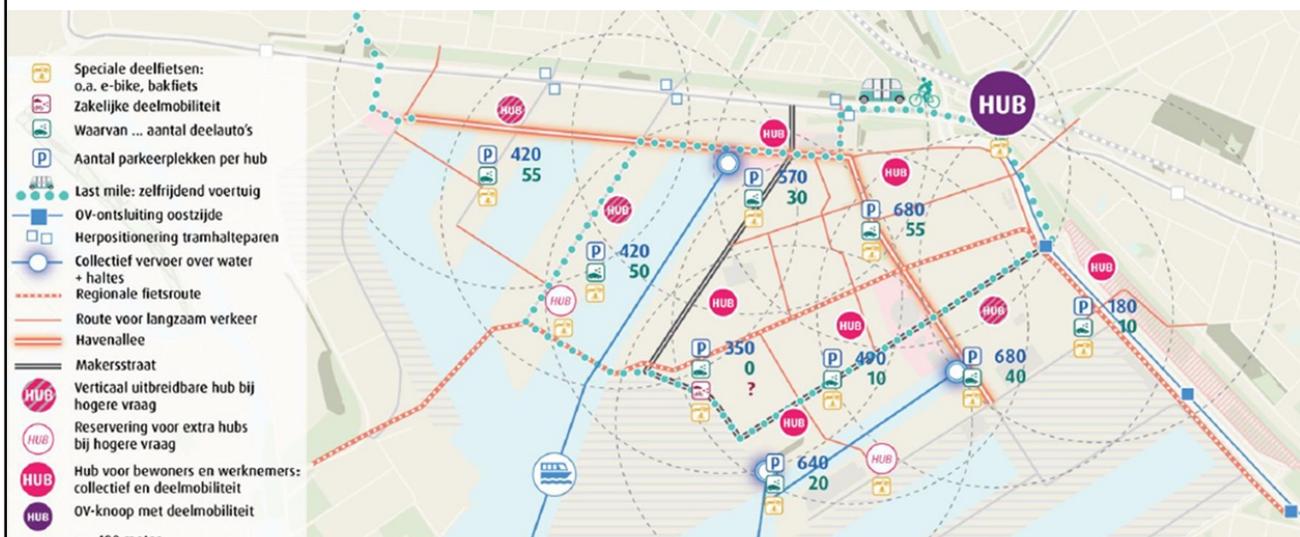
- Less car dominance
- **No on street parking**
- Efficient parking through collective facilities: hubs

ROTTERDAM
MAKERS DISTRICT

11

MOBILITY STRATEGY

CAR LOW ENVIRONMENT AND MOBILITY ALTERNATIVES



12

DISTRICT HUBS

COLLECTIVE BUILT PARKING FACILITIES

- Parking private and share cars
- Network: max. 400m
- Amenities



ROTTERDAM
MAKERS DISTRICT

13

NEIGHBOURHOOD HUBS

NEAT PUBLIC SPACE AND FINDABLE SHARED TWOWHEELERS

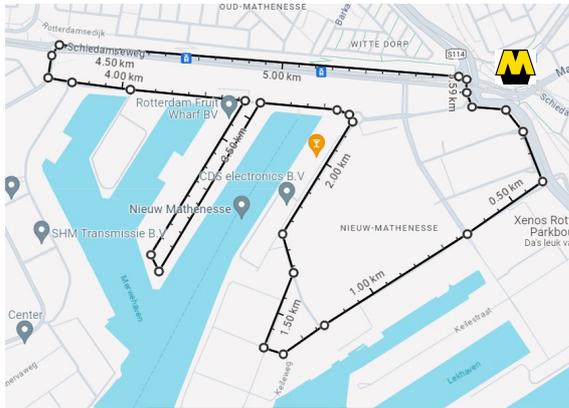


ROTTERDAM
MAKERS DISTRICT

14

COLLECTIVE FIRST & LAST MILE SOLUTION

CONNECTION TO PUBLIC TRANSPORT

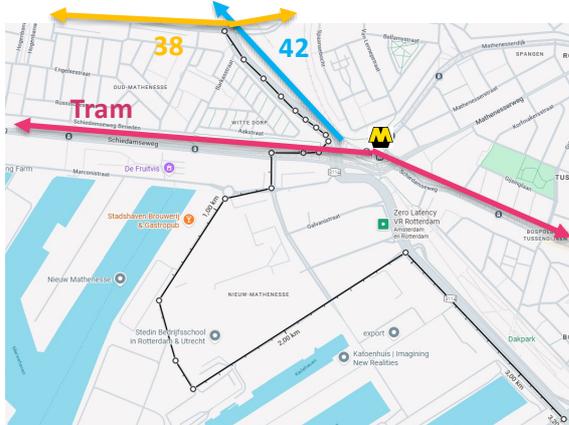


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COLLECTIVE FIRST & LAST MILE SOLUTION

EXPLORATIVE TALKS WITH RET (PTO)



- Financial profitability important → different target groups contributes
- Merwehaven close to tram stop >> reduces potential of Last Mile solution (focus on improving accessibility of tram)
- Galileipark low potential but improves with paid parking
- Stretching bus route 42 no option
- Exploring connection bus 38 ← → Schiedmond, through Galileipark

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CONNECTION TO PUBLIC TRANSPORT

COLLECTIVE FIRST & LAST MILE SOLUTION

Exploring Further

- Fixed route and timetable or demand-driven?
- Fixed fleet or with flexible additional vehicles/services?
- Potential of autonomous to reduce driver costs? Other chances?
- Implications of autonomous?



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M4H ROTTERDAM RDM ROTTERDAM

FUTURE IN THE MAKING

AREA DEVELOPMENT M4H

XCarCity
Session Autonomous Vehicles
January 21st 2026



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GOVERNANCE

City Council decision

- Lack of market activity (i.a. due to phasing of development)
- Active role for city in developing and exploiting hubs: influence and flexibility
- Remittance for developers into "Mobility Fund"

Work in progress:

- Allocation method for limited parking spaces
- Need for shared mobility
- Temporary situations
- Combination with amenities (which ones? in the building or vicinity? financing?)

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